4th International Research Conference


Strengthening Agriculture to Conserve the Environment and Develop Renewable Energy

Deployment of Quality Education and Health for Environmental Conservation and Renewable Energy Development

Application of Science, Engineering and Technology in Environmental Conservation and Renewable Energy Development

Linking Arts, Humanities and Social Sciences to Environmental Conservation and Renewable Energy Development

Utilization of Biodiversity to Conserve the Environment and Develop Renewable Energy

Proceedings
18th to 20th October, 2017
Fourth International Research Conference


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CHUKA UNIVERSITY

Knowledge is Wealth/Akili ni Mali (Sapientia divitia est)

CHUKA UNIVERSITY FUNDAMENTAL STATEMENTS

Motto: Knowledge is Wealth/Akili ni Mali (Sapientia divitia est)

Slogan: Inspiring Environmental Sustainability for Better Life

Philosophy: Quality education, training, research, extension, environmental sustainability, and entrepreneurship lead to social cohesion, human integrity, and economic development

Vision: A Premier University for the provision of quality education, training and research for sustainable national and global development

Mission: To provide access, generate, preserve and share knowledge for quality, effective and ethical leadership in higher education, training, research and outreach through nurturing an intellectual culture that integrates theory with practice, innovation and entrepreneurship.

CORE VALUES
(1) Customer Value and Focus
(2) Diversity and Social Fairness
(3) Environmental Consciousness
(4) Fidelity to the Law
(5) Innovation
(6) Integrity
(7) Passion for Excellence
(8) Peaceful Co-Existence
(9) Professionalism and Confidentiality
(10) Prudent Utilisation of Resources
(11) Teamwork
(12) Timeliness and Devotion to Duty
DISCLAIMER

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PREFACE

Chuka University became the 2nd Chartered and 9th Full-Fledged Public University in Kenya in 2013. It is located in Chuka Town in Tharaka-Nithi County at 186 km from Nairobi City along the Nairobi-Meru Highway. Chuka University has triple core Missions of Education, Research and Extension. The University strengthened and sustained these core missions by hosting the 4th International Research Conference. The theme of this Conference was “Harnessing Environmental Conservation and Renewable Energy Innovations for Sustainable Development”. The subthemes were: Strengthening agriculture to conserve the environment and develop renewable energy; Deployment of quality education and health for environmental conservation and renewable energy development; Application of science, engineering and technology in environmental conservation and renewable energy development; Linking arts, humanities and social sciences to environmental conservation and renewable energy development; Mainstreaming affirmative action and gender equity in environmental conservation and renewable energy development; and Utilization of biodiversity to conserve the environment and develop renewable energy.

The objectives of the Conference were to disseminate and share current knowledge, innovations and technologies to spur sustainable development, bring students, researchers, scholars, professionals and policy makers together to interact and network, facilitate interested parties and stakeholders to acquire and exhibit the new knowledge, technologies and capacities, and provide a forum for students, researchers and industrialists to take their creations and innovations to the next level.

The theme was anchored in the Chuka University’s higher education, research and extension niche area and the 17 UN Sustainable Development Goals (SDGs) that countries will be expected to use to frame their agendas and policies until 2030 in an ecologically sound manner. The SDGs framework contains a number of conceptual as well as implementation challenges that require enhancing collaboration among scholars, policy makers and other professionals to overcome. Coincidentally, the theme was topical as it coincided with when Kenya resolutely decided to tame plastic bags that had in the past contributed immensely to environmental pollution. In this theme, all disciplines were applicable, owing to the fact that the environment is where everything operates and energy is an essential utility we cannot do without as human beings. Additionally, dialogue on this theme should help us contribute to finding solutions to mitigate the harsh climate change effects; for instance, through exploitation of renewable energy resources. Environmental conservation and renewable energy innovations play important roles in sustainable development through prudent resource utilization and guarding against associated risks. The Conference was coined to exemplify the roles Environmental Conservation and Renewable Energy innovations can play in the realisation of Sustainable Development.

Ultimately, the over 125 abstracts and posters received were presented, disseminated and shared during the Conference. It was hoped that the conference would meet objectives and expectations of participants. Sincere gratitude went to all scholars, researchers, authors and stakeholders who had interpreted and contributed relevantly to theme of the conference in one way or another. Gratitude went to the Vice-Chancellor, Prof. Erastus Njoka, for being at the forefront of championing the conferences. Similarly, our esteemed partners were acknowledged for facilitating the Conference. Last but not least, the invaluable support received from Chuka University staff during the conference and book of abstracts organization and compilation was appreciated.

Professor Dorcas K. Isutsa, Ph.D.
Deputy Vice-Chancellor (Academic, Research & Student Affairs)
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<td>Email: <a href="mailto:dorcaski@yahoo.com">dorcaski@yahoo.com</a>, <a href="mailto:jkiharason@chuka.ac.ke">jkiharason@chuka.ac.ke</a>, <a href="mailto:esi.jedi2012@gmail.com">esi.jedi2012@gmail.com</a></td>
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<td>Email: <a href="mailto:dorcaski@yahoo.com">dorcaski@yahoo.com</a>, <a href="mailto:kirimijk@yahoo.com">kirimijk@yahoo.com</a></td>
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<td>Coffee Research Institute, P. O. Box 4-00232, Ruiru, Kenya</td>
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<td>Chuka University, P. O. Box 109-60400, Chuka, Kenya</td>
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<td>Jomo Kenyatta University of Agriculture and Technology, P. O. Box 6200-00200, Nairobi</td>
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<td>Email: <a href="mailto:rosemalyoli@yahoo.com">rosemalyoli@yahoo.com</a></td>
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<td>Email: <a href="mailto:musmuli2@gmail.com">musmuli2@gmail.com</a>, <a href="mailto:benjamin.muli@kalro.org">benjamin.muli@kalro.org</a></td>
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<td>Tel: 0724605328. Email: <a href="mailto:kamuriithi2011@gmail.com">kamuriithi2011@gmail.com</a></td>
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<td>Tel: +254 725 286 095. Email: <a href="mailto:njoroslyk21@gmail.com">njoroslyk21@gmail.com</a>, <a href="mailto:egithaeh@gmail.com">egithaeh@gmail.com</a></td>
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<td>²University of Brighton, United Kingdom</td>
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<td>E-mail: <a href="mailto:sammykipkorirbii@gmail.com">sammykipkorirbii@gmail.com</a>, Phone: 0728516951</td>
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<td>Tel.: 0722892521, E-mail: <a href="mailto:njagcatherine69@yahoo.com">njagcatherine69@yahoo.com</a></td>
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<td>Department of Education, School of Arts and Social Studies, Kenya Methodist University, Kenya</td>
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<td>Lecturer, School of Business, Kenya Methodist University, Kenya</td>
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<td>Senior Lecturer, School of Business, Kenya Methodist University, Kenya</td>
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<td>Author: Theresa Yula David, P. O. Box 157-90300 Makueni., Email:<a href="mailto:davidtheresia4@gmail.com">davidtheresia4@gmail.com</a></td>
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Email: albert.mogambi@yahoo.com, barasamargaret@yahoo.com, eucamore@yahoo.com

Matumizi ya Udhahania Katika Walenisi na Mafuta
Kwambai, Matthew na Bowen, Dave
Idara ya Fasih, Lugha na Isimu, Chuo Kikuu cha Egerton na Idara ya Elimu, Chuo Kikuu cha Kabarak
Email: kwambai9@yahoo.com, tbowenza@yahoo.com

Impact of Poor Governance on Deforestation in Africa
Maina, Paul Mwari
Department of Development Studies, St Paul’s University, P. O. Private Bag - 00217, Limuru
Email: mainapaul72@gmail.com

Assessing Knowledge Leakage on Performance amongst Teaching Staff in Public Universities in Kenya
Mugalavai, Anne K., Wafula, Alice and Odini, Cephas
School of Information, Communication and Media Studies, Rongo University, P. O Box 103-40404, Rongo
Department of Library, Records Management and Information Studies, School of Information Sciences, Moi University, Eldoret
Tel: +254-701716585; +254-724921977
Email: mugalavaia@gmail.com, konabwangu@yahoo.com, akituyi@hotmail.com

Psychological Effects of Divorce on Academic Achievement among Primary Schools Pupils in Kangata Division, Kenya
Mathamia, T., Mburugu, B., Kamoyo, J. and Kobia, J.
Chuka University P. O. Box 109-60400, Chuka
Email: tabbykiambi@yahoo.com

Tahakiki Ya Motifu Ya Safari Katika Kuhifadhi Mazingira Katika Utendi Wa Kalevala
Mwangi, Jackson Ndung’u
Idara ya Lugha, Isimu na Fasihi, Chuo Kikuu cha Laikipia, P. O. Box 120-20300, Nyahururu
Simu: 0720112251, E-mail: jigmwas@gmail.com

Responsible Leadership, Sustainable Development in the Post-independent Africa: A Kenyan Experience
Kagema, Dickson Nkonge
Department of Arts and Humanities, Chuka University
P. O. Box 109-60400, Chuka, Kenya
+254(0)725312360. Email: dicknkonge@gmail.com

Effectives of Religious Initiated Programmes in Curbing HIV/AIDS Pandemic in Kenya: Some Selected Programmes in Meru South Sub-County
Kagema, Dickson Nkonge and Mathai, Lucy Mutare
Department of Arts and Humanities, Chuka University, P. O. Box 109 Chuka Email: dicknkonge@gmail.com
Ikuu Girls High School, P. O. Box 84 Chuka. Email: mathaimu2006@gmail.com

Interpretation of EkeGusii Pop Songs within the Great Chain of Being Metaphor
Ntabo, Victor O., Gathigia, Moses Gatambuki and Moraa, Noam N.
Department of Languages, Karatina University, P. O. Box 1957-10101, Karatina, Kenya.
Tel: +254722398115, 0721993915, Tel: 0710365915, Email: ntabovictor@gmail.com, gatambukimoses@gmail.com, mgathigia@karu.ac.ke, mnyarigotikaru@gmail.com, mnyarigoti@karu.ac.ke

Effect of Micro Insurance Segment on Insurance Uptake in Kenya
Mutegi, Murithi Karugi and Mutegi, Tetu Mwenda
Department of Business Administration, Chuka University, P. O. Box 109-60400, Chuka. Tel.: 0708526724, mkarugi@yahoo.com, 0710975971, Tetumwenda@gmail.com

APPLICATION OF SCIENCE, ENGINEERING AND TECHNOLOGY IN ENVIRONMENTAL CONSERVATION AND RENEWABLE ENERGY DEVELOPMENT

Metric Equivalence as an Almost Similarity Property
Eric M. Gitonga, Sammy W. Musundi and Benard M. Nzimbi
Chuka University, P. O. Box 109-60400, Kenya.
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<td>Email: <a href="mailto:davidkibaara@yahoo.com">davidkibaara@yahoo.com</a></td>
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<td></td>
</tr>
<tr>
<td>Department of Computer Science and Informatics, University of Free State, Private Bag X13 Kestell 9866-South Africa. Email: <a href="mailto:george.musumba@dkut.ac.ke">george.musumba@dkut.ac.ke</a>, <a href="mailto:wariord@ufs.ac.za">wariord@ufs.ac.za</a></td>
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<td>¹Biochemistry and Molecular Biology Department-Egerton University P. O. Box 536-20115, Egerton</td>
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<td>²Biochemistry Department-Chuka University P. O. Box 109-60400-Chuka</td>
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<td>³Biological Science Department-Egerton University Box 536-20115 Egerton</td>
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<td>⁴Chemistry Department-Multimedia University of Kenya P. O. Box 15653-00503, Nairobi, Kenya. Email: <a href="mailto:njue30@gmail.com">njue30@gmail.com</a>, Tel: +254711 407780</td>
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<td>Institute of Biotechnology, Jomo Kenyatta University of Science and Technology. P.O Box 62, 000-00200, Nairobi, Kenya</td>
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<td>Email: <a href="mailto:echomba@chuka.ac.ke">echomba@chuka.ac.ke</a> Telephone: (+254) 706 459 315</td>
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<td>Kenya National Farmers Federation, P. O. Box 19-80108 Kilifi Mobile 0722454283. Email: <a href="mailto:sweru81@yahoo.com">sweru81@yahoo.com</a></td>
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<td>Chuka University (Part time Lecturer) Kenya</td>
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<td>Corresponding author: <a href="mailto:elosynyambura14@gmail.com">elosynyambura14@gmail.com</a></td>
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<td>Department of Forestry, Agroforestry and Rural Development, University of Kabianga, P. O. Box 2030-2020 Kericho, Kenya</td>
<td></td>
</tr>
<tr>
<td>Correspondence: M. Mueni-Koki, Postal, 5454-00100 Nairobi. Phone: +2547277774064. Email: <a href="mailto:kokiam@gmail.com">kokiam@gmail.com</a></td>
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<td>Department of Environmental Studies, Chuka University, P. O. Box 109-60400, Chuka Tel.: 0724614655; 0724412930</td>
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MARKETABILITY OF VALUE-ADDED PUMPKIN (*Cucurbita moschata* Duch.) FRUIT IN SELECTED KENYAN MARKET

Kiharason, J. W., Isutsa, D.K., and Ngoda, P. N.

*Chuka University, P. O. Box 109-60400, Chuka, P. O. Box 484-60400, Chuka, Kenya*

*Egerton University, P. O. Box 536-20115, Egerton, Kenya*

Correspondence: dorcask@yahoo.com

Abstract

Africa has an abundance of horticultural crops which unfortunately remain under-exploited and under-utilized. Their distribution and marketing is a great challenge due to the easy perishability. Horticultural crops experience losses both in quality and quantity between harvest and consumption and the magnitude of post-harvest losses in fresh fruits and vegetables is estimated to range from 20% to 50% in developing countries. Pumpkin (*C. moschata* Duch.) fruit being highly nutritious and with great potential for commercial utilization, is a traditional horticultural crop with little documented work on utilization options (few recipes exist) at household level in Kenya. Many households do not buy and utilize pumpkins regularly. Consequently there is low demand of pumpkins in Kenya. These scenarios increase post-harvest losses and provide no incentive for farmers to increase pumpkin production in Kenya. This study involved four market women in Nyeri County of Kenya, guided by two objectives: (1) To determine the spoilage rate of fresh fruit in various presentation formats (eighth, quarter and half slices and a control of whole fruit) (2) To determine marketability of fresh fruit in the various presentation formats. Spoilage occurred in quarter and half slices, with higher spoilage (39.5%) recorded in half slices. ANOVA analysis showed significant differences (p<0.05) in average number of spoiilt pieces over different days. Quarter slices recorded highest number of pieces sold (54.5%) and half slices (9.8%) the least. There were no significant differences between the average number of fruit pieces sold per day (p>0.05) in any presentation format over the selling days. Most consumers preferred buying smaller (less than half) slices of pumpkin fruit. Promotion and adoption of pumpkins presented in superior formats to increase shelf life can increase the number of high value crops available for small scale farmers to increase pumpkin production in Kenya.

Keywords: Pumpkin, Sale, Fruit, Post-harvest, Spoilage, Presentation

INTRODUCTION

Africa has an abundance of indigenous and traditional leafy vegetables which unfortunately remain under-exploited and under-utilized due to various constraints, including processing, distribution and marketing, as well as nutrition information (Oniang’o et al., 2005). The easy perishability of African Leafy Vegetables poses major challenges with their distribution and marketing. Because of the varied growing and harvesting seasons of different vegetables at different locations, the availability of fresh vegetables differs greatly in different parts of the world. Preservation of agricultural produce is one of the central problems facing developing countries. This is due to the lack of or inadequacy of preservation methods, resulting in massive spoilage of urgently needed food. As time goes on, these problems will be aggravated by the growing dietary needs of growing populations in these countries (Onyango et al., 2008). In Africa and Kenya in particular, this problem exists with many fruit and vegetable varieties (especially the indigenous ones) resulting in wastage during the in-season and limited supply during the off-season accompanied by high prices because most locally available vegetables are seasonal and not available year-long. African indigenous vegetables cannot be marketed fast enough when they are in-season owing to their limited shelf life. Appropriate preservation and storage methods should be undertaken to enable the consumption of such nutrient-rich foods all year round (Chavasit et al., 2002).

Post-harvest loss (PHL) is the measurable quantitative and qualitative food loss in the post-harvest system which comprises interconnected activities from the time of harvest through crop processing, marketing
and food preparation, to the final decision by the consumer to eat or discard the food (Kiaya, 2014; Kader, 2002). Post-harvest handling refers to subsequent processes performed immediately after removing a plant or plant part from its growth media until the removed plant or plant part reaches the final consumer in the desired form, including packaging, quantity, quality and price. Conventionally, the value chain encompasses cooling, sorting, cleaning and packaging up to the point of further on-farm processing, or shipping to wholesale or consumer markets (Masarirambi et al., 2010).

Along with roots and tubers, fruit and vegetables have the highest wastage rates of any food products (Kitinoja and Kader, 2015). The magnitude of post-harvest losses in fresh fruits and vegetables is estimated to range from 5% to 25% in developed countries; in some African countries it has been estimated that about 30% of produce is lost, and this figure can rise to 50% for very perishable foods such as fruits and vegetables (SPORE, 2011; Kitinoja and Kader, 2015; Masarirambi et al., 2010); losses have been reported to go up to 80% in some developing countries (Kitinoja et al, 2011). Losses occur in the field, during transportation, storage and processing. Losses of harvested produce may be in quality or quantity and may occur separately or together. Insects, bacteria and fungi are often responsible for severe loss of nutritive value in food. When bacteria and fungi develop on produce, unfavourable chemical changes occur. Some fungi produce carcinogenic toxins rendering food unsuitable for human or animal consumption (Masarirambi et al., 2010). Improper handling, storage, preservation techniques and microorganism spoilage increase the PHL in fruits and vegetables up to 40% (Sharma, et al., 2013).

Visual microbial growth on the fruit has been used as a main criterion to determine shelf life of fruit pieces stored under controlled atmosphere conditions (O’Connor-Shaw et al., 1996). A water soaked appearance is common in most crop produce (Saranraj et al., 2012). Shelf life, including microbial spoilage, results in 30-50% shrinkage of fresh-cut fruits and has been used by quality assurance departments as the objective indicator of quality failure for more than 50% of fresh-cut vegetables and almost 100% of fresh-cut fruits (Saranraj et al., 2012). Many fruits have nearly ideal conditions for growth of most microorganisms where internal tissues are nutrient-rich and many having pH near neutrality. Uncut fruit is covered by an outer protective epidermis typically covered by a natural waxy cuticle layer containing the polymer cutin (Lequeu et al, 2008). Hence once this is destroyed by bruising or slicing the fruit, water loss and eventual spoilage will result. Spoilage microorganisms exploit the host using extracellular lytic enzymes that degrade the polymers (cellulose, hemicellulose, pectin and majorly starch) to release water and other constituents. Fungi especially produce more diverse and greater amounts of extracellular depolymerases which successfully attack and spoil fruits and vegetables (Barth et al, 2009). According to Subrahmanyam, (1986), PHLs not only reduce the availability of fruits and vegetables but also result in increase in per unit cost of transport and marketing. This affects both the producers (reduction in share in consumers’ price) and the consumers (reduced availability and higher prices). Therefore, reducing PHL along with making more effective use of today’s crops is critical to facing the challenge of feeding an increasing world population (Kiaya, 2014).

Pumpkin is a multipurpose crop whose fruit has a yellow-orange characteristic color due to presence of carotenoids which are abundant in them (Fedha et al. 2010; Mnzava and Mbewe, 1997; Arnum, 1998). Previous research indicates that a diet rich in foods containing beta-carotene, which is an antioxidant and the major carotenoid present in pumpkin, may reduce the risk of some types of cancer and protects against heart disease. Antioxidants are required to boost the human body immunity against cancer and other deadly human diseases. Pumpkin fruit has been found to be rich in carbohydrate, protein and vast micronutrients, such that no other single food has such high nutritional potential (Oloyede et al. 2013; Encyclopedia of Foods, 2004). Moreover, pumpkin is not as bulky as other tubers such as the yam, and can be used as breakfast. Besides that, its production is less labour intensive and more profitable compared to yam and many other staples (Oloyede et al. 2013).
Internationally, records have indicated minor or inexistent trade of pumpkin leaves, fruits and seed, but at national level the leaves and fruits and often the seeds are important products on the local markets. *Cucurbita moschata* is most probably cultivated in all countries of tropical Africa, but it is more important in Southern Africa than in East and West Africa (Mnzava and Mbewe, 1997). It has been reported as lacking commercial importance in Nigeria (Blessing et al., 2011). Studies have also reported pumpkin as a crop which is not valued as a sales crop compared to other horticultural crops which are widely grown for household consumption as well as for sale by Kenyan farmers (Muendo and Tschirley, 2004). Ondigi and colleagues (2008) in their study reported that majority of farmers in the Lake Victoria basin did not consider pumpkins as first priority food crop as much as it was not considered as a viable commercial crop and was ranked fifth or sixth food crop by farmers in the region. Pumpkin is a traditional crop with high potential to overcome undernourishment and food poverty (Ondigi et al., 2008), yet very little has been done to generate income from this crop even amidst favourable ecological conditions throughout East Africa (Muendo and Tschirley, 2004; Hamisy et al, 2002). This study sought to determine marketability of fresh fruit in various presentation formats (eighth, quarter and half slices and a control of whole fruit), alongside establishing the spoilage rate of fresh fruit in the various presentation formats; and guided by two hypotheses i.e. (1) Packaging fresh pumpkin fruit into various presentation formats does not prolong shelf life (2) Packaging fresh pumpkin fruit into various presentation formats does not enhance sales in the market.

**METHODOLOGY**

The assessment for pumpkin fruit marketability involved four market women who were provided with fruit stocks to sell over a 14-day period, and instructed on the various presentation formats. They presented the whole fruit (control), fruit sliced once (into halves), sliced twice (into quarters) and sliced four times (into an eight slice) then wrapped with clear shrink wrap polythene. Records were kept on quantities sold each day over the period to identify the income generated from each of the presentation formats. The format with more pieces sold hence least wastage was considered optimal. The display of the different fruit presentations at the market was done randomly; i.e. the space and placement of each format was not done in any logical sequence which could influence the customers’ choice. In addition to the market test, a controlled experiment was carried out in laboratory to compare the spoilage rate among different presentation formats namely: whole fruit, sliced half and sliced quarter, either wrapped with clear shrink wrap polythene or not wrapped. Shelf life was determined at two days interval by recording weight loss and days the sliced fruit remained at acceptable condition as observed. Data were analysed using ANOVA to determine if there were significance differences between pumpkins presentation formats, number of pieces sold, number of pieces spoilt and total sale across different days at 5% significant level. The least significance difference (LSD) was used to separate those means which were significantly different at 5% probability level.

**RESULTS**

Marketability of pumpkin fruit was assessed by determining the amount of money received from sale of fruits of various presentation formats, besides recording the total number of pieces sold. Total number of pieces sold helped establish the presentation format which performed best in the market, not only considering the amount of money received but also considering the number of customers who preferred that format. Table 1 shows total amount of money received from sale of fruits from day 1 to 14. Generally, quarter slices and whole fruit fetched more money each day (but for a few exceptions like day 2 and 4 where there were no sales at all for whole fruit and in day 7 and 8 which had half slices realizing higher sales compared to whole fruit). It is noted that in total, sale of whole fruits realized the highest amount (KSh. 2,375/- which was received from sale of an average total of 15.75 fruits over the 14-day period). Of the sliced fruit, quarter slices recorded the highest sales (KSh. 1,440/- from 36 slices). It is notable that eighth slices realized the least amount of sale. There were no significant differences (p>0.05) in the amount of money received from sale of fruit from each of the presentation formats over the days.
Table 1- Means of Total Sales of Fruits in Various Presentation Formats

<table>
<thead>
<tr>
<th>DAY</th>
<th>EIGHTH</th>
<th>QUARTER</th>
<th>HALF</th>
<th>WHOLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.00ab</td>
<td>120.00ab</td>
<td>35.00a</td>
<td>62.50cd</td>
</tr>
<tr>
<td>2</td>
<td>5.00ab</td>
<td>50.00b</td>
<td>12.50a</td>
<td>0.00d</td>
</tr>
<tr>
<td>3</td>
<td>0.00b</td>
<td>120.00ab</td>
<td>32.50a</td>
<td>25.00d</td>
</tr>
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<td>25.00a</td>
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</tr>
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<td>20.00a</td>
<td>187.50abcd</td>
</tr>
<tr>
<td>6</td>
<td>15.00ab</td>
<td>90.00ab</td>
<td>57.50a</td>
<td>167.50abcd</td>
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<td>7</td>
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<td>50.00a</td>
<td>37.50d</td>
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<tr>
<td>8</td>
<td>10.00ab</td>
<td>60.00ab</td>
<td>77.50a</td>
<td>50.00cd</td>
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<td>45.00a</td>
<td>112.50bcd</td>
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<tr>
<td></td>
<td>Average sales (sh.)</td>
<td>160.00</td>
<td>1,440.00</td>
<td>465.00</td>
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<td>25.503</td>
<td>107.34</td>
<td>86.333</td>
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*Means followed by the same letter within a column are not significantly different at $P = 0.05$.

Further, the amount of money from fruit sales was compared to determine contribution from each presentation format. Out of a total of KSh. 4,440/- received from the sales over the 14-day period, whole fruit fetched more than half (53.5%) of this amount, as shown in figure 1. Of the sliced pieces, quarter slices had the highest sales percentage while eighth slices recorded the least (3.6%).

![Figure 1. Percentage of total cash from sale of various fruit presentation formats](image)

On assessing the amount of fruit slices sold from the different presentation formats, it was found that quarter slices recorded the most sales over the selling period, which averaged to 2.5 fruits per day. Table 2 shows that quarter slices recorded a total sale of 36 pieces in the 14-day period. It is noted that in day 11 and 14, quarter slices attained an average of 4 fruits sold and no zero sale in any day all along. This is opposed to all the other presentation formats which had at least one day with zero sale, whereby the eighth slices had the most number of days (3) with completely no sale recorded from this specific presentation format. The half slices however, were the least sold at only 6.5 pieces in total during the whole period. There were no significant differences ($p > 0.05$) between the number of fruit pieces sold per day.

Records for spoilage of fruit on display showed that out of the four presentation formats, spoilages were recorded only in quarter and half slices. Day four had the highest average number of spoilited pieces in both presentation formats compared to the other days. The quarter slices had notably seven consecutive days without any fruit spoilage in the whole of second week. More spoilage occurred in half slices, with a total...
4.25 fruits (39.5% of total half slices handled over the period) getting spoilt, while quarter slices had 10% of total quarter slices handled spoiling. There were significant differences (p<0.05) in the average number of spoilt pieces (both quarter and half slices) over the different selling days.

Table 2- Means of Pieces of Pumpkin Fruits Sold/Spoilt per Day

<table>
<thead>
<tr>
<th>DAY</th>
<th>EIGHTH</th>
<th>QUARTER</th>
<th>HALF</th>
<th>WHOLE</th>
<th>QUARTER</th>
<th>HALF</th>
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<td>3.00ab</td>
<td>0.50a</td>
<td>0.50bcd</td>
<td>0.00b</td>
<td>0.00c</td>
</tr>
<tr>
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<td>0.25ab</td>
<td>1.25b</td>
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<td>0.00c</td>
</tr>
<tr>
<td>3</td>
<td>0.00b</td>
<td>3.00ab</td>
<td>0.50a</td>
<td>0.25cd</td>
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<td>4</td>
<td>0.50ab</td>
<td>1.50ab</td>
<td>0.50a</td>
<td>0.00d</td>
<td>1.75a</td>
<td>2.00a</td>
</tr>
<tr>
<td>5</td>
<td>0.00b</td>
<td>2.50ab</td>
<td>0.25a</td>
<td>1.50abcd</td>
<td>0.25b</td>
<td>0.00c</td>
</tr>
<tr>
<td>6</td>
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<td>2.25ab</td>
<td>1.00a</td>
<td>1.25abcd</td>
<td>0.00b</td>
<td>0.00c</td>
</tr>
<tr>
<td>7</td>
<td>1.00ab</td>
<td>1.75ab</td>
<td>0.75a</td>
<td>0.25cd</td>
<td>0.50b</td>
<td>0.00c</td>
</tr>
<tr>
<td>8</td>
<td>0.50ab</td>
<td>1.50ab</td>
<td>0.75a</td>
<td>0.50bcd</td>
<td>0.00b</td>
<td>1.25ab</td>
</tr>
<tr>
<td>9</td>
<td>1.50a</td>
<td>3.00ab</td>
<td>0.00a</td>
<td>2.50ab</td>
<td>0.00b</td>
<td>0.00c</td>
</tr>
<tr>
<td>10</td>
<td>0.00b</td>
<td>3.50b</td>
<td>0.25a</td>
<td>2.25abc</td>
<td>0.00b</td>
<td>0.25c</td>
</tr>
<tr>
<td>11</td>
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<td>4.00ab</td>
<td>0.50a</td>
<td>2.75a</td>
<td>0.00b</td>
<td>0.75bc</td>
</tr>
<tr>
<td>12</td>
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<td>2.25ab</td>
<td>0.50a</td>
<td>1.25abcd</td>
<td>0.00b</td>
<td>0.00c</td>
</tr>
<tr>
<td>13</td>
<td>1.00ab</td>
<td>2.50ab</td>
<td>0.50a</td>
<td>2.00abcd</td>
<td>0.00b</td>
<td>0.00c</td>
</tr>
<tr>
<td>14</td>
<td>0.25ab</td>
<td>4.00a</td>
<td>0.25a</td>
<td>0.75abcd</td>
<td>0.00b</td>
<td>0.00c</td>
</tr>
<tr>
<td>Total pcs</td>
<td>8</td>
<td>36</td>
<td>6.5</td>
<td>15.75</td>
<td>4</td>
<td>4.25</td>
</tr>
<tr>
<td>P value</td>
<td>0.362</td>
<td>0.549</td>
<td>9.87</td>
<td>0.092</td>
<td>0.0023</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LSD</td>
<td>1.275</td>
<td>2.684</td>
<td>1.324</td>
<td>2.064</td>
<td>0.9343</td>
<td>0.7809</td>
</tr>
</tbody>
</table>

*Means followed by the same letter within a column are not significantly different at P = 0.05.

The percentage of slices sold out from each presentation format was determined by comparing with the total number of slices in all presentation formats which were sold over the assessment period. From figure 2 it is evident that more than half of all the pieces sold were the quarter slices, while half slices recorded the least sales at 9.8% of all pieces.

Figure 2. Percentage of pumpkin fruit pieces sold from various presentation formats

The shelf life of pumpkin fruit was determined in the laboratory by comparing whole fruit and after slicing into quarter and half slices which were either wrapped or not wrapped. Observations on whole fruit showed that spoilage signs were observed after an average of 142 days. On the other hand, observation on slices showed that keeping quality of fruit after slicing was drastically reduced, with the fruit beginning to deteriorate sooner, and by day four undesirable changes were evident rendering the fruit unfit for consumption. By day 4, the unwrapped fruit had begun to develop a few moulds, which had spread all over the fruit surface by day 6. The half unwrapped slices took 3 to 4 days before getting spoilt (whereby lots of mould growth was observed) while their quarter counterparts took 3 days. The wrapped
slices were characterized by less mould but had slimy surface under the wrapping, though they recorded slightly longer shelf stability whereby half wrapped slices generally took 5 days compared to 4 days in quarter wrapped slices. By day 6 observation showed that all the slices, whether wrapped or unwrapped, were completely spoilt.

Table 3 shows there were significant differences (p<.0001) between the number of days it took for whole fruit compared with the slices to get spoilt. It took a much longer time (142 days) for whole fruit to spoil while period taken for the different slices to spoil was not significantly different. It is however notable that half wrapped slice took the longest out of the four slice presentations. Quarter unwrapped slices took the shortest average number of days to spoil.

Table 3- Means of Number of Days before Spoilage of Whole and Sliced Fruit

<table>
<thead>
<tr>
<th>Presentation format</th>
<th>Number of Days</th>
<th>P value</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter wrapped</td>
<td>4.25b*</td>
<td>&lt;.0001</td>
<td>26.129</td>
</tr>
<tr>
<td>Quarter unwrapped</td>
<td>3.00b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half wrapped</td>
<td>4.75b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half unwrapped</td>
<td>3.5b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole fruit</td>
<td>142.5a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Means followed by the same letter within a column are not significantly different at P = 0.05.

Change in weight loss of the various presentation formats of slices is presented in figure 3. It is notable that the wrapped slices had a low rate of moisture loss due to the low rate of weight loss, with half slice losing only 17g (from 809g to 792g) and quarter slice losing 13g from 561g to 548g. This was much less as compared to the unwrapped ones where half slice lost 156g and quarter slice 146g.

![Figure 3. Trend in Weight Loss of Sliced Fruits in different Presentation Formats](image)

Table 4 compares the weight differences every two days since the time fruit was sliced. As earlier observed, wrapped pieces lost much less weight every two days which ranged from 3.6g to 6.2g, compared to much higher weight loss recorded in the unwrapped pieces which was between 34.5g to 74.3g every two days. More weight loss occurred between the day of slicing and the second day, then reduced with increasing days with least loss occurring between day 4 and 6. Half slices lost more weight compared to quarter slices. There were significant differences (p<.0001) between the weight loss among the quarter and half slices from day zero through to the sixth day.
### Table 4. Means of Weight Differences by Days in Various Sliced Fruit presentations

<table>
<thead>
<tr>
<th>Presentation format</th>
<th>Day two</th>
<th>Day four</th>
<th>Day six</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter wrapped</td>
<td>5.01b*</td>
<td>4.12b</td>
<td>3.62b</td>
</tr>
<tr>
<td>Quarter unwrapped</td>
<td>73.12a</td>
<td>42.38a</td>
<td>34.51a</td>
</tr>
<tr>
<td>Half wrapped</td>
<td>6.20b</td>
<td>5.12b</td>
<td>4.33b</td>
</tr>
<tr>
<td>Half unwrapped</td>
<td>74.37a</td>
<td>44.59a</td>
<td>35.66a</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>LSD</td>
<td>2.899</td>
<td>2.533</td>
<td>3.037</td>
</tr>
</tbody>
</table>

*Means followed by the same letter within a column are not significantly different at P = 0.05.

### DISCUSSION

Sale of pumpkin fruit generally appeared to be almost evenly distributed through all the selling days and all along, no single day recorded sale of three or more whole fruits (even after combining the various pieces sold daily). Amount (size) of fruit purchased and utilized in a single meal would most probably be determined by the size of the family. Of the various fruit presentation formats, the quarter slices appeared to be the most convenient size purchased by majority of the customers, probably enough to include in a single family meal (or to last for about two days for a baby’s meals). On the other hand, whole fruit was also purchased by a considerable number of customers. Probably this category of consumers utilize the fruit in preparation of family meals for two or three consecutive days, before the fruit begins to spoil.

Although whole fruits realized the highest amount of money from sale, it is notable that the highest number of customers preferred to buy quarter slices compared to the other presentation formats. Considering that a whole fruit would keep longer before spoiling (up to about 6 months), and that slicing the fruit drastically reduces its shelf life to between 3-5 days, it is therefore logical that a customer would prefer to buy a small slice enough for a single meal befitting their daily menu patterns, than purchase a whole fruit which may end up spoiling before it is fully utilized. On the other hand, a good number of customers also purchased whole fruit and it is assumed these were good pumpkin fruit consumers who would ensure the whole fruit is fully consumed before spoilage occurs.

When the spoilage rate of fruit at the market was compared with those in controlled experiment, was noted that while market quarter slices took an average of 3 days to spoil, their counterparts in the laboratory took 4.25 days, while half slices took 4 and 4.74 days respectively. This tends to indicate that the fruit was spoiling faster in the market. This can be attributed to the fact that conditions may be a bit harsh in the open as compared to the laboratory atmosphere where the fruit was stored in a cool place. As well, fruits in the open market will definitely be exposed to more microbial attack; hence will not keep as long. Barth et al (2009) indicate that bruising the waxy cuticle layer of fruit or slicing the fruit leads to water loss which eventually results to spoilage. The results of this study show that wrapping the fruit slices plays a role in preserving the fruit by reducing the rate of water loss from the fruit. On the other hand unwrapped fruit losses a lot of its water. Overall, slicing the fruit drastically reduces the shelf life of the fruit compared to whole fruit.

Observations on market fruit show that quarter slices never recorded any spoilage in the second week, and this can be attributed to the higher number of average daily sales hence the already cut fruit did not stay for too long to spoil before stock was cleared. It was also found that whole fruit did not record any spoilage over the selling period, which is expected due to the longer shelf life of whole pumpkin fruit, which was recorded at an average of 142 days. A study by Ndoro et al (2007) indicated that undamaged whole pumpkin fruit with the peduncle attached was able to keep for periods ranging from 2 to 6 months and that removal of the peduncle greatly reduced the storage period of the pumpkin fruit.
CONCLUSIONS AND RECOMMENDATIONS

There was no predictable pattern of fruit sale in the market and no significantly higher sales in any given day compared to others. There was no sale of more than three fruits in any single day, whether from whole fruit or in any of the slices. It can therefore be concluded that pumpkin fruit sale is not very popular in the study area. Consequently, consumption of the fruit is likely to be low especially among urban dwellers who are most likely to have no alternative source of the fruit besides the market. There is need to have pumpkin fruit value added options made available in the local market in order to provide more convenience foods which are more preferred by urban dwellers. This will promote consumption of the pumpkin fruit by a larger proportion of people thus promote their nutrition and food security, as well as provide an avenue for the market.

It is further concluded that whole pumpkin fruit has the longest shelf life; recorded at average of 142 days in this study (about 4.7 months), while slicing the fruit drastically reduces this period to between 3-4 days. Wrapping sliced pumpkin fruit slightly extends its shelf life by protecting it from excessive weight loss and microbial attack.

Majority of consumers prefer buying quarter slices of pumpkin fruit as opposed to other presentation formats. Although packaging pumpkin fruit into various presentation formats does not significantly enhance its sale, it is evident that bigger slices are not commonly preferred by most consumers considering that quarter slices sold much more compared to other formats. Promotion and adoption of pumpkins presented in superior formats which increase shelf life in local markets can increase the number of high value crops available for small scale farmers to increase pumpkin production in Kenya.

REFERENCES


ABSTRACT
Pumpkin potential has remained unexploited, distribution is haphazard and diversity is undocumented. The objective of the study was to enhance conservation and production of preferred multi-purpose pumpkin among smallholder farmers in Kenya. An expedition was done in 2012 and led to collection of 155 accessions. During the expedition, information on indigenous traditional knowledge (ITK) that determines how the pumpkins were cultivated and utilized over the years was gathered in Kakamega and Nyeri. The results showed that pumpkins were cultivated as an intercrop in less than half a hectare by majority, mainly for food and income (57%), food (33%) and medicinal (3%). Fruits and leaves were utilized by 38% during drought. Local accessions were the most preferred. Cultural beliefs, folklores and ITK were used by locals to safeguard pumpkin production and diversity. However, these socio-cultural values are weakening and eroding. Local pumpkins were originally inherited from the past, borrowed or bought from markets within and beyond the Kenyan borders, or introduced by NGOs. Retained seeds were used as seed source, with accessions for planting being selected based on fruit and leaf quality. Seed cleaning was not done by all the farmers. Packaging was mostly in plastic polythene bags. The accessions were mostly stored as seed or whole fruits in family houses. No protection against pest was done in most of the accessions. Above fire storage was only used by one farmer to preserve seeds. Local pumpkins were conserved by majority of the farmers, although exotic cultivars were also conserved. Pumpkins have immense potential as a source of food and income, nutrition and health benefits for food security of the communities growing them. Interventions to strengthen and preserve the ITK should be adopted and promoted to ensure its availability for reference and improvement by future generations.

Keywords: Accessions, Appropriate Technology, Conservation, Farmers, Storage, Selection

INTRODUCTION
Pumpkins are not highly regarded by smallholder farmers in Kenya. They are mostly cultivated for the purpose of overcoming problems of undernourishment and food poverty (Ondigi et al., 2008). Production of pumpkin and squash was estimated at 15,728 MT from 927 ha between the years 2005 to 2007 in Kenya (HCDA, 2008). World production in 2000 was estimated to be 16 million tones from 1.3 million ha. African production was estimated to be 1.8 million tonnes from 140,000 ha, corresponding to an average yield of 12.8 t/ha (FAO, 2003). However, these data are incomplete. Besides, only limited information per species is available. The great diversity in pumpkin cultivars indicates an enormously untapped potential (Ondigi et al., 2008). The present study conducted local surveys to collect the valuable indigenous knowledge with the farmers on productivity and use of pumpkins (Chweya, 1994; Onyango, 2002a). Enhanced knowledge plays pivotal role in food and nutrition security (Schippers, 2000; Onyango, 2002). Pumpkins grow well as intercrops and are less demanding in management since their short growing periods lend themselves favourable to mineral-nutrient intervention programmes (Onyango, 2003). They are also pest resilience (Muthoni et al., 2010).

Small scale farmers grow pumpkin at subsistence level using available organic manures on farms (Onyango, 2007). They are widely grown for their leaves, fruits and seeds, and supply calcium, iron, vitamin A, oil (25 - 55%, rich in unsaturated oleic and linoleic acids), protein (25 - 35%) with high amounts of arginine, aspartate and glutamic acid, but are deficient in lysine and sulphur containing amino acids (Ndoro et al., 2007). The present study collected pumpkin germplasm grown by smallholder farmers and the indigenous knowledge available with them. Local surveys were carried out in different agro ecological conditions in terms of temperature and rainfall, and farming activities. The aim of the
survey was to identify local pumpkin landraces grown, document indigenous technical knowledge, conservation methods and production constraints experienced by individual farmers and the community in Kakamega and Nyeri regions of Kenya.

METHODOLOGY
Local Survey
Diagnostic and formal surveys were conducted in Kakamega and Nyeri regional service units (RSUs). Kakamega lies at 00° 16’ N, 34° 45’ E and 1585 m above sea level. The mean annual temperature is 20°C, mean bimodal rainfall is 2012 mm annually, and soils are classified as dystro-molllic Nitisol (Jaetzold and Schmidt, 1983b). Nyeri lies at 36º - 38º E, 0º 38’ S, and 1810 m above sea level. Annual mean temperature is 19°C. The area receives bi-modal rainfall and 1500 mm mean rainfall annually (Kassam et al., 1991).

The soils are well-drained, extremely deep, dark-brown, friable and slightly smeary clay with acid humic top soil (andohumic Nitosols with umbric Andosols) (Jaetzold and Schmidt, 1983a). Participatory Rural Appraisal (PRA) techniques incorporated key informant interviews and checklists (Friss-Hansen and Bhuwon, 2000). IPGRI descriptors (IPGRI, 2003) were used to obtain specific information on practices, problems, indigenous traditional knowledge (ITK), constraints and opportunities for production and utilization of pumpkins. This information helped tap indigenous knowledge (Engels et al., 1995), important in determining cultivation, conservation and constraints of growing pumpkins in Kenya.

Sampling Strategy and Techniques
Ten sub counties of Kakamega and Nyeri were selected due to their abundance in terms of pumpkin germplasm and varied agro ecological zones. Initial information on pumpkin abundant sub counties was obtained from the former provincial director of agriculture (PDA) offices in both RSUs. A total of 76 key informant farmers were interviewed. Key informants who were known pumpkin farmers were identified through purposive sampling based on their interest and constraints that needed to be addressed. Checklists were used to hasten and facilitate discussions with key informants who were selected with the assistance of field extension officers (FEOs) in the ministry of agriculture. Purposive sampling was used with a focus of capturing maximum information on indigenous traditional knowledge (ITK) on pumpkins. The survey was fine-grid-intensive, targeting specific pumpkin farmers in each sub county. The survey was carried for 10 days in both RSUs.

Germplasm Identification
All the 155 accessions were planted in Chuka University research farm on 23rd May, 2015. Those that bore fruits and flowers were use for taxonomic identification. Pumpkin leaves, and stalks attached to the main vine, tendrils, and flowers were excised from each accession. The samples were placed between two newspaper pages, mounted on a hard paper and labeled to make a herbarium and then pressed between two wooden boards of the same size as the newspaper page. The boards were made of smooth timber with grid square open spaces to allow free air circulation. The samples were then dried at room temperature for one month. Seeds were extracted from fruits of each accession and dried at room temperature until they attained the required moisture content. Fifty seeds of each accession were packaged in zip lock polythene bags to accompany the corresponding herbarium. The herbaria of 96 accessions were taken to the National Museum of Kenya for taxonomic identification and the results delivered after two months.

Data Analysis
The questionnaires used for the interview were coded. Information from 76 questionnaires of farmers interviewed was analyzed using SAS, software. All qualitative data were numerically coded and arranged in nominal categories. Frequency or percentage for each descriptor state was calculated and data subjected to Chi-square analysis at $P = 0.05$. 

Proceedings of the Fourth International Research Conference
RESULTS

Local Survey
The survey took five days in each RSU and a day in each sub-county. The exercise was carried from 26th - 30th March, 2012 and 16th - 20th April, 2012 in Kakamega and Nyeri, respectively. A total of 34 farmers from Kakamega Central, Kakamega East, Kakamega South, Butere and Khwisero Sub counties of Kakamega, and 42 from Mathira East, Mathira West, Nyeri Central, Tetu and Nyeri South Sub counties of Nyeri were surveyed. The farmers surveyed were high in Mathira East and low in Nyeri South and Butere (Figure 1).

Figure 1: Farmers surveyed in each sub county

Pumpkin Production
A total of 155 pumpkin landraces were collected during the survey. All the farmers surveyed had grown pumpkin or were caring for volunteer crops. Most of these farmers intercropped pumpkins with main crops. Local variegated landraces were cultivated by majority of farmers, compared to exotic green leafed. Kakamega East farmers cultivated exotic green leafed accessions and Kakamega South the local variegated landraces more than the other sub counties (Figure 2). Majority of the farmers cultivated local variegated landraces, with a few cultivating both local and exotic cultivars. Farm size for most of the farmers surveyed were half a hectare (Table 1).

Figure 2: Type of pumpkin grown in each sub county
Table 1: Frequency of cropping patterns, type of pumpkin and farm sizes among farmers

<table>
<thead>
<tr>
<th>Cropping patterns</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>χ^2</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercropping</td>
<td>95</td>
<td>72</td>
<td>25.3</td>
<td>1.29</td>
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<td>0.000</td>
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<tr>
<td>Mono-cropping</td>
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<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercropping &amp; Mono-cropping</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of pumpkin grown</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>χ^2</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>59</td>
<td>45</td>
<td>25.3</td>
<td>23.1</td>
<td>2</td>
<td>0.000</td>
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<td>Exotic</td>
<td>19</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local and exotic</td>
<td>22</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Total</td>
<td>76</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Farm size holdings</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>χ^2</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter ha</td>
<td>9</td>
<td>7</td>
<td>10.9</td>
<td>30.8</td>
<td>6</td>
<td>0.000</td>
</tr>
<tr>
<td>Half ha</td>
<td>34</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three quarter ha</td>
<td>12</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One ha</td>
<td>20</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One half ha</td>
<td>11</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two ha</td>
<td>9</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pumpkin Utilization
Pumpkin was not cultivated as priority food crop by all the farmers. Majority of the farmers cultivated them mainly for food and income. They only traded on the surplus fruits and leaves. However, one farmer cultivated pumpkins for income only. Other farmers cultivated pumpkin for medicinal purposes, supplementary and for both human and animal food (Table 2). Pumpkin fruits and leaves were consumed by all the farmers after boiling. Seeds were consumed after roasting or were eaten raw after removing the outer cover. Some farmers mixed seeds with cereal grains to grind into flour. Majority of the farmers utilized fruits and leaves as food during drought. Whole pumpkin fruits, leaves, seeds, flowers and the vines were utilized only by one farmer (Table 2).

Table 2: Frequency of utilization pumpkin by farmers

<table>
<thead>
<tr>
<th>Pumpkin Utilization</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>χ^2</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food only</td>
<td>33</td>
<td>25</td>
<td>12.7</td>
<td>1.21</td>
<td>5</td>
<td>0.000</td>
</tr>
<tr>
<td>Supplemental food</td>
<td>4</td>
<td>3</td>
<td>12.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food and Income</td>
<td>57</td>
<td>43</td>
<td>12.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>1</td>
<td>1</td>
<td>12.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human and animal food</td>
<td>3</td>
<td>2</td>
<td>12.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicinal</td>
<td>3</td>
<td>2</td>
<td>12.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utilization of pumpkin parts</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>χ^2</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds</td>
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<td>18</td>
<td>19.0</td>
<td>26.63</td>
<td>3</td>
<td>0.000</td>
</tr>
<tr>
<td>Whole plant (leaves, fruits, seeds &amp; vines)</td>
<td>1</td>
<td>1</td>
<td>19.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruits &amp; seeds mixed with other food stuff</td>
<td>37</td>
<td>28</td>
<td>19.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit &amp; leaves used during drought</td>
<td>38</td>
<td>29</td>
<td>19.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Indigenous Traditional Knowledge (ITK)
There were general beliefs that pumpkin was for the children and pregnant women, a poor man’s crop or for the lazy. There were other believes such as children could have delayed speech if they consumed a lot of pumpkins, and a folklore, “Njamba itiriega marenge”, “brave men do not eat pumpkins”, while going
for war in Nyeri. These beliefs and folklore were gender biased and they contributed towards hampering the production of pumpkins. A belief that pumpkin cured worms when cooked and eaten with the outer peel and that an elephant that came in Murumba village in Kakamega deposited many seeds from its dung that resulted in proliferation and abundance of pumpkins, helped in promoting production of the pumpkins. Indigenous traditional knowledge such as the use of organic manure to enhance fruiting and vegetation longevity during dry seasons; restraining from leaf plucking to prevent fruit rotting or abortion of already formed fruits/flowers, and to prolong fruit shelf life. Discouraging of the main vine and lateral stems movement to avoid reduced fruiting and flower set promoted production of pumpkins.

**Seed Sources**
Retained seed was used for planting by all the farmers surveyed. The seeds of most accessions were originally inherited from the past generations (Table 3).

**Table 3: Frequency of farmers planting pumpkins and their original seed sources**

<table>
<thead>
<tr>
<th>Cultivation of accessions</th>
<th>%</th>
<th>Observed N</th>
<th>Exp N</th>
<th>χ²</th>
<th>df</th>
<th>P -value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planted pumpkin</td>
<td>84</td>
<td>64</td>
<td>38.0</td>
<td>35.579</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Volunteer plants</td>
<td>16</td>
<td>12</td>
<td>38.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source of original seed</th>
<th>%</th>
<th>Observed N</th>
<th>Exp N</th>
<th>χ²</th>
<th>df</th>
<th>P -value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inherited</td>
<td>63</td>
<td>97</td>
<td>17.2</td>
<td>442.89</td>
<td>8</td>
<td>0.000</td>
</tr>
<tr>
<td>Market within RSUs</td>
<td>13</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borrowed outside RSUs</td>
<td>5</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borrowed within RSUs</td>
<td>13</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nairobi Market</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mbale, Uganda</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROP</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KIOF</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Some of the accession seeds were extracted from fruits bought in markets within the RSUs and their source of origin was not known. Other seeds were borrowed in the RSUs, or bought from a market in Nairobi. Some of the seeds were brought from Mbale in Uganda and USA. Seeds were also borrowed from the neighboring Counties in the year 2009, and others brought by a nongovernmental organization through a programme called Rural Outreach Programme in 2008. Some of the exotic green leaved cultivars were introduced by Kenya Institute of Organic Farming in Kakamega East (Table 3).

**Seed selection**
Most of the farmers selected seeds for planting in the next season. The selection criteria differed significantly among the farmers (Table 4). Most of the accessions were selected based on fruit and leaf quality and drought tolerance (Table 4). Some of the farmers surveyed did not select, and others selected and mixed seeds of different accessions (Plate 1).

**Seed storage**
Farmer’s stored planting seed in different forms, methods and location. The preferred form of storage by most of the farmers was seed (Table 5). The method and location favoured for most of the accessions was storing in plastic polythene bags in a family house placed on the shelves, racks, raised place or on the floor on a section not frequently accessed. Storing in a gourd, open plastic containers, above fire, on a rack in a rented store or on farm (in situ) with fruit attached to the plant were the least favoured (Table 5).
Table 4: Frequency for seed selection and selection criteria

<table>
<thead>
<tr>
<th>Seed selection by farmers</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>χ²</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good seed selection</td>
<td>89</td>
<td>68</td>
<td>25.3</td>
<td>1.079</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>No seed selection</td>
<td>7</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor seed selection</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessions selection criteria</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>χ²</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought tolerance</td>
<td>19</td>
<td>29</td>
<td>12.9</td>
<td>1.315</td>
<td>11</td>
<td>0.000</td>
</tr>
<tr>
<td>Nutrition and medicinal purposes</td>
<td>5</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit and leaf quality</td>
<td>28</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pest and disease Resistant</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volunteer</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food supplement</td>
<td>3</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal input and labour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>requirement</td>
<td>14</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of fruits</td>
<td>5</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market requirement</td>
<td>7</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long vegetation and fruit storage period</td>
<td>4</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No reason specific reason</td>
<td>10</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf and fruit</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Plate 1: Seed mixtures stored by farmers

The favoured method and location storage combination was the use of plastic polythene bags, in a family on shelves or on the floor (Table 6). Farmers did not use any specific seed protection mechanism when storing their seed. One farmers in the survey area used firewood smoke to protect his pumpkin seeds from pests (Plate 2). There were no special containers used by farmers for seed preservation or storage, but plastic polythene bags, old newspapers or plastic containers were mostly used. Whole pumpkin fruits in most of the accessions were stored to be used for extracting seeds for the next crop. Seed cleaning and packaging was not done by all the farmers.
Table 5: Frequency of seed storage forms among the farmers, methods and locations of the accessions

<table>
<thead>
<tr>
<th>Storage forms</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>$\chi^2$</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed stored</td>
<td>54</td>
<td>41</td>
<td>15.2</td>
<td>62.8</td>
<td>4</td>
<td>0.000</td>
</tr>
<tr>
<td>Fruit stored</td>
<td>21</td>
<td>16</td>
<td>15.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed and fruit stored</td>
<td>16</td>
<td>12</td>
<td>15.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. seed/fruit stored</td>
<td>6</td>
<td>5</td>
<td>15.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed seed stored</td>
<td>3</td>
<td>2</td>
<td>15.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td>62</td>
<td>25.8</td>
<td>160.058</td>
<td>5</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Storage method

<table>
<thead>
<tr>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>$\chi^2$</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic polythene</td>
<td>40</td>
<td>62</td>
<td>25.8</td>
<td>160.058</td>
<td>5</td>
</tr>
<tr>
<td>Wrapped on old newspaper</td>
<td>4</td>
<td>6</td>
<td>25.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stored in Guard</td>
<td>3</td>
<td>5</td>
<td>25.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stored in open Plastic containers</td>
<td>2</td>
<td>3</td>
<td>25.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stored as whole fruits</td>
<td>41</td>
<td>63</td>
<td>25.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stored on metal or plastic plates</td>
<td>10</td>
<td>16</td>
<td>25.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Storage location

<table>
<thead>
<tr>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>$\chi^2$</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above fire</td>
<td>1</td>
<td>2</td>
<td>22.1</td>
<td>2.377</td>
<td>6</td>
</tr>
<tr>
<td>On or in a cabinet in kitchen or house</td>
<td>21</td>
<td>32</td>
<td>22.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On rented store rack</td>
<td>1</td>
<td>2</td>
<td>22.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm store</td>
<td>21</td>
<td>33</td>
<td>22.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>House on shelves etc or on floor</td>
<td>52</td>
<td>81</td>
<td>22.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside house on rack</td>
<td>2</td>
<td>3</td>
<td>22.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On farm and fruit attached to plant</td>
<td>1</td>
<td>2</td>
<td>22.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Cross tabulation of storage method and location of pumpkin accessions

<table>
<thead>
<tr>
<th>Storage method</th>
<th>Above fire</th>
<th>Kitchen cabinet in or house</th>
<th>Rented store rack</th>
<th>Farm store</th>
<th>Family house shelves or floor</th>
<th>Outside house on rack</th>
<th>On farm fruit on plant</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic polythene bags</td>
<td>0</td>
<td>9</td>
<td>1</td>
<td>13</td>
<td>39</td>
<td>0</td>
<td>0</td>
<td>62</td>
</tr>
<tr>
<td>Wrapped on old newspaper</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Gourd</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Open Plastic containers</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Fruit stored</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>20</td>
<td>3</td>
<td>2</td>
<td>63</td>
</tr>
<tr>
<td>Metal or plastic plates</td>
<td>0</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>32</td>
<td>2</td>
<td>33</td>
<td>81</td>
<td>3</td>
<td>2</td>
<td>155</td>
</tr>
</tbody>
</table>

Plate 2: Above fire dried pumpkin seeds
Germplasm Conservation
Most of the farmers conserved only local accessions, though exotic and both local and exotic cultivars were also conserved by some farmers, likewise the local accessions conserved were more compared to the exotic green leafed (Table 7). Cultivation of exotic cultivars was high in Nyeri compared to Kakamega.

Table 7: Chi-square analysis on the frequency of farmers and accessions type of germplasm conservation

<table>
<thead>
<tr>
<th>Conservation by farmers</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>$\chi^2$</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>59</td>
<td>45</td>
<td>25.3</td>
<td>23.1</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>Exotic</td>
<td>19</td>
<td>14</td>
<td>25.3</td>
<td>25.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local and exotic</td>
<td>22</td>
<td>17</td>
<td>25.3</td>
<td>25.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conservation of germplasm</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>$\chi^2$</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>68</td>
<td>105</td>
<td>77.5</td>
<td>19.52</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>Exotic</td>
<td>32</td>
<td>50</td>
<td>77.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pumpkin Constraints
Majority of the farmers reported no constraints in pumpkins. The constraints experienced by farmers while cultivating pumpkins varied from fruit rotting, fruit and flower abortion, wasps and fruit flies, leaf rollers, pest attacks on flowers, fruits and leaves, fruit warts, rats, porcupines, moles, blights, mildews, chlorosis, browning and death of young and old leaves, small unmarketable and low priced fruits and small land parcels (Table 8). Piercing of fruits by wasps and fruit flies were reported to be the most problematic by most of the farmers. Other major constraints reported included rodents, fruit rotting, and warts on fruit surfaces and pest attacks. Occurrence of pest and diseases were mostly observed on exotic green leafed cultivars. Moles were high in Kakamega, and porcupines in Nyeri. Fruit rotting was high in Nyeri, due to prevalence of wasps and fruit flies. Warty fruits were common on the fruits of exotic green leafed cultivars.

Table 8: Chi-square analysis on the frequency of pumpkin constraints encountered by farmers

<table>
<thead>
<tr>
<th>Pumpkin constraint</th>
<th>%</th>
<th>Obs N</th>
<th>Exp N</th>
<th>$\chi^2$</th>
<th>df</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit rotting</td>
<td>10</td>
<td>8</td>
<td>5.8</td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piercing by wasps and fruit flies</td>
<td>13</td>
<td>10</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit, leaf and flower abortion</td>
<td>3</td>
<td>2</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaf rollers</td>
<td>3</td>
<td>2</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pest attacks on flowers, fruits and leaves</td>
<td>7</td>
<td>5</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warts on fruit surfaces</td>
<td>8</td>
<td>6</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rodents (Rats, porcupine and moles)</td>
<td>12</td>
<td>9</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blights and Mildews (Downey and powdery)</td>
<td>1</td>
<td>1</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorosis, browning, death of young/old leaves</td>
<td>3</td>
<td>2</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small unmarketable, low priced fruits</td>
<td>5</td>
<td>4</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small land parcels reducing production</td>
<td>1</td>
<td>1</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of fruits due to shortage of rains</td>
<td>3</td>
<td>2</td>
<td>5.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No constraints</td>
<td>31</td>
<td>24</td>
<td>5.8</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Total</td>
<td></td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Taxonomic Identification
The voucher specimens of 96 accessions were delivered to NMK for taxonomic identification by a botanical expertise specialist, who understood plant morphology and had experience in taxonomy of plants. All the accessions belonged in Cucurbitaceae Family. They were classified as: Cucurbita moschata (Lam.) Poir. Botanical names were based on the Latin binomial system. The accessions were
separated into two categories; green-leafed and variegated-leafed (Table 9). The cultivar names of the accessions were not indicated. This was because NMK had only tools for wild plant collections save for a few crops with special tools.

**Table 9: Taxonomic classification of the accessions**

<table>
<thead>
<tr>
<th>Accession codes</th>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Author</th>
<th>Common name</th>
<th>Type of accession</th>
<th>Region of collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>KK 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 17, 24, 26, 29, 30, 31, 32, 34, 36, 38, 39, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 54, 56, 58, 59, 60, 62, 63, 64, 65, 66, 67, 69 &amp; 70</td>
<td>Cucurbitaceae</td>
<td>Cucurbita</td>
<td>moschata</td>
<td>Lam. Poir.</td>
<td>Pumpkin</td>
<td>Variegated</td>
<td>Kakamega</td>
</tr>
<tr>
<td>KK 15, 16, 35 &amp; 55</td>
<td>Cucurbitaceae</td>
<td>Cucurbita</td>
<td>moschata</td>
<td>Lam. Poir.</td>
<td>Pumpkin</td>
<td>Green-leafed</td>
<td>Kakamega</td>
</tr>
<tr>
<td>NY 74, 77, 100, 134 &amp; 147</td>
<td>Cucurbitaceae</td>
<td>Cucurbita</td>
<td>moschata</td>
<td>Lam. Poir.</td>
<td>Pumpkin</td>
<td>Green-leafed</td>
<td>Nyeri</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Local surveys were carried with farmers in Kakamega and Nyeri. The two regions are prime areas, covering a wide range of socioeconomic as well as natural conditions ideal for pumpkin production and agribusiness. The areas are similar in rainfall and population density. Rainfall is ample and accommodates two cropping seasons (Place *et al*., 2006). The survey was done for a single day in each sub county, on a single farm crop (pumpkin). Pumpkin being an annual crop, the short visit didn’t miss the required ethno botanic information and ITK. During the survey 76 farmers participated in the exercise, a large number of farmers was expected, but challenges such as failure to access some of the targeted areas due to poor road conditions; long and rough roads to cover an otherwise would be short distances, lack of agriculture staff in some locations which made it difficult to trace the right farmers; Information barrier due to patriarchal family system in some instances which hindered information divulge without permission from the counterpart; transport scarcity and information delivery failure delayed the start of the survey in some sub counties which contributed to the low number of respondents surveyed.

**Pumpkin Production**

Local pumpkins were mostly cultivated by majority of the farmers. One of the reasons for their preference was their cultural identity. This signified their value and importance in the local cultures (Ngugi *et al*., 2007). Other reasons included biotic and abiotic stress tolerance; ability to grow naturally with little or no care using organic manure which is locally available; retained seeds recycled every year without significant yield reduction, and their good taste of leaves and fruits. The local species have naturally evolved over the years in specific environments (Mooney and Cleland, 2001). This has enhanced their continued production and use (Irungu *et al*., 2011). Maarten van (2013) reported pest resistance and abiotic stress tolerance, Onyango and Onyango (2005) low prevalence to pest and diseases and Brown, (2002) repelling of aphids by silvery-leafed in local landraces than green leafed pumpkins. Exotic green leafed cultivars were also grown by some of the farmers. They had low yields, pest and diseases were common and vegetative period was short. Wien *et al*. (2004) stated that pest and disease attacks and poor adaptation result in low yields. Weltzien and Fischbeck (1990) reported exotic cultivars not being superior to the local landraces. However, the response of genotypes in different locations, years or seasons, depends on the environmental interaction (Razim, 2011), because yields are polygenic in nature (Pandey *et al*., 2008). Low yields in present pumpkins compared to the past one, and also high yields
were reported by farmers. The low yields were attributed to intercropping of pumpkins by majority of the farmers, who were only interested in obtaining full yield of the main crops. Momirovic et al. (2015) reported significant high yields in a sole crop of pumpkin than in intercropping. Intercropping reduces yields through competition for assimilates (Maynard, 2007), when interspecific and intraspecific competition are high in the same environment (Momirovic et al., 2015). The increased yields obtained by some farmers attributed to trellising of pumpkins with main crop that enhanced better opportunity to exploit light interception. Chukwudi and Agbo (2014) reported increased number of branches, leaves, and vine length and leaf area in trellised plants than non-trellised.

Pumpkin Utilization
Farmers mainly cultivated pumpkins for food and income. They only sold the surplus because pumpkins have considerable potential as income earners (Onyango, 2002). Onyango (2007) reported pumpkin leaves as one of the African Leafy Vegetables important for food and income in many western Kenya communities. Commercialization of pumpkins by farmers in Kakamega and Nyeri was necessitated by closeness to nearby towns of Kakamega, Butere, Nyeri, Othaya and Karatina, Kisumu and Nairobi among others. In the survey area medicinal application of pumpkins based on farmer training, indicated that fruits and leaves were helpful in maintaining body health, and the seeds were useful in preventing major sicknesses such as HIV when consumed regularly. Ondigi et al. (2008) reporting on farmer opinions as influenced by visits of health, social or agricultural workers indicated that pumpkin and pumpkin products boosted immunity and strong bones, the seeds improved eyesight of people above 30 years, acted as iron supplement, provided vitamin E; cleaned kidneys, treated stomach ulcers and acted as de-wormers, relaxatives, antiflatulents and anti-diarrhea.

The fruit stalks were used to treat heartburns and the roots as medicine for pregnant. Pumpkin fruits have active compounds such as: vitamin C and E, minerals, pectins and carotenoids. Carotenoids catch free radicals and active atomic oxygen in human body by acting as biological antioxidants, protecting cells and tissues from the damaging effects of free radicals and singlet oxygen. Xanthophyll pigments (lutein and zeaxanthin) in fruits play protective role for coronary heart diseases and stroke, cataract and macular degeneration (Kulaitiene et al., 2014). Farmers in the survey area also used pumpkin as supplemental food for human and animal feed during drought. Ondigi et al. (2008) reported pumpkin by regarded as supplementary food by most of the farmers. In the present study, pumpkin fruits were fed to livestock during drought due to shortage of fodder. The vines and leaves were only fed during farm preparation and clearing when whole crop was uprooted. They provide good sources of proteins and fibre (Kulaitiene et al., 2014), and nearly all nutrients required to maintain human and animal health (Ondigi et al., 2008).

Pumpkins were consumed most of the farmers during drought. They played an important role in maintenance of nutritional levels during the long dry seasons, when other fresh vegetables are not available. Their fruits stored for long up to 6 months (Onyango, 2002), or over 8 months with stalk attached to the fruit (Ondigi et al., 2008). Traditional pumpkins were mostly maintained by farmers (Thies, 2000), because they were known to have strong cultural importance and better withstanding of adverse weather conditions (Oloyede, 2014). They possessed important genes for drought resistance (Marilene et al., 2012), and could grow in a wide range of environments (Ondigi et al., 2008). They were grown with ease using minimal external inputs, low rainfall and poor soils (Muthoni et al., 2010). Farmers consumed pumpkin seeds raw, roasted or after grinding into flour when mixed with cereal grains. Kulaitiene et al. (2014) reported seeds used either for direct consumption or for preparation of other foods such as syrups, jellies, jams, and purees. Processed pumpkin flour had longer shelf life, flavour, sweetness, deep yellow orange color and considerable amount of dietary fiber. Pumpkin fruits were cooked then mashed into watery substance and mixed with wheat flour for baking or mixed with maize and beans or consumed as snacks after boiling. Kulaitiene et al. (2014) reported pumpkin supplementing cereal flours in bakery products, soups, sauces, instant noodles and also as a natural coloring for food.
Indigenous Traditional Knowledge (ITK)
To help manage and conserve pumpkin diversity, cultural beliefs, folklores and ITK were used. Cultural beliefs safeguarded the growth and development of pumpkins (Ondigi et al., 2008). They set out rights and responsibilities of the local communities (Swiderska, 2009). Indigenous technical knowledge ensured traditional knowledge fulfilled community needs and addressed new challenges (Swiderska, 2009). Folklores were important in preserving the original local landraces (Howard, 2006). These socio-cultural values safeguarded the diversity of local landraces (Ondigi et al., 2008), from wanton destruction by cautioning the way indigenous people used their resources for continuum (Swiderska, 2009). However, some of these values were gender-biased, which hindered the overall expansion of pumpkin production (Ondigi et al., 2008). Some of the socio-cultural values are maintained, but others have been weakened and eroded (Swiderska, 2009). The weakening among other reasons has contributed to loss or erosion of local landraces (Bott, 2007). The elderly had made significant contributions to the maintenance of local landraces through traditional sustainable resource use practices and culture-based respect for nature (Beltran, 2000). For instance, a proverb “pumpkin in the old homestead must not be uprooted” was used to plead with and admonish people not to destroy their cultural identity (Bott, 2007). In Kenya, the socio-cultural values are on the decline due to spread of western cultures in the rural areas. They have been lost or modified, or are selectively recognized. In most areas, they have been lost entirely, with some only remaining amongst the elderly (Swiderska, 2009). Abandonment and neglect of these the socio-cultural values that safeguard genetic diversity of local landraces, that have all relevant allelic diversity necessary for pumpkin improvement could lead to loss of the entire gene pool (Mwaura, 2004; D’hoop et al., 2010).

Seed Source
The seeds of local accessions were mostly inherited from past generations. Ndoro et al. (2007) reported seeds of landraces that have been maintained by farmers over long periods of time. Most of the farmers in the surveyed used retained seed, although some used borrowed seed from neighbours and relatives. Ndoro et al. (2007) reported retained seed constituting the bulk of the pumpkin seed source, and borrowing by a few of the farmers. Pumpkin fruits were also bought from local or outside markets and seed extracted. The disadvantage of buying fruits from the market was that their source was not known. Longley et al. (2001) and Ndoro et al. (2007) reported seed sources to include local markets. Informal seed supply systems are critical components of resource-poor farming systems (Bates et al., 2011), they hinge on the cultural heritage where farmers save, sell and exchange germplasm (Majuju, 2010). Some farmers brought in accession seeds from beyond Kenyan borders or introduced by nongovernmental organizations. In the present study, farmer’s reacted that the introduced exotic pumpkins did not outperform local species. Pest and diseases and low yields were common on these cultivars. IBC (2007) reported that exotic or non-native species result in unknown disease and pest problems. Purposeful introduction of non-native species by humans threaten native species with extinction by hybridization and introgression. Hybridization leads to the decline of local species through inbreeding depression, genetic mixing, genic dilution and dispersion. Introgression causes genetic swamping of the local species gene pool, creating hybrids that supplant the native stock (Rhymer and Simberloff 1996; Potts, et al, 2001). Unequal gene exchange between the local species and introduced varieties affects adaption (Grant et al., 2005), and also threatens local species genetic diversity through genetic erosion (Mathur, 1995; Su et al., 2003) and existence (Rhymer and Simberloff 1996; Potts, et al, 2001).

Selection, Storage and Conservation of Seed
Farmers in the survey area selected accessions for the next planting after harvesting. The selected accessions were based taste of fruits and leaves. Rajendran et al. (2014) reported a strong relationship between dietary and farm produce on diversity. Selection based on quality and preference can affect plant diversity if the associated accessions have better nutritional profile (Kulkarni and Gokhale, 2014). Diversity is significantly related to dietary and consumption of own produced than market-purchased varieties. Farmers extracted seed during fruit utilization or before planting. Seed cleaning was not done by all the farmers. Seed extraction and cleaning can influence pumpkin genetic diversity. Pumpkin genetic
diversity loss can result from inadvertent selection, such as throwing away smaller or lighter seeds during the cleaning process. The loss can also be intentional, if larger, more uniform, or faster germinating seeds are selected, and others excluded. In both cases, if the selected characteristics have a genetic basis, loss of diversity occurs. On the other hand, there may be no or negligible genetic effects if the losses are small (USDA, 2006).

Farmers mostly used seed size to select seeds of pumpkin accessions. Some did not select seeds, while others selected and mixed seeds of different accessions. Good seed selection improves physiological quality by eliminating small, empty and under-developed. Seed size variation of accessions can be caused by heredity, environmental or developmental factors. Small seeds yet viable are deliberately eliminated by farmers based on the assumption that seed size and vigour are correlated. Selection based on seed size can change the genetic constitution of the accessions by eliminating part or whole family by discarding small seeds (Schmidt, 2000). The accessions were stored in seed form by majority of the farmers in plastic polythene bags in a family house. Seed packaging and storage method can result in pumpkin loss of diversity from mortality of some seeds in storage (USDA, 2006). Storage locations and methods determine vulnerability of seeds to pests, diseases, physiological deterioration, quantity and quality, act as forces for selecting seeds that are better adapted and are more likely to survive until the next planting season (Jarvis et al., 2000). In the survey, one farmer stored seeds above fire. Storage above fire protects the seeds from pest, since smoke and heat produced by fire creates inhospitable environment for pests, however seed viability is affected (Bates et al., 2011).

The seeds of local species were mostly conserved in situ by farmers. They serve as a genetic resource for breeding and improvement of well-adapted species (Porth and El-kassaby, 2014). Conservation within local environment ensures adaptation is maintained within the farming systems. On-farm conservation is central to the local communities, as it conserves not only the existing germplasm, but also in conditions allowing development of new germplasm (Jarvis et al., 2000). Local agro ecological conditions play an important role of ensuring crop genetic diversity remain directly in the hands of the primary users (Kumar et al., 2010). This empowers and recognizes individual farmers and local communities as the curators of local genetic diversity and indigenous knowledge (Jarvis et al., 2000). Exotic cultivars conserved by some of the farmers, can result in genetic erosion or threat to the local species (Jarvis et al., 2000). To extenuate the local species from relative erosion or threat can be done through establishment of conservation priorities (Kumar et al., 2010). This require collection, in-situ conservation and enhancement programmes involving individual farmers, local communities, breeders and other stakeholders in maintenance, restoration and improvement (IBC, 2007). These will enhance the local species genetic gain for a multitude of useful traits and vitality to withstand diverse biotic and abiotic stressors under changing and unpredictable environmental conditions (Porth and El-kassaby, 2014).

**Pumpkin Production Constraints**

Pumpkin constraints were not reported in local accessions by most of the farmers. However, reported constraints included fruit piercing by wasps and fruit flies, rodents (rats, porcupine and moles), fruit rotting, warty fruits, pests and diseases. The exotic cultivars grown by some of the farmers were highly susceptible to pests and diseases, produced low or no yields under severe infestation (Ndoro et al., 2007) and most of the fruits were warty. Constraints such as lack of quality seed (Onyango and Onyango, 2005), temperature rise, irregular and unpredictable rainfall (GoK, 2010) has hampered increased production and diversity of pumpkins. To mitigate the effects of unpredictable drought events farmers have continued production of locally adapted and drought tolerant crops as a strategy (Munisse et al., 2011). Exotic cultivars planted by some farmers, has resulted in unknown diseases and pests, which can lead to genetic vulnerability of local species (IBC, 2007). Planting of disease-tolerant varieties and good cultural practices will help farmers to control some of these important diseases (Wyenandt, 2006). Most of the farmers surveyed had land sizes below one hectare. Declined land sizes due to population pressure (Maina et al., 2010; Place et al., 2006), has adversely affected production of pumpkins that require large area for
cultivation (Oloyede et al., 2013a). These factors and many others have contributed to low cultivation and poor production of pumpkins in the survey area.

**Taxonomic Identification**

In the present study, three (Luhya, Kikuyu and Luo) communities were surveyed. They all had their local names that they used to commonly refer to different pumpkin species. Nesbitt et al. (2010) reported different local names, or one name describing different species with similar uses or taste. Plant identification computes a species taxon that a plant belongs (Nesbitt et al., 2010). It relies on phenotypic appearance that involves listing of observable characteristics of organisms and matching them with a diagnostic of a particular group (Echessa, 2011). Thus, taxonomy is a vital (Bennett and Balick, 2014), method in identification of species (Echessa, 2011). In the study, 96 local and exotic species were identified. They all belonged in: Cucurbitaceae family and Cucurbita moschata (Lam.) Poir species. The botanical names were based on the Latin binomial system (Nesbitt et al., 2010). Nesom (2011) reported Cucurbita moschata species identified as Duchesne ex Lam., or Duchesne ex Poir., based on Cucurbita pepo var. moschata Duchesne ex Lam.

The cultivar names of different accessions identified were not added. The species name alone is insufficient. Sub species or varietal names must be provided along with the cultivar name (Bennett and Balick, 2014). Distinct forms of cultivated plants bear an additional formal name: a cultivar name (cv) appended to the main botanical name (Nesbitt et al., 2010). The cultivar names were not added, since NMK had only tools for wild plant collections save for a few crops with special tools. Cucurbita moschata species has many cultivars which include: butternut squash, golden cushaw, calabaza, winter squash, crookneck squash, neck pumpkin, Tahitian squash, West Indian pumpkin, large cheese pumpkin, Long Island cheese pumpkin, Tennessee sweet potato, Kentucky field pumpkin and Dickinson pumpkin (Nesom, 2011), Buckskin, Thai and Cheese (Echessa, 2011), La Primera, Seminole, Soler, Golden crookneck, Waltham Butternut, Zenith and Upper Ground Sweet Potato (OECD, 2012), among others.

The identified accessions were further grouped as green-leafed or variegated-leafed. Brown (2002) reported variegated silvery-leafed and green-leafed pumpkins role in repelling of Aphids. The two groups depicted variation in leaf colour, fruit and seed characters. Their fruit ribs were smooth or rounded, with verrucose or granulose surfaces in some of the green-leafed accessions, fruit rind colour varied from light-green to uniform dark-green or cream or yellow spots, light to dark, orange, or completely grey and cream white surfaces (Purnomo, et al., 2015). The seeds had smooth or tubercular coats, intermediate to very large seed size; white, yellow-white, cream-yellow, light-brown or tan and brown in colour, narrowly-elliptic, elliptic to broadly-elliptic shapes, with blunt or pointed hilum ends. Nesom (2011) reported differences of five domesticated Cucurbita species, as seen in growth habit, stems, leaves, fruit peduncles, fruit size, shape, surface, colour, seed shape, size and colour (OECD, 2012).

**CONCLUSIONS AND RECOMMENDATIONS**

In Kenya, pumpkins are not grown as a priority crop by most farmers, couching them at a risk of genetic loss. The local pumpkins are well adapted to the local environment and are tolerant to biotic and abiotic stresses. This diversity can be harnessed to improve production and income for small scale farmers. They also have the potential of promoting health, nutrition and food security for the poor small scale farmers. However, growing native species together with the local ones can cause genetic erosion and loss of diversity. Farmers in the survey area used cultural beliefs, folklores and indigenous technical knowledge to safeguard growth and development, address new challenges and preserve genetic diversity of local pumpkins. These socio cultural values are slowly weakening among individual farmers and local communities. It is therefore necessary to sensitize them about the need to promote pumpkin production and consumption. Lack of quality seed has hindered expansion in pumpkin production. Strengthening of informal seed systems should be promoted by government and all other stakeholders involved the seed industry to ensure quality seed is available. Breeders and seed merchants have a big task of improving the
existing or come up new cultivars tolerant to biotic and abiotic stresses, and adapted to the changing environmental conditions. Empowering farmers to be custodians and recognizing them as curators of local genetic diversity and indigenous knowledge should be encouraged to avoid further genetic erosion and loss of genetic diversity. Seed storage practices should be strengthened and on-farm conservation of species within the local agro ecological conditions should be maintained to ensure sustainable pumpkin production for food security. Plant identification is critical to reproducibility, documentation, and prediction of plant species. Lack of proper identification ignores history, similarities and differences between living things. For plant species to become useful they should be properly identified and accessioned correctly. This can only be achieved by collecting, identifying and conserving different species ex-situ or in-situ for breeders and other plant users to utilize them in improving the local species.

ACKNOWLEDGEMENT
This research was supported by funds from the KAPAP to whom we are most obliged. Authors are grateful to ministry of agriculture staff in Kakamega and Nyeri counties, to Mr Manyengo, KAPAP representative in Kakamega and to farmers who offered germplasm and participated in the survey to give all important information for their cooperation and collaboration.

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IDENTIFICATION AND QUANTIFICATION OF PHYTO-COMPONENTS PRESENT DURING DEVELOPMENT OF COFFEE (Coffea arabica L.) SOMATIC EMBRYOS IN VITRO

Mayoli, R. N.1,2 Isutsa, D. K. 3, Nyende, A. B.3, Mweu, C. M.3

1 Coffee Research Institute, Kenya P. O. Box 4-00232 Ruiru, Kenya
2 Chuka University, P.O. Box 109-60400 Chuka, Kenya
3 Jomo Kenyatta University of Agriculture and Technology, P. O. Box 6200-00200 Nairobi.
Corresponding author: rosemayoli@yahoo.com

ABSTRACT
Coffee was the first major export crop in Kenya and has remained an important part of the Kenyan economy throughout the years. Endogenous factors related to development of coffee somatic embryos are not well understood and this results in poor induction of few embryos and subsequent low regeneration of coffee seedlings. The research was formulated to identify and quantify endogenous phyto components associated with somatic embryogenesis in Coffea arabica cultivar Ruiru 11. Third leaf pair of greenhouse-grown mother plants was used as explants and were cultured in half-strength Murashige and Skoog (MS 1962) media. Both green and brown leaf discs cultures with and without embryos, were used to characterize these phyto with fresh culture media and leaf explants used as controls in a completely randomized design replicated thrice and repeated once in 2016. These compounds were extracted and analyzed using a GC-MS (Model QP2010 SE, Shimadzu). Their identification entirely relied on the matching of the mass spectrometric fragmentation pattern corresponding to those present in the NIST mass spectral database. Several phytocomponents were identified and classified as fatty acids, alcohols, aldehydes and hydrocarbons. Oleic acid, trans-(2-phenyl-1, 3-dioxolan-4-yl) 9-Octadecenoic acid methyl ester, Heptadecanoic acid heptadecyl ester, Hexadecanoic acid, 1-(hydroxymethyl)-1, 2-ethanediyl ester, (8)-Heptadecane, Dodecane, n-Octylidencyclohexane, 2-methyltetrasocane, 2-butyl-1-Octanol, and 1-Hexadecanol, (Z)-7-Hexadecenal, (Z)-9-Octadecenal, 2-Undecenal, 3,7-dimethyl-7-Octenal were detected in all the treatments. Fatty acids are essential in producing an active compound that acts as auxin-like plant growth promoting activity and their degradation results to alcohols and aldehydes. Hydrocarbons detected may play a role in maintaining inner cell structure and act as energy storage components. Embryogenic cultures released more and higher quantities of phytocomponents as compared to non-embryogenic cultures and thus embryogenic competence in coffee appeared to be related to the synthesis of phytocomponents.

Keywords: Phytocomponents, Coffee, in vitro, somatic embryogenesis

INTRODUCTION
Coffee was the first major export crop in Kenya and has remained an important part of the Kenyan economy throughout the years. Coffee is ranked 5th contributor to GDP after horticulture, tourism, tea, and diaspora remittance. Currently, the industry contributes about 3.2% of Kenya’s foreign exchange earnings, 0.2% national GDP (Commodity Fund, 2017), 8% of the total agricultural export earnings and up to 25% of the total labor force employed in agriculture (AFFA, 2015).

Coffee production in Kenya has been constrained by many factors which include; high cost of production, inappropriate technology and mismanagement of coffee co-operatives (Karanja and Nyoro, 2002). Major diseases that attack coffee include; Coffee Berry Disease (CBD) caused by Colletotrichum kahawae, Coffee Leaf Rust (CLR) caused by Hemileia vastatrix and to a lesser extent, the Bacterial Blight of Coffee (BBC) caused by Pseudomonas syringae pathovar garcae (Omondi et al., 2001). Coffee Research Foundation developed new coffee varieties namely Ruiru 11 and Batian. These elite varieties combine CBD and CLR resistance with improved yield and quality. Despite the release of the two new varieties, an emerging challenge is meeting the rising demand for the improved disease-resistant coffee planting material. Plant tissue culture plays an important role in agricultural biotechnology as it allows in vitro regeneration and multiplication of plants under aseptic conditions. Plant regeneration in tissue culture occurs through two developmentally and morphologically divergent processes: (a) Somatic
embryogenesis (SE) and (b) organogenesis (shoots and roots). Somatic embryogenesis is a type of vegetative propagation based on plant cell totipotency, which offers a powerful alternative to other vegetative propagation methods, i.e. cuttings or grafting. In the case of coffee, its main use is for F1 hybrid propagation, thereby avoiding manual hybrid seed production and cuttings which are costly and difficult to root.

Coffee, especially the green bean is rich in bioactive compounds or phyto-components (Dong et al., 2015). Fatty acids are molecules attached to other compounds such as sugars, glycerol or phosphate head groups to form lipids (Karimi et al., 2015) and are associated with many biological activities. Hydrocarbons, aldehydes and alcohols are known to be products of the enzymatic breakdown of unsaturated fatty acids (El Hadi et al., 2013). Hydrocarbons, especially the n-alkanes are highly hydrophobic aliphatic molecules and are important components of the cuticle and they assist in maintaining plant water balance (Cunha and Fernandes-Ferreira, 2001). Aldehydes on the other could arise from the degradation of polyunsaturated fatty acids either by autoxidation or by the action of enzymes such as lipoxygenases as reported by Takahashi et al. (2002).

Many Coffea species have difficulty regenerating somatic embryos in tissue culture, in spite of the great progress accomplished in development of embryogenic cell induction protocols. The difficulty results in regeneration of few embryos during the induction process and subsequently fewer coffee seedlings that don’t meet farmers’ demands of new disease resistant varieties. Therefore, it is imperative to determine the endogenous phyto-components which may be inhibitors and stimulators of coffee somatic embryogenesis so as to counteract and augment them, respectively.

MATERIALS AND METHODS

Plant material and induction of somatic embryos

This research was conducted in laboratories and greenhouses of the Coffee Research Institute at Ruiru in Kenya. Coffea arabica cultivar Ruiru 11 was used in this study. Third leaf pair explants were excised from greenhouse-grown mother plants between March and April 2016. The explants were washed thoroughly under running tap water followed by water containing Teepol detergent and finally sterile distilled water. The subsequent sterilization steps took place under the laminar flow cabinet. The explants were dipped quickly (approximately 30 seconds) in 70% alcohol and rinsed 2-3 times in sterilized distilled water. The explants were further sterilized using 20% sodium hypochlorite for 20 minutes followed by rinsing thoroughly (4 times) in sterilized distilled water. The basal culture media contained half-strength Murashige and Skoog (MS 1962) inorganic salts, supplemented with vitamins, 30 g/L sucrose, 100 mg/L myo-inositol 100 mg/L cysteine, and 1 ml/L Thidiazuron. The pH of the media was adjusted to 5.7 using 1 M NaOH or 1 M HCL and 3 g/L gelrite added before autoclaving for 15 minutes at 121°C and 100 kPa. Culture media (25 ml) was poured into Magenta vessels (Sigma Chemical Co.) and 5 leaf discs (approximately 1 cm²) cultured in each vessel to be maintained in the dark at 25°C ± 2 and 70% humidity growth chamber.

Treatments

After 6-8 months of culture, treatments for this experiment were selected. The treatments were categorized as follows: culture vessels with green and brown leaf discs with and without embryos as shown below in figure 1 were used to identify various phyto components. Fresh culture media and fresh leaves excised from greenhouse-grown mother plants were used as the controls. The experimental layout was a completely randomised design, with three replications and three Magenta vessels per treatment.

Extraction of Phyto-components
For the extraction phyto-components, about 50ml methanol was added to each of the eight culture vessels containing green and brown leaf discs with and without embryos and immediately deep frozen at −20°C for overnight. The polarity of the samples was increased before partitioning against ethyl acetate, and about 1ml of distilled water which had been adjusted to pH 8 was added. The pH of the sample was adjusted with 1 M KOH to values higher than 9 to keep the phyto-components ionized and then partitioned against 100% ethyl acetate. The aqueous and organic phases were separated using a separating funnel and the lower aqueous phase was transferred to a new 10ml tube. The pH of the solution was lowered to below 3 with concentrated acetic acid to conserve the phyto-components in protonated forms. The acidic sample was partitioned against 100% ethyl acetate dried by passing it through anhydrous sodium sulphate. The sample was spiked with 50ppm internal standard (Benzophenone) and injected into GC-MS (Model QP2010 SE, SHIMADZU) and fitted with DB 5 column. Detector used was MS and Helium was used as the carrier gas at a flow rate of 1ml/min.

Data collection and analysis
Identification of the compounds in this study entirely relied on the matching of the mass spectrometric fragmentation pattern corresponding to the various peaks in the samples total ion chromatogram with those present in the National Institute of Science and Technology mass spectral database. Integration was done automatically for the individual peaks.

The phyto-components were quantified using the following equation: Concentration of analyte (C1) = Peak area of analyte/ peak area of internal standard x concentration of internal standard. Content (µg/g) of the analyte = [C1 x V]/W, Where C1= the concentration (ppm) of the analyte in the test solution, V= the volume (mL), of the test solution, and W= the weight (g) of the sample used for the preparation of the test solution. SAS 9.2 computer software was used to analyze data. Data was subjected to analysis of variance using the General Linear Model for a completely randomized design. Differences between treatment means was separated using LSD test at α = 5% level of significance. In order to identify phyto components which are either promoters or inhibitors of somatic embryogenesis in Ruiru 11, the data was subjected to Agglomerative Hierarchical clustering using XLSTAT software and a dendrogram constructed using unweighted pair group average mathematical average (UPGMA).

RESULTS
Several phyto components were identified during the study and these phyto-components can be classified as fatty acids, alcohols, aldehydes and hydrocarbons (Tables 1-5). The contents of both saturated fatty acids (SFA) and unsaturated fatty acids (UFA) accounted for the highest quantities of biological active components in both green and brown leaf discs cultures with and without embryos (Table 1). Oleic acid
(18:1) and Elaidic acid (Trans 18:1), both unsaturated fatty acids were present in most of the treatments. Palmitoleic acid (16:1), an esterified unsaturated fatty acid was present in green and brown leaf discs with embryos. Margaric acid (17:0) a saturated fatty acid was present in all treatments. Lauric acid (12:0) was present in green and brown non-embryogenic cultures. Palmitic acid (16:0) and stearic acid (18:0) was present in all treatments except brown leaf disc with embryos whereas caprylic acid (8:0) was only detected in brown leaf discs with embryos. Nonadecylic acid (19:0) was present in brown leaf discs with and without embryos.

Table 1: Fatty acids content (µg/g) during development of coffee somatic embryos

<table>
<thead>
<tr>
<th>Class</th>
<th>Common name</th>
<th>Fatty acid</th>
<th>GE</th>
<th>BE</th>
<th>GW</th>
<th>BW</th>
<th>CL</th>
<th>CM</th>
<th>CV (%)</th>
<th>LSD (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UFA</td>
<td>Palmitoleic acid</td>
<td>(Z)-7-Hexadecenoic acid, methyl ester,</td>
<td>18.99</td>
<td>23.28</td>
<td>0</td>
<td>0</td>
<td>6.65</td>
<td>7.1</td>
<td>1.03</td>
<td></td>
</tr>
<tr>
<td>UFA</td>
<td>Elaidic acid</td>
<td>(2-phenyl-1,3-dioxolan-4-y1) methyl ester, trans-9-Octadecenoic acid,</td>
<td>1.99</td>
<td>1.13</td>
<td>15.01</td>
<td>11.12</td>
<td>5.11</td>
<td>0</td>
<td>7.9</td>
<td>0.803</td>
</tr>
<tr>
<td>UFA</td>
<td>Oleic acid</td>
<td>(9Z)-Octadecenoic acid</td>
<td>42.84</td>
<td>32.32</td>
<td>18.68</td>
<td>16.51</td>
<td>133.98</td>
<td>15.99</td>
<td>13.5</td>
<td>10.45</td>
</tr>
<tr>
<td>SFA</td>
<td>Lauric acid</td>
<td>3-hydroxy-Dodecanoic acid</td>
<td>0</td>
<td>0</td>
<td>3.67</td>
<td>7.04</td>
<td>0</td>
<td>0</td>
<td>3.4</td>
<td>0.108</td>
</tr>
<tr>
<td>SFA</td>
<td>Caprylic acid</td>
<td>Octanoic acid, 4-pentadecyl ester</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>38.62</td>
<td>0</td>
<td>0</td>
<td>0.8</td>
<td>0.087</td>
</tr>
<tr>
<td>SFA</td>
<td>-</td>
<td>Pentadecanoic acid</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>35.05</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>1.347</td>
</tr>
<tr>
<td>SFA</td>
<td>Palmitic acid</td>
<td>Hexadecanoic acid, 1-hydroxymethyl) -1,2-ethanediyl ester</td>
<td>19.95</td>
<td>17.90</td>
<td>21.48</td>
<td>0</td>
<td>195.91</td>
<td>4</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>SFA</td>
<td>Margaric acid</td>
<td>Heptadecanoic acid, heptadecyl ester</td>
<td>43.08</td>
<td>32.17</td>
<td>12.12</td>
<td>15.49</td>
<td>138.10</td>
<td>0</td>
<td>23.8</td>
<td>17.03</td>
</tr>
<tr>
<td>SFA</td>
<td>Stearic acid</td>
<td>Octadecanoic acid</td>
<td>37.11</td>
<td>69.92</td>
<td>43.96</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.8</td>
<td>1.713</td>
</tr>
<tr>
<td>SFA</td>
<td>Nonadecylic acid</td>
<td>Oxiraneundecanoic acid, 3-pentyl-, methyl ester, cis-</td>
<td>0</td>
<td>33.82</td>
<td>0</td>
<td>27.82</td>
<td>75.98</td>
<td>0</td>
<td>4.8</td>
<td>1.956</td>
</tr>
</tbody>
</table>

Key: UFA- unsaturated fatty acid, SFA- Saturated fatty acid
GE - Green leaf discs with embryos, BE - Brown leaf discs with embryos, GW - Green leaf discs without embryo, BW - Brown leaf discs without embryos, CL- Fresh leaves (Control), CM - Fresh media (Control). Mean separation done using least significant difference (LSD) at p ≤ 0.05

Various hydrocarbons were detected in this study (Table 2). Both green and brown leaf discs cultures with and without embryos had (8)- Heptadecane, Dodecane, n-Octylidencyclohexane and 2-methyltetrasocane. Most alkanes detected which include 3-Trifluoroacetoxy pentadecane, 2-Trifluoroacetoxy dodecane, 2, 1, 3-Oxadisilacyclopentane, 1,1,3,3-tetraethyl-, 11,20-didecyl-2-Cyclopropylcarbonyl oxytetra decane, Triacan tane, were detected in green leaf discs with embryos. However, alkanes such as 3, 5, 24-trimethyl- Tetraco tan tane, and Hexatracantane were detected in brown leaf discs with and without embryos. Alkenes namely 1-chloro-7-Heptadecene, was present in brown leaf discs with embryos whereas (Z)- 3-Tetradecene, and 8-Heptadecene were detected in brown leaf discs without embryos. Several aldehydes were detected in this study (Table 3). These aldehydes include: (Z)-7-Hexadecenal, (Z)- 9-Octadecenal, 2-Undecenal, 3,7-dimethyl-7-Octenal which were present in green leaf discs with and without embryos whereas Pentadecanal and (E)- 2-Tridecenal, were present in brown leaf discs with and without embryos.
### Table 2: Hydrocarbon content (µg/g) during development of coffee somatic embryos

<table>
<thead>
<tr>
<th>Class</th>
<th>Phyto-component</th>
<th>GE</th>
<th>BE</th>
<th>GW</th>
<th>BW</th>
<th>CL</th>
<th>CM</th>
<th>CV (%)</th>
<th>LSD (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkane</td>
<td>[hexadecyloxy)methyl]-Oxirane</td>
<td>46.45</td>
<td>12.04</td>
<td>10.38</td>
<td>20.69</td>
<td>0</td>
<td>0</td>
<td>5.6</td>
<td>1.474</td>
</tr>
<tr>
<td>Alkane</td>
<td>hexadecyl-Oxirane,</td>
<td>9.93</td>
<td>39.16</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.5</td>
<td>0.225</td>
<td></td>
</tr>
<tr>
<td>Alkane</td>
<td>1,1,3,3-tetraethyl-2,1,3-Oxadisilacyclopentane,</td>
<td>4.95</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.50</td>
<td>2.4</td>
<td>0.0451</td>
<td></td>
</tr>
<tr>
<td>Alkane</td>
<td>n-Octylidencyclohexane</td>
<td>20.75</td>
<td>21.36</td>
<td>13.46</td>
<td>9.24</td>
<td>0</td>
<td>20.7</td>
<td>3.972</td>
<td></td>
</tr>
<tr>
<td>Alkane</td>
<td>2-Trifluoroacetoxydodecane</td>
<td>1.72</td>
<td>0.13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>27.7</td>
<td>0.151</td>
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</tr>
<tr>
<td>Alkane</td>
<td>Dodecane</td>
<td>28.43</td>
<td>10.57</td>
<td>7.26</td>
<td>6.50</td>
<td>38.33</td>
<td>4.07</td>
<td>8.4</td>
<td>2.378</td>
</tr>
<tr>
<td>Alkane</td>
<td>1-iodo-Trimdecane,</td>
<td>0</td>
<td>0</td>
<td>20.61</td>
<td>0</td>
<td>0</td>
<td>4.9</td>
<td>0.299</td>
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</tr>
<tr>
<td>Alkane</td>
<td>2-Cyclopropyl carboxyloxytetradecane</td>
<td>1.67</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.7</td>
<td>0.019</td>
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</tr>
<tr>
<td>Alkane</td>
<td>1,1-bis(dodecyloxy)-Hexadecane,</td>
<td>4.04</td>
<td>0</td>
<td>0</td>
<td>9.24</td>
<td>0</td>
<td>1.8</td>
<td>0.071</td>
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</tr>
<tr>
<td>Alkane</td>
<td>(8)Heptadecane</td>
<td>13.40</td>
<td>30.34</td>
<td>4.97</td>
<td>4.94</td>
<td>0</td>
<td>11.8</td>
<td>1.876</td>
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</tr>
<tr>
<td>Alkane</td>
<td>Cris 7,8 epoxy-2-methyl octadecane</td>
<td>253.05</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.8</td>
<td>2.836</td>
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<tr>
<td>Alkane</td>
<td>6-methyl-Octadecane</td>
<td>0</td>
<td>0</td>
<td>7.60</td>
<td>0</td>
<td>0</td>
<td>9.7</td>
<td>0.218</td>
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<tr>
<td>Alkane</td>
<td>1- sulphonyl chloride Octadecane</td>
<td>13.39</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12.05</td>
<td>6</td>
<td>0.451</td>
</tr>
<tr>
<td>Alkane</td>
<td>2-methyltetrasosane</td>
<td>38.33</td>
<td>14.29</td>
<td>6.82</td>
<td>9.99</td>
<td>46.04</td>
<td>0</td>
<td>27.6</td>
<td>9.457</td>
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<tr>
<td>Alkane</td>
<td>Hexatriacontane</td>
<td>0</td>
<td>0</td>
<td>6.41</td>
<td>9.30</td>
<td>0</td>
<td>4.9</td>
<td>0.228</td>
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<tr>
<td>Alkane</td>
<td>11,20-didecyl-Triacontane</td>
<td>43.04</td>
<td>6.64</td>
<td>0</td>
<td>0</td>
<td>8.67</td>
<td>2.3</td>
<td>0.393</td>
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</tr>
<tr>
<td>Alkane</td>
<td>3,5,24-trimethyl-Tetracontane,</td>
<td>0</td>
<td>23.25</td>
<td>9.41</td>
<td>9.19</td>
<td>55.99</td>
<td>0</td>
<td>4.8</td>
<td>1.384</td>
</tr>
<tr>
<td>Alkene</td>
<td>(Z)-3-Tetradecene</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25.47</td>
<td>0</td>
<td>3.2</td>
<td>0.243</td>
<td></td>
</tr>
<tr>
<td>Alkene</td>
<td>8-Heptadecene</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>38.07</td>
<td>0</td>
<td>0.4</td>
<td>0.047</td>
</tr>
<tr>
<td>Alkene</td>
<td>1-chloro-7-Heptadecene</td>
<td>0</td>
<td>0</td>
<td>4.37</td>
<td>0</td>
<td>0</td>
<td>5.3</td>
<td>0.069</td>
<td></td>
</tr>
<tr>
<td>Alkene</td>
<td>(E)-9-Octadecene</td>
<td>0</td>
<td>0</td>
<td>11.93</td>
<td>0</td>
<td>0</td>
<td>28.1</td>
<td>0.995</td>
<td></td>
</tr>
<tr>
<td>Alkene</td>
<td>1-Docosene</td>
<td>0</td>
<td>0</td>
<td>4.43</td>
<td>4.72</td>
<td>0</td>
<td>6.6</td>
<td>0.178</td>
<td></td>
</tr>
</tbody>
</table>

**Key:** GE - Green leaf discs with embryos, BE - Brown leaf discs with embryos, GW - Green leaf discs without embryo, BW - Brown leaf discs without embryos, CL - Fresh leaves (Control), CM - Fresh media (Control). Mean separation done using least significant difference (LSD) at p ≤ 0.05

### Table 3: Aldehyde content (µg/g) during development of coffee somatic embryos

<table>
<thead>
<tr>
<th>Aldehydes</th>
<th>GE</th>
<th>BE</th>
<th>GW</th>
<th>BW</th>
<th>CL</th>
<th>CM</th>
<th>CV (%)</th>
<th>LSD (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,7-dimethyl-7-Octenal,</td>
<td>7.42</td>
<td>5.71</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20.3</td>
<td>0.79</td>
</tr>
<tr>
<td>2-Undecenal</td>
<td>51.70</td>
<td>8.87</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9.72</td>
<td>6</td>
<td>1.248</td>
</tr>
<tr>
<td>Dodecanal</td>
<td>2.22</td>
<td>0.23</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14.9</td>
<td>0.109</td>
<td></td>
</tr>
<tr>
<td>(E)-2-Tridecane,</td>
<td>0</td>
<td>0</td>
<td>3.93</td>
<td>4.83</td>
<td>0</td>
<td>6.8</td>
<td>0.176</td>
<td></td>
</tr>
<tr>
<td>Pentadecanal</td>
<td>0</td>
<td>0</td>
<td>21.47</td>
<td>17.34</td>
<td>0</td>
<td>7.2</td>
<td>0.832</td>
<td></td>
</tr>
<tr>
<td>(Z)-7-Hexadecenal,</td>
<td>70.19</td>
<td>30.86</td>
<td>0</td>
<td>25.74</td>
<td>0</td>
<td>3.3</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>(Z)-9-Octadecenal,</td>
<td>31.83</td>
<td>15.49</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7.9</td>
<td>1.105</td>
<td></td>
</tr>
</tbody>
</table>

**Key:** GE - Green leaf discs with embryos, BE - Brown leaf discs with embryos, GW - Green leaf discs without embryo, BW - Brown leaf discs without embryos, CL - Fresh leaves (Control), CM - Fresh media (Control). Mean separation done using least significant difference (LSD) at p ≤ 0.05
Table 4 shows alcohols detected during development of coffee somatic embryos. In both green and brown leaf disc cultures with and without embryos, alcohols namely 2-butyl-1-Octanol and 1-Hexadecanol were present. 12-Methyl-E, E-2, 13-octadecadien-1-ol was present in all treatments except brown leaf discs without embryos. 2-ethyl-1-Decanol was present in brown leaf discs with and without embryos. E-2-Tetradecen-1-ol and Z, Z-8, 10-Hexadecadien-1-ol were found present in green leaf discs with embryos. Z, Z-3, 13-Octadecadien-1-ol was present in green leaf discs with and without embryos. Z-2-Tridecen-1-ol and 12-Methyl-E, E-2, 13-octadecadien-1-ol were present in brown leaf discs without embryos.

Table 4: Alcohol content (µg/g) during development of coffee somatic embryos

<table>
<thead>
<tr>
<th>Alcohols</th>
<th>GE</th>
<th>BE</th>
<th>GW</th>
<th>BW</th>
<th>CL</th>
<th>CM</th>
<th>CV (%)</th>
<th>LSD (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-butyl-1-Octanol</td>
<td>13.21</td>
<td>13.88</td>
<td>6.90</td>
<td>11.70</td>
<td>59.74</td>
<td>3.19</td>
<td>11.4</td>
<td>3.663</td>
</tr>
<tr>
<td>2-ethyl-1-Decanol</td>
<td>33.74</td>
<td>9.34</td>
<td>9.36</td>
<td>24.25</td>
<td>84.77</td>
<td>0</td>
<td>6.9</td>
<td>3.322</td>
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<tr>
<td>1-Dodecanol</td>
<td>0</td>
<td>14.79</td>
<td>5.36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13.6</td>
<td>0.809</td>
</tr>
<tr>
<td>Z-2-Tridecen-1-ol</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20.25</td>
<td>0</td>
<td>0</td>
<td>12.7</td>
<td>0.763</td>
</tr>
<tr>
<td>E-2-Tetradecen-1-ol</td>
<td>10.74</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.3</td>
<td>0.105</td>
</tr>
<tr>
<td>1-Hexadecanol</td>
<td>0</td>
<td>11.17</td>
<td>10.14</td>
<td>24.92</td>
<td>159.24</td>
<td>2.7</td>
<td>2.7</td>
<td>1.659</td>
</tr>
<tr>
<td>3,7,11,15-Tetramethyl-2-hexadecen-1-ol</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>61.62</td>
<td>0</td>
<td>5.2</td>
<td>0.955</td>
<td></td>
</tr>
<tr>
<td>Z,Z-8,10-Hexadecadien-1-ol</td>
<td>5.79</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.8</td>
<td>1.015</td>
</tr>
<tr>
<td>Z,Z-3,13-Octadecadien-1-ol</td>
<td>32.06</td>
<td>0</td>
<td>9.02</td>
<td>0</td>
<td>0</td>
<td>3.86</td>
<td>5.8</td>
<td>0.775</td>
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<tr>
<td>12-Methyl-E, E-2,13-octadecadien-1-ol</td>
<td>19.10</td>
<td>14.83</td>
<td>15.58</td>
<td>1.39</td>
<td>0</td>
<td>4.7</td>
<td>4.7</td>
<td>0.702</td>
</tr>
</tbody>
</table>

Key: GE - Green leaf discs with embryos, BE - Brown leaf discs with embryos, GW - Green leaf discs without embryo, BW - Brown leaf discs without embryos, CL - Fresh leaves (Control), CM - Fresh media (Control). Mean separation done using least significant difference (LSD) at p ≤ 0.05

Other volatile compounds detected during the development of somatic embryos are shown in table 5. Volatile compounds belonging to the ester group detected in the study include 2- Bromopropionic acid, pentadecyl ester present in green leaf discs with embryos and 3-Chloropropionic acid, heptadecyl ester present in green leaf discs with embryos and brown leaf discs without embryos.

Table 5: Phyto-components (µg/g) identified during development of coffee somatic embryos

<table>
<thead>
<tr>
<th>Class</th>
<th>Other Phyto-component</th>
<th>GE</th>
<th>BE</th>
<th>GW</th>
<th>BW</th>
<th>CL</th>
<th>CM</th>
<th>CV (%)</th>
<th>LSD (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ester</td>
<td>2- Bromopropionic acid, pentadecyl ester</td>
<td>22.70</td>
<td>11.96</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0.3129</td>
</tr>
<tr>
<td>Ester</td>
<td>3-Chloropropionic acid, heptadecyl ester</td>
<td>15.98</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.3</td>
<td>0.1561</td>
</tr>
<tr>
<td>Ester</td>
<td>3-Chloropropionic acid, tetradecyl ester</td>
<td>0</td>
<td>0</td>
<td>5.48</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.6</td>
<td>0.2209</td>
</tr>
<tr>
<td>Ketone</td>
<td>9,9-Dimethoxybicyclo[3.3.1] nona-2,4-dione</td>
<td>27.20</td>
<td>34.82</td>
<td>1.5</td>
<td>9.37</td>
<td>0</td>
<td>0</td>
<td>21.7</td>
<td>4.6832</td>
</tr>
<tr>
<td>Steroid derivative</td>
<td>Ethyl iso-allocholate</td>
<td>0</td>
<td>23.58</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6.2</td>
<td>0.4358</td>
</tr>
<tr>
<td>Organic compound</td>
<td>5-Hydroxymethylfurfural</td>
<td>0</td>
<td>12.06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>23.7</td>
<td>0.8461</td>
</tr>
<tr>
<td>Unknown</td>
<td>Disparlure</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16.97</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
<td>0.0218</td>
</tr>
</tbody>
</table>

Key: GE - Green leaf discs with embryos, BE - Brown leaf discs with embryos, GW - Green leaf discs without embryo, BW - Brown leaf discs without embryos, CL - Fresh leaves (Control), CM - Fresh media (Control). Mean separation done using least significant difference (LSD) at p ≤ 0.05
Disparlure, whose immediate direct precursor is an alkene were detected in brown leaf discs without embryos. An organic compound 5-hydroxymethylfurural, which is formed by the dehydration of sugars and a steroid derivative Ethyl iso-allocholate were detected in brown leaf discs with embryos.

A cluster dendrogram was used to profile endogenous phyto-components that promote or inhibits somatic embryogenesis in coffee (Figure 2). The phyto-components separated into three (3) supported clusters. The phyto components which were the highest in non-embryogenic cultures i.e. green and brown leaf discs without embryos were clustered in class 1. Phyto-components highest in fresh leaves were clustered in class 2. The third class clustered together phyto-components highest in embryogenic cultures. The dendrogram further separated the third class into two (2) unsupported clusters, which grouped the green and brown leaf discs with embryos although the quantities were not enough to significantly separate them into supported clusters. Presence and or high levels of phyto-components indicated in cluster 3 can be said to promote somatic embryogenesis in coffee. Similarly, presence and or high quantities of phyto-components in cluster 1 can be said to inhibit somatic embryogenesis.

Several phyto-components were identified and classified as fatty acids, alcohols, aldehydes and hydrocarbons. Fatty acids C16:1, C18:1, Trans C18:1, C16:0, C17:0 and C18:0 were observed in embryogenic cultures. Higher quantities of fatty acid may have resulted from cell membrane degradation. Carrier et al. (1997) reported that in white spruce somatic embryos, most abundant fatty acid was linoleic acid (18:2) followed by oleic acid (18:1) and linolenic acid (C18:3) indicating somatic embryos contained relatively greater levels of unsaturated fatty acid. Similarly, Aly et al. (2008) reported that somatic embryos of jojoba are characterized with presence of C16:0, C18:0, 18:1, 18:2 and 18:3 indicating that these fatty acids stimulate somatic embryogenesis. Fatty acids are used in the formation of new membranes during the rapid growth of the developing embryo and are assembled into triacylglycerols that are specifically synthesized during embryo development and used as an energy source during germination. Storage lipid accumulation occurs primarily during the maturation phase of embryo development. Oxygen esters of fatty alcohols and fatty acids are main components of biological systems. These components are found on the surfaces of plants and animals and provide protection against desiccation, wetting, and pathogen attack. Negi et al. (2005) reported that the unsaturated fatty acids are essential in producing an active compound that acts as auxin-like plant growth promoting activity when linked to an aromatic molecular base like naphthophenone, thus indicating the important role that the unsaturated fatty acids play in the biochemical mechanisms in plants. High levels of unsaturated fatty acids detected in the study may have stimulated the development of somatic embryos.

Alkanes are widely distributed in the plant kingdom although their physiological role within the plant cells is not well understood. Cunha and Fernandes-Ferreira (2001) suggested that the n-alkane variation can be in time, where there is a decline associated with cellular multiplication and growth; and in space, where carbon mobilisation from embryogenic callus is probably related to somatic embryos differentiation. Lamarque et al. (1998) indicated that the n-alkanes in seed oil and in internal hydrocarbons may play a role in maintaining inner cell structure and act as energy storage components. Cunha and Fernandes-Ferreira (2001) postulated the role for short-chain n-alkanes, as translocable reduced carbon reserves during the initial process of embryo germination from somatic tissues. Fatty acids and or their derivatives are seemed to be closely related to the direct precursor for the hydrocarbons produced in plants (Kaneda, 1969). Plant species, age of the plant and
Figure 2: Cluster dendrogram profiling endogenous phyto-components identified during somatic embryogenesis of Ruiru 11. The broken line shows the point at which the dendrogram was truncated to define distinct clusters.
Among the aldehydes detected in this study, a majority of them could arise from the degradation of polyunsaturated fatty acids either by autoxidation or by the action of enzymes such as lipoxygenases as reported by Izzreen and Ratnam (2011). Plant volatiles are also derived by oxidative cleavage and decarboxylation of various fatty acids, resulting in the production of shorter-chain volatiles with aldehyde and ketone moieties. These compounds originate from C18 unsaturated fatty acids (linoleic or linolenic acids), which enter the “lipoxygenase pathway” (Fu et al., 2015). Lipid peroxidation often occurs in response to oxidative stress, and a great diversity of aldehydes is formed when lipid hydroperoxides break down in biological systems.

Both green and brown embryogenic cultures generally released more and higher quantities of volatile compounds as compared to non-embryogenic cultures. As postulated by Alonzo et al. (2001) embryogenic competence appeared to be related to biochemical activity, namely the synthesis of the phyto-components. However, it is not clear whether the differences observed between the treatments are due to differential biochemical maturation of the not fully organized cellular tissues.

CONCLUSION AND RECOMMENDATION
Different fatty acids, alcohols, aldehydes and hydrocarbons were identified in in vitro cultures of coffee. Embryogenic cultures generally released more and higher quantities of phyto components as compared to non-embryogenic cultures and thus embryogenic competence in coffee appeared to be related to the synthesis of phyto components. A study on compounds such as plant growth regulators that promote selective stimulation of the synthesis of fatty acids which enhance somatic embryogenesis in coffee should be done. Further study on these phyto components released during somatic embryogenesis can be useful in biochemical, genetic and breeding research in coffee.

ACKNOWLEDGEMENTS
The authors thank staff of Crop Physiology and Chemistry Quality unit, Coffee Research Institute (CRI) for their assistance. This paper is published with the permission of the Institute Director, CRI on behalf of Director General, Kenya Agricultural and Livestock Research Organization.

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ABSTRACT
The major constraint to food production in arid and semi-arid lands (ASALs) of coastal Kenya is low soil moisture and lack of improved drought tolerant maize varieties. Average annual rainfall is low in most areas and total annual evapo-transpiration is high. The evapo-transpiration exceeds rainfall in most months of the year and calls for water harvesting or irrigation. The ASAL areas have traditionally been considered best suited to extensive livestock grazing but not anymore as more people have moved into these areas introducing crop farming. Despite the adversity of the marginal areas, farming is practiced, notwithstanding the frequent crop failures. In these areas farmers grow maize varieties recommended for the medium to high rainfall zones resulting to crop failures. This state of affairs has been aggravated by prevailing climate change conditions. Work was therefore carried out to demonstrate how the adverse effects of climate change can be mitigated through drought tolerant maize varieties, water harvesting, grain legume crops and drip irrigation. Two water harvesting technologies of zai pits and tied ridges were evaluated/demonstrated against conventional method. Three drought tolerant maize varieties: PH1, DH01, DH02 were evaluated against PH4 (check) and along three different planting patterns of 90 x 30 cm, 90 x 60 cm and 90 x 90 cm with varied number of seeds per hill. Pulse crop demonstration comprised of three cowpea: K80, M66 and Kenkunde. Vegetable production under two irrigation methods of drip and sprinkler was also demonstrated. Results showed that zai pits and tied ridges were superior to conventional method. DH01 showed significantly (P<0.05) same yield as PH4 (check). Significantly (P<0.05) higher grain yield was observed between the pattern of 90 x 30cm and the rest of the patterns. There were no significant (P<0.05) yield differences among the three cowpea varieties. Tomato variety; Tegemeo had the best performance of 38.7 ton/ha. Kale leaf yields were significantly different (P<0.05) among the varieties. Collards had the best performance of 34 ton/ha. Capsicum fruit yields were significantly different (P<0.05) between the two varieties evaluated. Commandant had the best performance of 22.67 ton/ha. The irrigation methods did not show any significant yield differences among vegetable type and varieties.
Keywords: ASALS, Climate change, Dry land farming, Maize, Cowpea

INTRODUCTION
The coastal region of Kenya is a food deficit area with households purchasing one third of their food requirements (Obong’o et al., 1993; Saha et al., 1993). Maize is the most important food stable and constitutes a major component of the diet in the region (Wekesa et al., 2003; Waiyaki et al. 2006). The crop is grown in all agro-ecological zones of the region including arid and semi-arid lands more suited for grain legumes, sorghum and millets (KARI, 2005; Wekesa et al., 2003). The region produces 1.56 million bags, while the demand is 3.80 million bags (MOA, 2012). Over 75% of the coastal area is either arid or semi-arid (Jaetzold and Schmidt, 1983). Crop productivity in these sites is limited by high ambient temperatures and low soil moisture. Crop productivity can be enhanced through use of water harvesting technologies such as zai pits and tied ridges. The zai pits and tied ridges have been shown to harvest and conserve the rain water for the maize crop. This in combination with the drought tolerant maize varieties would reduce the effects of low moisture in these sites. Maize grown in plots demonstrating zai pits technology in semi-arid lands showed some yield advantage compared to tied ridges and flat planting (Sangina and Woomer, 2009). Muli et al. (2012) showed that there was no significant difference in maize performance between zai pits and tied ridges treatments. Pulses are drought tolerant crops and would perform better than maize even without water harvesting. It is a common practice by farmers to plant more than one maize seed per hill. Where this is practiced, it has been observed that the plants are of
different sizes and this is also reflected in the cob size. Irrigation ensures crop production even out of season. The study was done to demonstrate role of water harvesting technologies, drought tolerant maize varieties, pulses, and small-scale irrigation in mitigating the adverse effects of prevailing climate change conditions in Tana River County.

METHODOLOGY

Research Sites
The demonstrations were carried out in Tana River County. Three sites were selected for the crops demonstrations. The sites were Matomba, Shirikisho and Kisuliani. The latter is in coastal lowland (CL) 5 but the other two sites are in CL6. The major food crops grown in the area are maize, green gram, cowpea and cassava. The sites are characterized by unreliable and erratic rainfall. The soils for Shirikisho and Kisuliani sites are low in two of the major nutrients i.e. Nitrogen and phosphorus but have adequate amounts of Potassium.

Use of demonstration plots for technology transfer was identified as the best methodology to be adopted. However, the technologies in each demonstration were replicated in order collect data for comparison of technologies and permit farmers make informed decisions for technology adoption. Four categories of technologies were identifies for promotion. These were: use of water harvesting (zai pits and tied ridges), use of drought tolerant maize varieties under different planting patterns, use of a pulse crop and use of small scale irrigation for vegetable production.

Water harvesting technologies
Four commercial drought tolerant maize varieties were evaluated under three water harvesting methods. The four varieties were PH1, DH01, DH02 and PH4. Efforts to obtain a local variety to use as a check did not bear fruit. The three water harvesting methods included; Zai pits, tied ridges and conventional (flat). The treatments were laid in a split plot design with water harvesting methods assigned to main plots and maize varieties to sub-plots. Two seeds were planted at 5 equidistant spots within the zai pit and were thinned to one plant per hill resulting in 5 plants per pit. Ridges were spaced at 90 cm. Crop spacing at the ridges and conventional method treatments were 90 x 30 cm. Agronomic practices were carried out as necessary.

Planting patterns
Three drought tolerant maize hybrids were evaluated under three planting patterns. The maize varieties were: DH01, DH02 and PH4. The three planting patterns were 90 x 30 cm (one plant per hill), 90 x 60 cm (two plants per hill) and 90 x 90 cm (three plants per hill). The treatments were laid out in a split plot design with planting patterns assigned to main plots and maize varieties assigned to sub-plots. Data was collected on: stand count at harvest, plant height, number of ears harvested, number of rows per ear, ear length, ear weight, grain moisture content and grain weight.

Activity 3: Use of cowpea
The cowpea trial comprised of three cowpea varieties namely: K80, M66 and Kenkunde. The crop was planted during the long rains 2014 at a spacing of 50 x 20 cm. The treatments were replicated three times in a randomized complete block design.

Activity 4: Use of irrigation for vegetable production
Vegetable production was demonstrated in two sites i.e. Matomba and Shirikisho. The vegetables were tomatoes (3 varieties: Cal J, Rio Grande and Tegemeo), kales (3 varieties: Collards, Thousand headed and Kale Keeper) and capsicums (2 varieties: California Wonder and Commandant F1). The irrigation methods were drip irrigation and sprinkler irrigation. The three crops were planted under each of the irrigation methods. The vegetables were raised in nursery managed by each group.
RESULTS
Water harvesting technologies
Table 1 shows the performance of improved maize varieties under different water harvesting technologies. The performance under tied ridges was better than that under zai pits except for PH1 which showed the contrary. It was also observed that the performance in both zai pits and tied ridges was remarkably better than that of the conventional method for all maize varieties. However, statistical analysis was not conducted since farmers harvested and mixed the produce for some plots in two out of the three replications.

Table 1: Performance (grain yield in t ha\(^{-1}\)) of maize varieties under different water harvesting technologies at Kisuliani

<table>
<thead>
<tr>
<th>Variety</th>
<th>Zai pits</th>
<th>Tied ridges</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>DH01</td>
<td>2.9</td>
<td>3.1</td>
<td>2.1</td>
</tr>
<tr>
<td>DH04</td>
<td>3.5</td>
<td>4.0</td>
<td>2.0</td>
</tr>
<tr>
<td>PH1</td>
<td>3.7</td>
<td>3.1</td>
<td>2.3</td>
</tr>
<tr>
<td>PH4</td>
<td>4.0</td>
<td>4.2</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Planting patterns
There were no significant (P<0.05) variety by planting pattern interaction and therefore the results are presented and discussed separately. For the planting patterns, the plant height ranged from 191.0 to 200.2 cm for cropping systems of 90 x 30 cm and 90 x 90 cm respectively. Grain yield decreased with the increase in intra-row spacing. However, significant (P<0.05) grain yield difference was observed between the planting pattern of 90 x 30cm and the rests of the patterns. As regards maize varieties, PH4 showed significantly (P<0.05) higher plant height than the rest of the hybrids. DH02 showed the least number of rows per ear which was significantly less than that of DH01 and PH4. As regards ear length, PH4 recorded the largest length of 19.0 cm which was significantly higher than that for the other two varieties. The same trend was observed for grain yield except that there was no significant (P<0.05) difference between PH4 and DH01.

Table 2: Effect of planting pattern on yield and yield components of maize

<table>
<thead>
<tr>
<th>Planting pattern</th>
<th>Plant height (cm)</th>
<th>Number of rows per ear</th>
<th>Ear length (cm)</th>
<th>Grain yield (t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 x 30 cm (one plant per hill)</td>
<td>191.0</td>
<td>14</td>
<td>18.3</td>
<td>2.4</td>
</tr>
<tr>
<td>90 x 60 cm (Two plants per hill)</td>
<td>197.7</td>
<td>14</td>
<td>17.9</td>
<td>1.9</td>
</tr>
<tr>
<td>90 x 90 cm (Three plants per hill)</td>
<td>200.2</td>
<td>14</td>
<td>16.5</td>
<td>1.5</td>
</tr>
<tr>
<td>LSD</td>
<td>15.03</td>
<td>1.26</td>
<td>1.97</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Table 3: Effect of variety on yield and yield components of maize

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plant height (cm)</th>
<th>Number of rows per ear</th>
<th>Ear length (cm)</th>
<th>Grain yield (t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH4</td>
<td>212.7</td>
<td>14.5</td>
<td>19.0</td>
<td>2.1</td>
</tr>
<tr>
<td>DH02</td>
<td>187.8</td>
<td>13.2</td>
<td>16.8</td>
<td>1.5</td>
</tr>
<tr>
<td>DH01</td>
<td>188.3</td>
<td>14.2</td>
<td>17.0</td>
<td>1.8</td>
</tr>
<tr>
<td>LSD</td>
<td>16.25</td>
<td>0.95</td>
<td>1.97</td>
<td>0.46</td>
</tr>
</tbody>
</table>
Use of pulse crop - Cowpea
Table 4 shows the performance of the three cowpea varieties as pertains to grain yield and percent grain recovery after threshing. There were no significant (P<0.05) differences among the three cowpea varieties as regards grain recovery. Grain yield ranged from 2.0 to 2.6tha⁻¹ for K80 and M66 respectively and there were no significant (P<0.05) differences among the cowpea varieties.

Table 4: Effect of variety on cowpea grain yield and percent grain recovery

<table>
<thead>
<tr>
<th>Variety</th>
<th>Percent grain recovery</th>
<th>Grain yield (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K80</td>
<td>76</td>
<td>2.0</td>
</tr>
<tr>
<td>M66</td>
<td>80</td>
<td>2.6</td>
</tr>
<tr>
<td>Kenkunde</td>
<td>84</td>
<td>2.3</td>
</tr>
<tr>
<td>LSD</td>
<td>9.83</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Tomatoes
The marketable yields for tomato varieties grown under different irrigation methods at Matomba site are shown in Table 5. The yields were significantly different (p<0.05) among the varieties. Tegemeo had the best performance of 38.66 ton/ha. The irrigation methods did not show any significant differences.

Table 5: The effect of variety and irrigation method on marketable fruit yield (tons/ha) of tomatoes

<table>
<thead>
<tr>
<th>Variety</th>
<th>Drip</th>
<th>Sprinkler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cal J</td>
<td>25.34</td>
<td>25.4</td>
</tr>
<tr>
<td>Rio Grande</td>
<td>30.94</td>
<td>30.86</td>
</tr>
<tr>
<td>Tegemeo</td>
<td>38.66</td>
<td>32.86</td>
</tr>
<tr>
<td>LSD</td>
<td>1.18</td>
<td>1.44</td>
</tr>
</tbody>
</table>

Kales
The marketable leaf yields for kale varieties grown under different irrigation methods at Matomba site are shown in Table 6. The yields were significantly different (p<0.05) among the varieties. Collards had the best performance of 34 t ha⁻¹. The irrigation methods did not show any significant differences.

Table 6: The effect of variety and irrigation method on leaf yield of kales

<table>
<thead>
<tr>
<th>Variety</th>
<th>Drip</th>
<th>Sprinkler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thousand-headed</td>
<td>23.33</td>
<td>24.4</td>
</tr>
<tr>
<td>Sukuma wiki</td>
<td>28.33</td>
<td>29.86</td>
</tr>
<tr>
<td>Collards</td>
<td>34.00</td>
<td>33.86</td>
</tr>
<tr>
<td>LSD</td>
<td>1.06</td>
<td>1.37</td>
</tr>
</tbody>
</table>

Capsicums
The marketable fruit yields for capsicums varieties grown under different irrigation methods at Matomba site are shown in Table 7. The yields were significantly different (p<0.05) between the two varieties evaluated. Commandant had the best performance of 22.67 t ha⁻¹. The irrigation methods did not show any significant differences.

Table 7: The effect of variety and irrigation on marketable fruits of capsicums (t ha⁻¹) yield of kales

<table>
<thead>
<tr>
<th>Variety</th>
<th>Drip</th>
<th>Sprinkler</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Wonder</td>
<td>16.00ᵃ</td>
<td>16.33ᵃ</td>
</tr>
<tr>
<td>Commandant</td>
<td>22.67ᵇ</td>
<td>23.00ᵇ</td>
</tr>
<tr>
<td>LSD</td>
<td>0.87</td>
<td>2.42</td>
</tr>
</tbody>
</table>
DISCUSSION
The better maize performance in zai pits and field ridges was attributed to water collection and retention for a longer period compared to conventional. Plant height and ear height increased with the increase in the number of plants per hill and this was attributed to intra plant competition as the number of plants per hill increased. The same reason is also attributed to decrease in grain yield. Maize varieties demonstrated showed significant (P<0.05) differences in plant height, number of rows per ear and ear length and this was expected since the parameters are varietal characteristic. These results show that the three varieties are suitable for the area and should be adopted by the farmers. Though not presented in the results, DH01 was observed to mature earlier than the rest of the varieties and this was an attributed preferred most by the participating farmers.

Since the three cowpea varieties did not show any significant differences as regards grain yield, farmers in the area can grow either of the varieties although differences among the varieties were pointed by the farmers. Kenkunde had many but smaller pods and the variety matured earlier than the rest. The variety was erect and determinate and therefore not good as a vegetable crop. Both K80 and M66 had fewer but long pods and the two remained vegetative for a longer time compared to Kenkunde. The leaves of the two varieties are suitable as vegetables.

The farmers were also trained on vegetable production under irrigation: They were trained in vegetable nursery establishment, transplanting, fertilizer application and pre-and post-harvest handling. They were also trained on various methods of using water for irrigation e.g. drip and sprinkler irrigation. Each group planted an acre of tomatoes, kales and capiscums which they sold for income generation and home consumption. Matomba group was able to raise KES. 30,000 in the first season while Shirikisho raised KES. 16,000.

CONCLUSION
All the crops/varieties demonstrated were found to be adaptable to the region and farmers have a wide choice for mitigating the adverse effects of climate change.

ACKNOWLEDGEMENTS
The authors acknowledge the financial support provided by the IDRC and both participating farmers and extension staff of the Agriculture Department of Tana Delta Sub-county for management of the demonstrations.

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APPLICATION OF DESIRABILITY FUNCTION FOR OPTIMIZATION OF MULTIPLE RESPONSES OF WATERMELON USING ORGANIC MANURE

Muriithi, D.K.
Department of Business Administration, Chuka University P. O. Box 109-60400, Chuka
Email: kamuriithi2011@gmail.com; Tel: 0724605328

ABSTRACT
Field experiment was conducted at horticultural research and teaching farm of Chuka University to evaluate the responses of watermelon to organic manure. The study investigated the use of Central Composite Design (CCD) in formulation of optimal use of organic manure in order to obtain maximum growth and yield of watermelon. The main objective of this study was to optimize the multiple responses of watermelon to organic manure using desirability function. A 5-level-3-factor central composite design was employed in watermelon crop experiment where optimization required 20 experimental runs. The parameters assessed were vine length, number of branches/plant and fruit weight of watermelon. A statistical model of the second-order that best fits the data was used to achieve the objective. Desirability function approach for simultaneous optimization of several response variables was adopted in this study. The findings revealed that the process was well optimized, because the indices were very close or equal to the condition great value of one (1.0). The results of the study found that the optimal values of watermelon responses are 93.73 t/ha of fruit weight at maturity, 9 branches/plant and vine length of 225.43 cm at 8weeks. Based on the findings of the study, it was recommended that farmers in the study area apply 17.64 t/ha, 11.17 t/ha and 18.05 t/ha of poultry, goat and cow manure respectively for increased growth and yield of watermelon. Further research may be commissioned with CCD, Box–Behnken and Doehlert design approach to plan the experiments for growth and yield of watermelon with an overall objective of optimizing the responses (such as number of fruits/plant and number of leaves per plant) of watermelon to organic manure (poultry manure, goat manure, rabbit manure and donkey manure). The study exemplified that the development of statistical mathematical models for crop production can be useful for predicting and understanding the effects of experimental factors.

Keywords: Central composite design; Response surface methodology; Fruit weight

INTRODUCTION
Watermelon (Citrullus lanatus thumb) is a member of the cucurbitaceous family. According to Jarret [9], it originated from the Kalahari and Sahara deserts in Africa. In Kenya, the crop is mainly grown in lower and dry Semi-arid areas of the Country, namely Nyanza, Central, Eastern, Coast and Rift valley regions. Watermelon is a crop with huge economic importance to man as well as highly nutritious, sweet and thirst quenching, Mangila et al., [11]. It is mostly used to make a variety of salads, juice and food flavor. It is a cash crop for farmers due to its high returns on investment. Watermelon contains Vitamin C and A in a form of disease-fighting beta-carotene. In spite of the increasing relevance of watermelon in Kenya, yields across the country are decreasing and not encouraging because of rapid reduction in soil fertility caused by both continuous cropping and use of inappropriate soil amendment materials. One of the ways of increasing the soil fertility is by application of organic material such as poultry manure, cow manure, and goat manure which are available in most parts of the country. Animal waste is essential for establishing and maintaining the optimum soil physical, chemical and biological condition that are appropriate for plant growth and development. Although readily available, utilization of organic manures in watermelons has not been optimized for increased plant growth and fruit production. The study sought to optimize the multiple responses of watermelon to organic manure using desirability function.

In order to get the most efficient result in the approximation of empirical model the proper experimental design must be used to collect data. The data is then used to develop an empirical model that relates the process response to the factors. The Method of Least Square is used to estimate the parameters in the empirical model, Box & Hunter, [1]. Regression models are used for the analysis of the response as well.
as the nature of the relationship between the response and the factors. Details of experimental designs for fitting response surfaces are found in Montgomery, [14] and Khuri, [10].

In this study, Central Composite Design was used for experimental design model with 5-level- 3 factors experiment. A 5-level-3-factor central composite design was employed in watermelon crop experiment where optimization required 20 experimental runs. Poultry manure, cow manure, and goat manure were the independent variables to optimize the response of interest that include; fruit weight at maturity, number of branches and vine length per plant. Also, the study optimized several of responses at the same time. Multi-response problem is often difficult due to different factors taken into account during problem-solving. Optimizing multiple responses is of main concern among decision makers. Derringer et al. [5] proposed desirability function approach for simultaneous optimization of several response variables. The proposed procedure optimizes multiple responses simultaneously and overcomes the limitations of RSM when dealing with a large number of responses. Desirability function was used to consider several responses as efficiency response surface.

MATERIALS AND METHODS

Materials

Sukari F1 watermelon a newly developed variety from East Africa Seed Company was used in the study. Similarly, poultry, goat and cow manure used for the experiment was sourced from Chuka University Agricultural farm and from local community. Data was obtained from an experiment carried out at horticultural research and teaching farm of Chuka University. A land measuring 448 meters squared (28 M by16 M) was selected for the study and prepared for planting. Twenty plots of 4M by3M each was made and composite samples collected from the plots at 0-15 cm depth in order to assess the initial physical-chemical properties of the soil. The composite soil samples collected from individual plots was analyzed in the laboratory to determine initial physical-chemical properties of soils for the study. Similarly, the chemical analysis of poultry, goat and cow manure used for the experiment was evaluated using appropriate method. Each plot had 3 seeds per stand at a depth of 3cm, using a spacing of 200cm by 100cm, with 100cm Alley pathways. Data on watermelon fruit weight at maturity, number of branches and vine length per plant were collected.

Design of the Experiment

The experiment was carried out as a CCD consisting of 20 experimental runs determined by the \(2^3\) full factorial designs with six axial points and six center points as shown in Figure 1.

![Figure 1: Layout of the Central Composite Design (CCD) for 3 variables at 5 levels](image)

In this study, Central Composite Design was used for experimental design model with 5-level- 3 factors experiment. A 5-level-3-factor central composite design was employed in watermelon crop experiment where optimization required 20 experimental runs. Poultry manure \((X_1)\), cow manure \((X_2)\) and goat manure \((X_3)\) are the independent variables to optimize the response values of interest (Fruit weight of watermelon at maturity, number of branches and vine length per plant). In developing the regression
model, the test factors were coded according to the formulae given as $x_i = \frac{X_i - X_0}{X}$ where $x_i$ is a coded variable of the $i^{th}$ variable, $X_0$ is an average of the variable in high and low level, $X$ is (variable at high level - variable at low level)/2 and $X_i$ is an encoded value of the $i^{th}$ test variables. Analysis of data was done using R- Program and Design Expert version 10

**Table 1: Three Factors at Five Levels Estimated Values**

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Predictor Variable</th>
<th>Code Levels</th>
</tr>
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<tbody>
<tr>
<td>$X_1$</td>
<td>Poultry manure (Tons/Ha)</td>
<td>-1.682, -1, 0, +1, +1.682</td>
</tr>
<tr>
<td>$X_2$</td>
<td>Cow manure (Tons/Ha)</td>
<td>1.6, 1, 10, 15, 19.4</td>
</tr>
<tr>
<td>$X_3$</td>
<td>Goat manure (Tons/Ha)</td>
<td>1.6, 1, 10, 15, 19.4</td>
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**Table 2: Full Factorial Central Composite Design Matrix and Experimental Results**

<table>
<thead>
<tr>
<th>Runs</th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>EXPV</th>
<th>PREDV</th>
<th>EXPV</th>
<th>PREDV</th>
<th>EXPV</th>
<th>PREDV</th>
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</thead>
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<td>0</td>
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<td>50.2</td>
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<td>168.1</td>
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<td>1</td>
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<td>56.7</td>
<td>6</td>
<td>7</td>
<td>176.0</td>
<td>180.6</td>
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<td>-1</td>
<td>1</td>
<td>46.0</td>
<td>49.2</td>
<td>3</td>
<td>4</td>
<td>169.0</td>
<td>167.2</td>
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<td>0</td>
<td>60.8</td>
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<td>72.0</td>
<td>71.0</td>
<td>7</td>
<td>7</td>
<td>195.9</td>
<td>194.4</td>
</tr>
</tbody>
</table>

**Mathematical Models**

The second-order model representing the watermelon fruit weight at maturity, number of branches and vine length per plant each were expressed as a function of poultry manure, cow manure and goat manure being in the input variable of watermelon response. To define the response equation, $X_1$, $X_2$ and $X_3$ are assigned to poultry manure, cow manure and goat manure respectively. An appropriate polynomial (second-order) models were expressed as:

$$Y_1 = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_{11} X_1^2 + \alpha_{22} X_2^2 + \alpha_{33} X_3^2 + \alpha_{12} X_1 X_2 + \alpha_{13} X_1 X_3 + \alpha_{23} X_2 X_3 + e$$
\[ Y_2 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + e \]

\[ Y_3 = \delta_0 + \delta_1 X_1 + \delta_2 X_2 + \delta_3 X_3 + \delta_{11} X_1^2 + \delta_{22} X_2^2 + \delta_{33} X_3^2 + \delta_{12} X_1 X_2 + \delta_{13} X_1 X_3 + \delta_{23} X_2 X_3 + e \]

Where \( Y_i ; (i=1,2,3) \) is the \( i^{th} \) predicted response (1= for Fruit weight of watermelon at maturity, 2= for Number of branches per plant and 3= for Vine length at 8 weeks), \( X_i \) represent the control factors in the experimental data, \( \alpha_0, \beta_0 \) and \( \delta_0 \) the constant, \( \alpha_i, \beta_i \) and \( \delta_i \) the linear coefficient, \( \alpha_{ii}, \beta_{ii} \) and \( \delta_{ii} \) are the quadratic coefficient and \( \alpha_{ij}, \beta_{ij} \) and \( \delta_{ij} \) the cross-product coefficient (For \( i=123; j=2,3 \) and \( i<j \)).

**Method of Optimization**

In this study, the experimenter optimized a number of responses at the same time. The problem in dealing with multiple responses is that the three might be conflicting objectives because of the difference requirement of each of the responses, Candioti, [3]. In such a case experimenter opt to involve the use of desirability function. The Desirability method is very effective in optimizing processes that have multiple answers, which should be optimized simultaneously. Under this study, each \( i^{th} \) response was assigned a desirability function, \( d_i \), where the value of \( d_i \) varies between 0 and 1. The function \( d_i \) is defined differently based on the objective of the response. The objective of the responses is to maximize the fruit Weight of watermelon at maturity, Number of branches and vine length per plant. Then \( d_i \) is defined as follows

\[
d_i = \begin{cases} 
0 & y_i < L \\
(y_i - L)^w & L \leq y_i \leq T \\
1 & y_i > T 
\end{cases}
\]

Where \( T \) is the target value of the \( i^{th} \) response \( y_i \), \( L \) is acceptable lower limit value for this response and \( w \) the weight. When \( w = 1 \), the function is linear, \( w > 1 \), more weight is assigned to achieving the target for the response and \( w < 1 \) less weight is assigned the target for the response.

Once a desirable function is defined for each of the responses, an overall desirability function is defined as the weighted geometric average of the individual desirability \( (d_i) \) according to the following equation.

\[
D = \left( d_1^{r_1} d_2^{r_2} d_3^{r_3} \right)^\frac{1}{r_1+r_2+r_3} = f(y_1, y_2, y_3)
\]

Where the \( ri \)'s importance of each response. The greater \( ri \) the more importance the response with respect to the other responses, Myers, [18]. The objective is to find the setting that returns the maximum value of \( D \) (global index) that is maximum response surface of efficiency in the feasible region, Wang [20].

**RESULTS AND DISCUSSION**

**Models Summary Statistics**

The researcher sought to evaluate the component of the second order models in order to assess their suitability and the results are portrayed in Table 3.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-Squared</td>
<td>0.9337</td>
<td>0.959034</td>
<td>0.956697</td>
</tr>
<tr>
<td>Adjusted R-Squared</td>
<td>0.8591</td>
<td>0.912947</td>
<td>0.907981</td>
</tr>
<tr>
<td>Predicted R-Squared</td>
<td>0.5489</td>
<td>0.764972</td>
<td>0.790799</td>
</tr>
</tbody>
</table>

Model summary statistics focus on the model maximizing the Adjusted R-Squared and the Predicted R-Squared. R-Squared refer to a measure of proportion of the variation in the dependent variable that is explained by the independent variable for a regression model. Adjusted R-Squared it is used to adjust the
statistic based on the number of independent variable in the model. It compares the explanatory power of regression model that contain different independent predictors. In this case, since the multiple regression models have more than one variable, Adjusted R-Squared is the most preferred. The study found that quadratic models were suggested for the data fitting with an Adjusted R-Squared value of 85.91%, 91.3% and 90.8% for model 1, model 2 and model 3 respectively. For instance, Model 1 explains about 85.9% of the variability in the response variable. The adjusted R-squared is often used to summarize the fit as it takes into account the number of variables in the model.

**Mathematical Model**

The data obtained from the experiment were analyzed to develop mathematical models. The multiple regressions were obtained by employing a least square technique to predict quadratic polynomial model for the fruit weight, number of branches and vine length of watermelon and pertinent results are presented in Table 4.

Organic manure (especially poultry manure) is most important parameter affecting growth and production of watermelon, Enujeke, [7]. In order to study the interaction factors (combine effect of poultry, cow and goat manure) experiment were conducted varying physical parameter using CCD. A multiple regression data analysis was carried out with “R-Gui” statistical package. The study found that poultry and goat manure had positive significant effect on fruit weight of watermelon at P-value=0.00052<0.05 and 0.00046<0.05 respectively. In addition, it was observed that goat manure was slightly superior in terms of its effect on fruit weight of watermelon. In the findings, one unit change of goat or poultry manure influenced the fruit weight by a factor of 1.57 and 1.54 respectively. However, cow manure had insignificant effect on the fruit weight of watermelon at 5% level (P-value=0.204>0.05). The study found that combined poultry and goat manure had a significant effect on the fruit weight of watermelon at P-value less than 0.05. Poultry manure is the richest known animal manure Enujeke et al., [8] and Mangila et al., [11], and it is essential for establishing and maintaining the optimum soil physical condition for plant growth and production. In this study, combining cow and goat manure had a significant effect on watermelon production. The results indicates that a one unit change in combined poultry and goat manure, led to change in watermelon fruit weight by a factor of 1.0625 whereas combining cow and goat manure changed the same by a factor of 0.9375. This implies that combined poultry and cow manure would be more superior compared to combine cow and goat manure in influencing the fruit weight of watermelon. The adjusted model obtained for watermelon production as a function of the significant variables is indicated in Model 1.

The regression coefficient estimates shows that for one unit change in poultry manure and goat manure, number of branches of watermelon would increase by a factor of 0.6856 and 0.5392 respectively. This implies that poultry manure is slightly more effective than goat manure on growth (number) of branches of watermelon plant. In addition, it was found that combined application of poultry and goat manure had a regression coefficient value of 0.5 and a P-value of 0.022423<0.05, hence statistically significant at 5% significance level. This implies that for one unit change in combine poultry and goat manure (\(X_1X_3\)), growth of branches (in number) of watermelon plant would increase by a factor of 0.5. Moreover, it was observed that quadratic terms were not statistically significant except goat manure where the parameter estimate was -0.3544 with a P-value of 0.028<0.05. The results indicate that for one unit increase of quadratic term goat manure, growth of watermelon would be negatively affected by a factor of 0.3544. The predicted model for number of branches of watermelon plant in terms of coded factors is as shown in Model 2.
### Table 4: Regression Coefficients Estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate 1</th>
<th>SE 1</th>
<th>t-Value 1</th>
<th>P-value 1</th>
<th>Estimate 2</th>
<th>SE 2</th>
<th>t-Value 2</th>
<th>P-value 2</th>
<th>Estimate 3</th>
<th>SE 3</th>
<th>t-Value 3</th>
<th>P-value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>15.14838</td>
<td>0.46321</td>
<td>32.703</td>
<td>1.69e-11 ***</td>
<td>6.1848</td>
<td>0.2139</td>
<td>28.921</td>
<td>5.69e-11 ***</td>
<td>181.2218</td>
<td>1.9721</td>
<td>91.893</td>
<td>5.70e-16 ***</td>
</tr>
<tr>
<td>X₁</td>
<td>1.54326</td>
<td>0.30731</td>
<td>5.022</td>
<td>0.00052 ***</td>
<td>0.6856</td>
<td>0.1419</td>
<td>4.832</td>
<td>0.000689 ***</td>
<td>7.8065</td>
<td>1.3084</td>
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<td>5.106</td>
<td>0.00046 ***</td>
<td>0.5392</td>
<td>0.1419</td>
<td>3.800</td>
<td>0.003485 **</td>
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<td>-0.301</td>
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<td>X₂²</td>
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<td>0.29912</td>
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<td>0.01580 *</td>
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<tr>
<td>X₃²</td>
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<td>X₁X₂</td>
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<td>-2.697</td>
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<td>0.7500</td>
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<td>4.046</td>
<td>0.002340 **</td>
<td>3.9125</td>
<td>1.7095</td>
<td>2.289</td>
<td>0.045119 *</td>
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\[ Y_1 = 15.148 + 1.543X_1 + 0.418X_2 + 1.569X_3 - 0.868X_2^2 + 1.063X_1X_3 + 0.938X_2X_3 \]  
Model 1

\[ Y_2 = 6.1848 + 0.6856X_1 + 0.1231X_2 + 0.5392X_3 - 0.3544X_2^2 - 0.500X_1X_3 + 0.500X_1X_3 + 0.938X_2X_3 \]  
Model 2

\[ Y_3 = 181.2218 + 7.8065X_1 + 2.7833X_2 + 8.3926X_3 - 3.084X_2^2 + 4.8375X_1X_3 + 3.9125X_2X_3 \]  
Model 3

Where \( Y_i \) (i=1,2,3) represent the fruit weight, Number of branches and vine length of watermelon plant respectively

- \( X_1 \) is the poultry manure
- \( X_2 \) is the cow manure
- \( X_3 \) is the goat manure

These are coded equations, useful for identifying the relative impact of the factors by comparing the factor coefficients.
The study found that goat and poultry manure were statistically significant at 5% significance level with a P-value of 0.00008<0.05 and 0.00014<0.05 respectively. The regression coefficient estimates shows that for one unit change in goat manure and poultry manure, vine length of watermelon would increase by a factor of 8.3926 and 7.8065 respectively. This implies that goat manure is slightly more effective than poultry manure on growth of watermelon plant. In addition, it was found that combined application of poultry and goat manure had a regression coefficient value of 4.8375 and a P-value of 0.018<0.05, hence statistically significant at 5% significance level. This implies that for one unit change in combined poultry and goat manure (X1X2), growth of watermelon plant (vine length) would increase by a factor of 4.84.

Similarly, it was noted that quadratic terms were not statistically significant except goat manure where the parameter estimate was -3.0840 with a P-value of 0.035956<0.05. The results indicate that for one unit increase of quadratic term of goat manure, growth of watermelon would be negatively affected by a factor of 3.0840. The adjusted model obtained for watermelon growth (vine length) as a function of the significant variables is given in Model 3.

Analysis of Variance
Analysis of variance (ANOVA) was used to check the adequacy of the model for the response (fruit weight, Number of Branches and Vine Length) of watermelon in the experimentation at 95% confidence level and the result are as shown in Table 5.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>F-critical</th>
<th>Pr(&gt;F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>9</td>
<td>95.647</td>
<td>10.627</td>
<td>8.239</td>
<td>3.0204</td>
<td>0.00141</td>
</tr>
<tr>
<td>Residuals</td>
<td>10</td>
<td>12.899</td>
<td>1.290</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>108.546</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 2</td>
<td>9</td>
<td>21.4480</td>
<td>2.3831</td>
<td>8.6690</td>
<td>3.0204</td>
<td>0.00114</td>
</tr>
<tr>
<td>Residuals</td>
<td>10</td>
<td>2.7493</td>
<td>0.2749</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>24.1973</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3</td>
<td>9</td>
<td>2392.47</td>
<td>265.83</td>
<td>11.37</td>
<td>3.0204</td>
<td>0.00036</td>
</tr>
<tr>
<td>Residuals</td>
<td>10</td>
<td>233.80</td>
<td>23.38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>2626.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*F (9,10, 0.95)=3.0204

ANOVA results revealed that the predicted response models were statistically significant since F-Value were 8.239>3.02038, 8.669>3.02038 and 11.37>3.02038 (critical value) and p-value of 0.00141<0.05, 0.001143<0.05 and 0.00036<0.05 respectively. The suggested regression model is statistically significant in the prediction of fruit weight, number of branches and vine length of watermelon as a measure of growth and production of watermelon plant in the study area. From Table 5, it is observed that the model 1, model 2 and model 3 satisfy the adequacy conditions in non-linear form. In general, the overall models are adequate for prediction purpose in this study.

Application of Desirability Function for Optimization
Process optimization through the use of the desirability function, started with defining the specifications required for increased growth and production of watermelon. In this case, the data was analyzed separately to optimize the variable responses. Specifications (minimum, target and maximum) are related to the experimental data and they are presented in Table 6. In this case, the study sought target value to fruit weight, the number of branches and vine length of watermelon, search the maximization because the higher value is better for the increased growth and production of watermelon in the study area.
Table 6: Specification for Increased Growth and Production of Watermelon

<table>
<thead>
<tr>
<th>Response Variable</th>
<th>Minimum</th>
<th>Target/Average</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit Weight (Kgs)</td>
<td>17.0</td>
<td>23.287</td>
<td>29.574</td>
</tr>
<tr>
<td>No. of Branches</td>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Vine Length (cm)</td>
<td>165.4</td>
<td>223.743</td>
<td>282.09</td>
</tr>
</tbody>
</table>

The desirability (D) is the global index calculated from the combination of each of the variables response processed through a geometric mean and this index is responsible for showing the best condition for optimization of all variable responses at the same time. To achieve the greatest possible value for D which reflects, in the best condition variable responses in relation to the attendance of their specification, the best settings using standardized variables of the factors are as shown in Table 7.

Table 7: Optimal Parameter-Setting of Responses

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Organic Manure</th>
<th>Optimal Values (coded)</th>
<th>Actual Optimal Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>X₁</td>
<td>Poultry Manure</td>
<td>1.52754</td>
<td>17.6377 tons/Ha</td>
</tr>
<tr>
<td>X₂</td>
<td>Cow Manure</td>
<td>0.233256</td>
<td>11.1663 tons/Ha</td>
</tr>
<tr>
<td>X₃</td>
<td>Goat Manure</td>
<td>1.61003</td>
<td>18.0515 tons/Ha</td>
</tr>
</tbody>
</table>

Analyzing the Table 7, it was found that the value of D, belong to the range from 0 until 1 and is maximized when all the answers are approaching their specifications, because the nearest one in D, closer to the original answers will be their respective specifications limits. The great general point of the system is achieved by maximizing the geometric mean, calculated from the individual desirability functions (dᵢ) which in this case are the value for each of the variable responses as shown in Table 8.

Table 8: Desirability Function Values

<table>
<thead>
<tr>
<th>Response Variable</th>
<th>Individual Desirability (dᵢ) Values</th>
<th>Global index (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit Weight</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>No. of Branches</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Vine Length (cm)</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

The values obtained for the compound desirability (D) and individual desirability (dᵢ) demonstrate that the process was well optimized, because these indices are equal to the condition great value of one (1.0). Thus under the best parameter setting all the responses were maximized as shown in Table 9.

Table 9: Simultaneous Optimization of Multiple Responses

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Responses</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y₁</td>
<td>Fruit Weight</td>
<td>23.295 Kgs/plant</td>
</tr>
<tr>
<td>Y₂</td>
<td>Number of Branches</td>
<td>8.97122</td>
</tr>
<tr>
<td>Y₃</td>
<td>Vine Length (cm)</td>
<td>225.43</td>
</tr>
</tbody>
</table>

The aim of the study was to optimize the multiple responses of watermelon to organic manure. It was revealed that, 17.64 tons/Ha of poultry manure, 11.2 tons/Ha of cow manure and 18.1 tons/Ha of goat manure was essential or required to simultaneously optimize the multiple responses of watermelon. These optimal conditions (requirement of organic manure) could attain a maximum of 93.73 tons/Ha of fruit weight of watermelon. Also under the same conditions nine (9) branches per watermelon plant were achieved. Indeed, the length of about 225.4 cm was attained at the same optimal conditions. An increase of poultry manure led to an increase in fruit weight, numbers of branches and vine length of watermelon plant as well as desirability compound D (Figure 2). Noting the increase of cow manure factor, it is
possible to perceive that there will be fall in the value of the response variables and increased desirability compound D. Also an increase of poultry manure led to an increase in fruit weight, numbers of branches and vine length of watermelon plant. Multiple response optimization using desirability functions have until now had its utilization limited to the chromatographic field, its related techniques, and to electrochemical methods, Candioti, [3]. However, its principles can be applied to the development of procedures using various analytical techniques, which demand a search for optimal conditions for a set of responses simultaneously.

![Figure 2: Desirability Function Applied in Multiple Responses](image)

CONCLUSION AND RECOMMENDATION
The great general point of the system was achieved by maximizing the geometric mean, calculated from the individual desirability functions which in this study were the value for each of the variable responses. The findings revealed that the process was well optimized, because the indices were very close or equal to the condition great value of one (1.0). In the study, the best solution was found to be 17.64 tons/Ha, 11.17 tons/Ha and 18.05 tons/Ha of poultry, goat and cow manure respectively that is required to achieve maximum response values as 93.73 tons/Ha of fruit weight, 9 branches/plant and 225.43 cm of vine length of watermelon plant. The responses were used to assess the increased growth and production of watermelon plant in the study area. Finally, this study exemplified that the development of mathematical
models for crop production based on statistics can be useful for predicting and understanding the effects of experimental factors. What must be noted here is that RSM does not explicate the mechanism of the studied crop production, but only a certain the effects of variables on response and interactions between the variables. It can also be stated that it would be a scientific and economic approach to obtain the maximum amount of information in a short period of time and with the lowest number of experiments.

ACKNOWLEDGEMENT
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REFERENCES


FACTORS AFFECTING ECONOMIC BENEFITS OF INDIGENOUS VEGETABLES GROWN BY SMALL-SCALE FARMERS IN KENYA: A CASE STUDY OF MWEA SUB-COUNTY

Njoroge, S. M. and Githae, E.W.
Department of Biological Sciences, Chuka University, P. O. Box 109-60400, Chuka, Kenya
Tel.: +254 725 286 095, Email: njoroslyk21@gmail.com, egithaeh@gmail.com

ABSTRACT
Indigenous vegetables have long been part of traditional diets in communities worldwide. They are valuable sources of nutrients with some having significant medicinal properties and they contribute greatly to food security. Their consumption is by-passing the production in Kenya due to health check by many, although in Kenya, indigenous vegetables have been faced by various challenges that include land size, quality, cost of input and agronomic factors that in turn reduce returns earned by farmers. This research was conducted in Mwea sub-County to assess the major factors that affect the profit gain of indigenous vegetable by small-scale farmers. Stratified sampling and snowballing techniques were used in carrying out the research in four locations where indigenous vegetables are rigorously grown. Data was collected using questionnaires and observations and the population targeted was indigenous vegetables farmers only. The survey results demonstrate that land size affected profitability of small-scale farmers since cost of labor and other factors were constant regardless of farm size. More than 80% of farmers reported that size of land determined the profit returns of indigenous vegetable. Furthermore, agronomic factors like mode of management and type of seed used also affected production. Water availability, soil fertility, pests and diseases had a negative effect on leaf quality and therefore affected production. The study recommends policy interventions to reduce transaction costs as well as awareness creation on agronomic and post-harvest management on cultivation of indigenous vegetables.

Keywords: Indigenous vegetables, profitability, small-scale farmers, agronomy

INTRODUCTION
Agriculture is under increasing pressure to produce greater quantities of food, feed and biofuel on limited land resources for the projected nine billion people on the planet by 2050. It is envisioned that agricultural production has to increase by 70% by 2050 to cope with an estimated 40% increase in world population (Andreas, 2014). In current time, over-reliance on some of major staple crops has been characterized by ecological, agronomic, nutritional and economic risks and is probably unsustainable in the long run and therefore, use of underutilized minor crops like indigenous vegetables provide more options to enhance resilience to both biotic and abiotic stress. Indigenous vegetables have long been part of traditional diets in communities worldwide. They are valuable sources of nutrients with some having significant medicinal properties (Hilou et al., 2006) and contribute significantly to nutritional balance and food security (Yiridoe and Anchirinah, 2005). Indigenous vegetables are of considerable commercial value and therefore an important source of household income in both rural and urban. Due to the increase in population especially in sub-Saharan Africa (UN-Habitat, 2007), consumption of indigenous vegetables will also improve at a higher rate. In Kenya, vegetables constitute a substantial portion of the horticultural output. In 2003, vegetables constituted about 18 per cent of the horticultural export volumes. The colonialist classified them as weeds as they introduced exotic vegetables which later contributed to a decline in indigenous vegetables. Due to climatic changes and effect of biotic and abiotic stress in these exotic vegetables, more research has been emphasized on indigenous vegetables in Kenya to promote food security and nutritional value and this has led to commercial production with increased consumption in urban areas. This has subsequently increased the income level of farmers and also forming a source employment to most Kenyans. Despite the increase in demand for these indigenous vegetables in different areas, there are several challenges facing the small-scale farmers which reduce their profitability. These include reducing land size in rural areas, inadequate production and marketing skills to the farmers, climatic changes, inadequate water to support irrigation, effect of diseases and pest on the quality of leaf produced and the types of agronomy culture practices used. This has seen a decline in production of indigenous vegetables thus reducing returns to the farmers which does not fully feed the increasing need.
If these challenges are mitigated, production of indigenous vegetables can improve and help to increase income level of the farmers and also to meet the nutritional demand.

In Kenya, the rural population depends on indigenous vegetables both as a source of food and income (Abukutsa-Onyango, 2002). They have a huge potential of being cash income earners thus enabling the poorest people in the rural communities to earn a living and make them economically stable (Onyango, 2003). They are also well adapted to harsh climatic conditions and infestation of disease and are easier to grow. Nonetheless, there is no explicit government policy that attempts to promote production and marketing of these products in the high-demand areas, such as Nairobi (Abukutsa-Onyango, 2002). The study therefore assessed the various factors affecting the economic benefit of selected indigenous vegetable to small scale farmers in Kenya for policy interventions.

METHODOLOGY
Area of Study
The study was conducted in Mwea constituency where four wards were selected: Nyangati, Kangai, Kiarukunga/Tebere, and Mahiga-ini, since this is where the most farmers who grow indigenous vegetables are concentrated. The constituency is located in the southern part of Kirinyaga County with a total population of 190512 people covering an area of about 542.8kms$^2$. The wards are served by two rivers, Nyamindi River and Thiba River for irrigation purposes and household chores. The Nyamindi river system serves Tebere, and Mahiga-ini if the cultivation is done through irrigation while the other two wards are served by the Thiba River. Water is extracted from both rivers by gravity and is distributed through unlined open channels (Mati et al., 2010) where farmers use the water through small canals or pumps. The area has an altitude between 1110 m to 1393 m above sea level with exception of hill tops, which have a higher altitude. It has two rainfall seasons with annual average precipitation of 950 mm (Kennenni, 2002). The area is mostly hot with average temperatures ranging between 23 and 25°C.

Research Design
The study adopted the use of survey design which enabled the study of the selected wards within the county. Population under study was drawn from indigenous vegetable farmers distributed in the 4 selected locations. The sample was drawn from a population of 95142 people living in these 4 locations according to statistic data from KNBS (2013). Stratified random sampling method was used to obtain data from the four wards each forming a stratum. From there snowballing was used so as to reach other farmers from each region. A total of 96 farmers were sampled as shown in Table 1.

<table>
<thead>
<tr>
<th>Stratum(locations)</th>
<th>Population in each stratum</th>
<th>Strata sample prop*pop in each stratum</th>
<th>Sample in each stratum(location)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyangati</td>
<td>25016</td>
<td>25016*0.001</td>
<td>25</td>
</tr>
<tr>
<td>Kangai</td>
<td>19300</td>
<td>19300*0.001</td>
<td>20</td>
</tr>
<tr>
<td>Tebere</td>
<td>31695</td>
<td>31695*0.001</td>
<td>32</td>
</tr>
<tr>
<td>Mahiga-ini</td>
<td>18331</td>
<td>18331*0.001</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>95142</td>
<td></td>
<td>96</td>
</tr>
</tbody>
</table>

A semi-structured questionnaire was administered to farmers through face to face interviews. This covered demographic characteristics of the farmers, cost of production and agronomic skills. Observation was used to help in gathering primary data on the indigenous vegetables on the farm and how farmers and other stake holders do pre-and post-harvesting management. Secondary data was also collected through literature review of various articles to obtain information about land tenure system, water regulation, quality of vegetable required for export and the type and regulation of chemicals sprayed.
Data Analysis
Data was analyzed using the Statistical Package for Social Science (SPSS) version 20 and Excel. Descriptive statistics measures such as percentages, standards, means and frequencies were computed for all quantitative data and the results presented using pie charts and frequency distribution tables. Correlation and regression was used to analyze the level and degree of relationship between economic benefit and cultivation of indigenous vegetables.

RESULTS AND DISCUSSION
Demographic characteristic of farmer respondents
The sample size of farmer respondents during the survey was 96 of which 87% were female and 13% were males. This shows that majority of the farmers cultivating indigenous vegetables in Mwea county are female hence women have more control over the production process. Based on education levels, 38% of the respondents had primary level education, 50% had acquired secondary level education, while the rest had tertiary education level with either diploma or certificate (Fig. 1). This show that majority of the farmers had acquired basic education, which is seen as a key to shaping and influencing farmers productivity. Highly educated farmers always demonstrate better means of crop production and adoption of new technologies as opposed to poorly educated farmers (Thirtle et al., 2003).

![Figure 1 Education level of the farmer respondents](image)

With respect to age distribution of the respondents, the study shows that on average, most farmers were between the age of 31-40 years, followed by those between the age of 41-50 years, with least ranging between the age of 21-30 years and those above 50 years (Fig. 2). This shows that most of the farmers are between the economic active ages.

According to Figure 3, the highest percentage of the responders had their source of income in crop growing (70%) with 20% practicing combined livelihoods. This indicates that most of the farmers solely depend on farming hence if the profit is reduced this reduces their income and may affect their living standard. In addition, 50% of the respondent preferred doing both cash and food crop farming. Furthermore, 40% of the farmers cultivated only exotic vegetable while 10% cultivated indigenous vegetables only with 50% cultivating both indigenous and exotic vegetables. This variation is because when the exotic vegetables were introduced, the indigenous vegetable were termed as weeds which resulted in many people not to cultivate them and later contributed to their decline in cultivation.
According to the observation, the most consumed type of indigenous vegetable variety was cowpeas (67.8%) followed by the African nightshade (64.4%) and spider plant (62.7%), while the least consumed vegetable was pumpkin (Fig. 4). This is because most farmers preferred leaving the pumpkin to produce fruit rather than leaves.
Cost of production on indigenous vegetables
According to the data collected, 50% of the farmers cultivate less than an eighth of an acre while 40% of the farmers had less than or equal to a quarter of an acre. Only 10% of the farmers cultivated more than an acre of the farm. This indicates that cultivation of indigenous vegetable is not well done due to lack of land hence the economic benefit to the farmers is not fully met since they can only cultivate one type of crop at a given time which increases cost of production and reduces returns due to small size. This is brought by the fact that the cost of production is constant regardless of the size of the land.

The total cost of input of indigenous vegetable in average per acre was 12,100 Ksh where the cost of fertilizer was 2,600 Ksh which increase with time (Fig. 5). Over usage of the inorganic fertilizers increases acidity in the soil and hence requires another basic fertilizer to reduce the acidity in the soil, which in turn increases the cost of production. The cost of labour was the highest (5,300 Ksh) in terms of cost of production. This is accelerated by manual usage of labour since there is no mechanical mode introduced and in turn reduces the profit return of the farmers. The cost of chemical was 1,200 Ksh and the cost of rent per acre was 3000 Ksh.

![Figure 5 Cost of input on average](image)

Figure 5 Cost of input on average

Market and agronomic skills
The mode of marketing affects the profitability of the IVS production. According to the farmer respondents, 85% of the farmers sell their produce in the markets or to the brokers while 15% of the farmers do contract farming which controls their production and marketing as well. Where they do a contract annually, price is negotiated at the beginning of production hence even if there will be price fluctuations in the market these farmers will sell their product at the contracted price thus are assured of the market. On the other hand in an open market, the produce dictates the price due to economic factors of demand and supply. This show affects the prices and subsequent returns to farmers on the production of indigenous vegetables.

There were various agronomic factors that were mentioned as affecting profitability of the indigenous vegetables. These include the type of seed used. Most respondents got planting seeds from their previous production (44%) and 43% got their seeds from their neighbours. Nonetheless, there was a risk in transferring diseases to the new plots, which increased the cost of production by using more chemicals to control pest and diseases and also more fertilizer to boost production. Only 13% of the respondents used certified seeds which are more productive with 95% germination rate. However, even though certified seeds were the best, they were regarded as expensive compared to the others and therefore increased the cost of production. Another factor mentioned was the mode of management. The pre- and post-
management of the indigenous vegetables affected productivity where 83% of the farmers used own management method while 17% used contract farming. Those who were under contract farming had high yields because under contract farming the contacting company provided the expertise on the type of certified seeds to use, type of pesticides and how much fertilizer to apply. They were also assured of the market compared to those who did self-controlled production.

From the survey, leaf quality was one of the major determinants in the market. Healthy leaf fetches higher prices in the market hence more returns to the farmers. According to the farmer respondent the health of the leaf is affected by different factors such as pests and disease, water availability and soil fertility. The respondents said that pests and diseases affected the quality of the leaf and hence reduced the profits. Pest like aphids results in leaf curl as they suck water from the leaf. Others are cut worms, spider mites, crickets and root-knot nematodes which affect the uptake of water thus resulting in plant death or low quality. Diseases like leaf spot and late blight contribute greatly to reduced leaf quality and profitability in the market. In addition, water also affected the quality of the leaf from the period of germination to maturity. Lack of water reduced the produce and also contributed greatly to disease infection. Furthermore, the respondents said that soil fertility affected the average produce per acre.

CONCLUSION AND POLICY RECOMMENDATION
This study shows that various factors affect production of indigenous vegetables. These include the land size, soil fertility, use of labour, mode of marketing and various agronomic factors. There is also a great relationship between the quality of leaf and the profitability where healthy leaf fetches high prices in the market hence more returns to the farmers. However, the quality of leaf is affected by pests and diseases, water availability and the soil fertility.

In order to improve the growth and production of indigenous vegetables by small-holder farmers, there is need to educate farmers on various agronomic practices such as crop rotation, use of organic fertilizers and certified seeds. Contract farming should also be encouraged because the contracting companies provide experts who guide the farmers on these practices. In addition policies that can assist in reducing the cost of production to farmers should be established and implemented. These include creation of irrigation schemes for cultivation of indigenous vegetables. Furthermore, researchers should carry out research and innovations to come up with high yielding variety of indigenous vegetables which will have a high output even if the land is reduced. They should also come up with biological methods of controlling pest and diseases rather than using pesticides and herbicides which are very expensive and may have an effect on the human health.

REFERENCES
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IMPORTANCE OF PRODUCT ATTRIBUTES IN THE SUCCESSFUL BRANDING OF FRESH FRUITS AND VEGETABLES

Nkari, Isaac Micheni
Department of Business Administration Chuka University, Kenya
Email: isaacknari@yahoo.com, Tel.: 0722978836

ABSTRACT
The objective of this study was to establish the importance of specific product attributes in the successful branding of fresh fruits and vegetables (FFV). The population of study consisted of 213 commercial farmers of FFV in Kiambu County. The study adopted stratified random sampling in which 140 farmers were sampled from the seven sub-counties in Kiambu County. The study adopted a descriptive cross sectional survey design. Data was collected using a semi structured questionnaire and analyzed using both descriptive and inferential statistics. The study established that among the seven identified product attributes; longer shelf life had the highest contribution followed by special taste/colour while unique place of origin had the least contribution followed by special medical value. It was observed that since the branding of FFV had low adoption, the average contribution of the attributes to successful branding of FFV was low. The generalizability of the study findings was limited by the limited number of respondent farmers engaging in branding of FFV and lack of corroborative secondary data. The study recommends that farmers should establish available attributes for their products and utilize them in the branding of FFV as a means of adding value to their products. The government should identify and protect special product attributes of the FFV grown in various parts of the country and avail them to only farmers from these areas for branding purposes. Future studies should focus on product attributes of other fresh agricultural products and also target other counties with differing social economic and climatic conditions. A study should be done to establish why branding of FFV has low adoption despite availability of requisite product attributes. A study with collaborative secondary evidence would increase objectivity in the collected data.

Keywords: Product Attributes, Commercial Farmers, Fresh Fruits and Vegetables

INTRODUCTION
As noted by Aaker (2003), the continued fragmentation of mass markets has creates multiple consumer offerings that require continuous identity clarification and modification. Marketers undertake differentiation through product branding. The theory of branding postulates that producers will strive to offer products with superior attributes to gain market dominance. These attributes signal the quality and characteristics of products as well as the characteristics of consumers (Meads & Sharma, 2008).

Kotler and Keller (2009) described branding as a means of helping consumers identify a product by giving it a name and using other brand elements that create mental structures that organize their knowledge about the product. According to Wood (2000), the term brand has been highly conceptualized and its theory is evolving continuously. This makes it difficult to have one generally accepted definition of a brand. By combining product-plus and owners’ perspectives, Kotler and Keller (2009) present a brand as a name, term, sign, symbol, or design or a combination of them, intended to identify products of one seller and differentiate them from those of competition.

Aaker (2003) further observes that it is difficult to build strong brands because of both internal and external pressures which confront a marketer. These pressures demand extra effort on the part of the producer to convince consumers of the superiority of their products over competition. This effort is even more difficult for fresh fruits and vegetables (FFV) which as noted by Cook (2013) lack year round supply of quality products and also require specialized handling due to their perishability. Trienekens (2011) observes that for most fresh food products, there is limited differentiation and branding of the products at farm level despite the availability of numerous product differentiating attributes.
Gwin and Gwin (2003) postulate that each product is a bundle of attributes and that consumers have preferences for characteristics (or attributes) of specific products. The products’ attributes theory avers that rather than comparing products themselves, consumers’ choice is based on the characteristics (or attributes) of brands. The model explains that individual choices is a process of choosing bundles of product attributes inherent in goods and services. Attributes can be classified as either hard-attributes or soft-attributes.

Gwin and Gwin (2003) present hard-attributes as objective and measurable, and have to do principally with the functioning and performance of a product; for example, strength, speed, weight, and price. Hard attributes which are also referred to as tangible attributes can include such product characteristics as size, color, weight, volume, smell, taste, touch, quantity, or material composition. Soft-Attributes are subjective and emotional. They are described using words like attractive, young; sporty, pleasant, and feminine, and cannot be quantified or measured by objective means. Hard-Attributes define the product’s abilities, performances, and reliability. The Soft-Attributes define the product’s user-experience, character, look, and feel. Any good product must balance both hard and soft attributes.

Crawford (1997), states that the initial decision of a producer is whether to brand or not or not to brand. The author notes that historically, most unprocessed agricultural products have been sold unbranded and that agricultural products are frequently marketed as commodities wherein particular grade bands of a product from one source is considered identical to that from another source. By their nature, fresh fruits and vegetables are commodities. A fresh fruit or vegetable is one which is marketed in the form in which it was harvested without any processing or preservation beforehand either “by freezing, canning, pickling, salting, drying, or any other means” (Random House Webster College Dictionary with CD-Rom). These products are largely considered as commodities.

Keller (2000) notes that a commodity is a product presumably so basic that it cannot be physically differentiated in the minds of consumers. He suggests that the key success factor in branding commodities is that consumers have to become convinced that all the product offerings in the category are not the same and that meaningful differences exist.

Connolly and McDermott (2009) note that successful differentiation for agricultural products just like any other product should be based upon genuine differences. If the products being branded are essentially similar to other products, or the buyers cannot be convinced of their superiority over other products, then the firm seeking to brand needs to adopt a broader perspective and look at the entire experience it offers potential buyers and search for a distinct differentiating factor.

The concept of firm performance relates to the manner in which a firm’s resources are used to achieve its overall objectives. Kinyua-Njuguna (2013) presents firm performance as the actual output of an organization measured against its intended outputs. Product branding is demanding in terms of time, efforts and financial resources. Both financial and non-financial parameters are used to measure firm performance arising from branding. Product output, price premium, profitability and satisfaction were the performance measures adopted for this study since as established by Ailawadi, Lehmann and Neslin (2002), they are easy to assign and are consistent with the focus of business executives.

Kiambu County consists of twelve administrative sub counties namely Kiambu, Kikuyu, Limuru, Lari, Githunguri, Thika, Ruiru, Juja, Kiambaa, Kabete, Gatundu North and Gatundu South. The County has a wide agro-ecological zone ranging from the cold climate of the upper highlands of Limuru and Lari to the relatively dry and warm climate of the lower parts of Ruiru, Thika and Gatundu enabling the county to produce tropical FFV such as bananas and mangoes as well as temperate ones such as peaches and plums. Horticulture is widely practiced in the county in both small scale units and large farms. In 2010, FFV farming in the County covered 26,407 hectares equivalent to three percent of total area under FFV in
Kenya. FFV earned the County Kshs. 12.92 billion equivalent to 5.7 percent of the crops’ total earnings in Kenya (Republic of Kenya, 2011).

The choice of a product attribute to form the basis of branding a fresh fruit or vegetable will depend on the opportunity it presents for creating a tangible difference for the product. To achieve the aspired increase in productivity, commercialization, and competitiveness of agricultural commodities, the strategy adopted by the Kenyan Government is to transform small holder agriculture from subsistence to an innovative, commercially oriented and modern sector. This entails engaging in such value addition activities as product processing, branding, quality certification and farm level quality improvements (Ministry of Agriculture, 2012). To supplement these initiatives by the Ministry of Agriculture, Livestock and Fisheries (MOALF), there is need to determine the extent to which product attributes contribute to the successful branding of fresh fruits and vegetable.

Various shortcomings were noted in the reviewed studies which render them inadequate in establishing the contribution of product attributes to the successful branding of fresh fruits and vegetables in Kiambu County. The study by Hauser and Urban (1979) was not product specific and focused on establishing the importance of product attributes in determining consumer utility functions. A study by Muthukrishnan and Kardes (2001) focused on establishing the conditions under which persistent product attributes occur and how consumers form preferences for attributes or other aspects of products and brands. On their part Gwin and Gwin (2003) aimed at establishing how product’s attributes model helped managers to understand the strategic implications of positioning decisions. The cited studies were conducted under different social economic and regulatory conditions compared to Kenya and were therefore location variant. They were also not related to horticultural products.

To bridge the identified gaps, the current study simultaneously considered different categories of product attributes and their contribution to the successful branding of fresh fruits and vegetables in Kiambu County. The study addressed the following research question: what is the influence of product attributes on the successful branding of fresh fruits and vegetables in Kiambu County?

**Review of Related Literature**

The subject matter of this paper was to determine whether there are product attribute related opportunities for the branding of Fresh Fruits and Vegetables (FFV). Crawford (1997), states that the initial decision of a producer is whether to brand or not. The author notes that historically, most unprocessed agricultural products have been sold unbranded and that agricultural products are frequently marketed as commodities wherein particular grade bands of a product from one source is considered identical to that from another source. As an illustration, the author claims that Blue Mountain Arabica Coffee from Kenya is a perfect substitute for Blue Mountain Arabica Coffee from Colombia, and vice versa. Similarly, the same grade of Broken Orange Pekoe (B.O.P.) tea from Sri Lanka and from India is a ready substitute for one another. Trienekens (2011) holds a similar position and observes that for most fresh food products, there is limited differentiation and branding of the products at farm level despite the availability of numerous product differentiating attributes.

Keller (2000) notes that a commodity is a product presumably so basic that it cannot be physically differentiated in the minds of consumers. He suggests that the key success factor in branding commodities is that consumers have to become convinced that all the product offerings in the category are not the same and that meaningful differences exist. The basis for successful branding of commodity products is to convince consumers that a product is not a commodity and actually varies appreciably in quality. Keller (2000) notes that what distinguishes a brand from its unbranded commodity counterparts is the sum total of consumers’ perceptions and feelings about the product’s attributes and how they perform; the brand name and what it stands for; and the company associated with the brand and what it stands for. Product attributes are the usual criteria by which a consumer will make a buying decision. Hard-Attributes define
the product’s “infrastructure” – abilities, performances, and reliability. The Soft-Attributes define the product’s user-experience, character, looks and feel. The balance between the two is different in different products, but any good product must consider them both in totally separate and different manners.

Connolly and McDermott (2009) assert that today’s agricultural producers face the increased challenge of determining how to differentiate their offerings, so that their products are perceived and awarded premium status and price in the consumers’ minds. They further note that successful differentiation for agricultural products just like any other product should be based upon genuine differences. However, Trienekens (2011) observes that for most fresh food products, there is limited differentiation and branding of the products at farm level despite the availability of numerous product differentiating attributes. The farmers therefore don’t benefit from the value addition acquired through branding. However, due to increased competition, agricultural producers have started adopting branding as a value adding activity (Beverland, 2007).

In differentiation, the physical product need not change since differentiation is due to buyers perceiving a difference in a product (McEwen, 2000). The causes of product differences may either be the functional aspects of products, how they are distributed and marketed or who buys them. Major sources of product differentiation include quality, functional features or design, ignorance of buyers’ regarding essential characteristics and qualities of products, sales promotion activities especially advertising, and availability. McEwen (2000) further notes that successful product differentiation moves a product from competing primarily on price basis to competing on non-price factors. Together with facilitating the charging of a price premium, differentiation also adds higher value to a firm’s products by making consumers less sensitive to all aspects of a competitor’s offerings.

Branding has been described by Kotler and Keller (2009) as a means of helping consumers identify a product by giving it a name and using other brand elements that create mental structures that organize their knowledge about the product. Hess and Bitterman (2008) present brand identity as a mechanism for communicating and shaping public perception of a brand while Heding, Knudtzen and Bjerre (2009) observe that companies build and manage brand identity to express an exact set of values, capabilities, and unique sales propositions for the product.

Brand identity is the face of a company or organization and is often the first connection between the brand and its target audience. Effective visual brand identity is achieved by the consistent use of particular visual elements to create distinction such as specific fonts, colors, and graphic elements. It is observed that a good brand identity should be uniquely identifiable, simple enough to be instantly recognizable, culturally relevant and easily reproduced. Further, the identity should use shape and colour to enhance recognition and emotional response, stand the test of time and not date itself quickly, and also have a hidden element or meaning that demands attention. Visual identity as presented by Heding et al. (2009) is an effective vehicle for demonstrating the distinctiveness of the observable features of a brand.

Brands have been classified on the basis of ownership, market area/geographic coverage, number of products and use by owners of the brand. Poudel (2012) identifies manufacturer's and distributor or middleman's brands on the basis of ownership; local, private and national brands on the bases of area/geographic coverage; family and individual brands on the bases of number of products, and primary and secondary brands on the bases of ownership. Guha (2011) classifies brands depending on the nature of their names. Descriptive brands have names that describe a key benefit or aspect associated with the products and services; person-based brands are identified by the names of owners, partners or key individuals; associative brands use fabricated words that do not normally have meaning in this context, and then uses promotion to forge them into an identity; geographic brand names use local or regional folklore to create a local feel for the product or service or use words to provide a patriotic appeal.
Geographic names are used to create an exotic image while alpha-numeric brand names involve the combination of letters and numbers to describe a product.

Geographical indicators guarantee a minimum level of organoleptic attributes to a fresh fruit and vegetable brand. Point of origin branding provides a relatively simple way for farmers to differentiate and add value to their special product attributes arising from their unique place of origin. Halprin (2006) presents eco-labeling as a way of signifying products that meet environmental and/or social standards. Eco-labeling can serve to promote and educate consumers about locally, sustainable or family farm grown foods. On his part, Pearson (2003) noted that some of the attributes sought by consumers such as taste in fresh fruits fluctuates and are hidden from them at the time of purchase and therefore, a branding is relevant for fruits to reassure consumers of their quality. Consumer satisfaction in fruits was found by Poole and Baron (1996) to be vested largely in quality attributes that cannot be identified before consumption. The consumer is tends to be unable to distinguish between products from different sources and therefore relies heavily on past experience in deciding which fruit to buy.

As regards variability of quality attributes, Pay et al. (1996) in their study noted that where a producer has a low level of control over product variability and the intrinsic cue is revealed, no label/brand will be necessary. Where there is low control over variability of quality attributes of a product, and the important intrinsic cues are hidden, the level of labelling/branding is high. Products in this category are mostly fruits. For these products, taste was the most important product attribute.

The availability of special product features and properties due to their geographical origin presents opportunities to brand the product on the basis of their geographical place of origin (Willoughby 2004 & Cook 1990). Botonaki (2006) highlights the usefulness of quality assurance schemes to the consumers in the establishment of “quality” which has been accepted as an important ingredient of marketing that offers producers a great opportunity to differentiate themselves in the market and add value to their products. Botonaki (2006) further notes that a place of origin is considered a special property and, the name of many products and the text on the packaging often refers to the region of origin as a way of helping consumers to make the connection between “regional” and/or “authentic”, “healthy”, “natural” and “exotic” products. According to Thode and Maskulka (1998), where certain crops and livestock are grown, bred or manufactured makes a huge difference to price and perceived quality. Branding FFV can also be based on product’s nutritional value. Gonzalez Diaz, et al. (2002) observes that due to the importance consumers are now attaching to nutritional and health values in foods, marketers of FFV are creating brands for these products based on these two attributes.

Aaker (2002) identified product attributes used to brand a certain product to include: high quality, durability, reliability and a premium price. He further noted the importance of using product attributes in branding since attributes are important to the purchase decisions and use experiences. In regard to benefits of product attributes, Aaker (2002) noted that customers are more comfortable talking about attributes than about less tangible benefits. Attributes reassure managers that customers will evaluate brands using a logical models whereby strong product-attribute associations potentially provide a source of advantage to a brand’s ability to respond to changing markets and also provide functional benefits and sometime emotional benefits for customers. Product related attribute can create a value proposition by offering something extra or offering something better.

On his part Kardes (2001), identified what he referred to as an extreme form of attribute preference that involved the tendency of consumers to favor persistently an attribute or a set of attributes to the exclusion of other equally relevant or even more relevant attributes. He further established that the persistent preference for attributes partially explains how consumer bond with a brand.
RESEARCH METHODOLOGY

To establish the associations among product attributes and successful branding of FFV, a descriptive cross-sectional survey design was adopted. This design facilitated the establishment and description of relationships among the key study variables (Kothari, 2004). It was cross-sectional since it was conducted once to pick the parameters of a phenomenon at a specific time with an aim of accurately capturing the characteristics of the population relating to what, where, how and when of a research topic (Cooper & Schindler, 2003).

The population of study consisted of 213 commercial farmers of FFV in Kiambu County. The population consisted of individual farmers (male & female), women groups, resident groups, cooperatives, limited liability companies and government departments growing between one and three crops in farms ranging between 5.5 to 0.125 acres. They engaged in farming activities to generate income. This study adopted stratified random sampling which allowed for making probability based confidence estimates of various parameters (Cooper & Schindler, 2003). The key target was the owners or managers of commercial FFV farms. From the target population, the farmers were stratified into seven sub-counties and a proportionate sample drawn relative to the size of each. To determine the sample size, a formula proposed by Israel (2009) was applied as follows:

\[ n = \frac{N}{1+N(e)^2} \]

where \( n \) is sample size, \( N \) is the population size, and \( e \) is the error term (0.05). Using \( N = 213 \) in the formula, the resulting sample size (n) is 140 farmers.

The data was collected using a semi-structured questionnaire through the direct interrogation method (Cooper & Schindler, 2003). The questionnaire was administered directly to the respondents through the assistance of Agricultural Extension Officers (AEO) who were recruited as research assistants due to their close association with the farmers. The extension officers offer technical advice and other related services to the farmers in their normal day to day activities.

The study variables were operationalized and measured using direct measures and 4 point rating scales ranging from 1=Not important to 4=Very important; 1=Not strong to 4=Very strong; 1=Not at all to 4=Great extent. Data was analyzed using both descriptive statistics (frequencies, percentages, mean and standard deviation) and inferential statistics (chi square, linear regression and correlation analysis). Stepwise regression analyses were used to bring out the individual effects in the form: 

\[ Y_1 = a_0 + b_1X_1 + e_1 \]

for effect of product attributes on successful branding of FFV.

FINDINGS

Data was collected from 140 farmers spread in seven sub-counties in Kiambu County. The 140 questionnaires were successfully filled and found suitable for further analysis resulting in a response rate of 100%. This compared favourably with a similar study conducted among farmers by Bremmer et al. (2002) which had a response rate of 86.5%.

The study sought to establish the reliability of the research instrument by computing the Cronbach’s alpha coefficient in regard to the elements in the study variables. The Cronbach’s alpha reliability coefficients indicated reliability level of the instrument at 0.7364. The level was above the acceptable minimum value of 0.50 (Cronbach, 1951) and above the recommended value of 0.7 (Nunnally & Bernstein, 1994). The internal consistency of the measures used was therefore considered to have adequately measured the relevant study variables.

Product Attributes and Successful Branding of Fresh Fruits and Vegetables

Product attributes attract customer’s attention and are a basis for branding practices. To establish the effect of these attributes on successful branding of FFV in Kiambu County, the respondents were asked to mention the importance of various attributes in motivating consumers’ preference for their products. The
identified attributes were: they have longer shelf life; have higher nutritional value; they have a unique place of origin; they have special taste/colour; they have medical value; use unique production method and they mature faster. Their responses on importance of the attributes in successful branding of Fresh Fruits and Vegetables are summarized in Table 1 below.

Table 1: Product Attributes and Successful Branding of Fresh Fruits and Vegetables

<table>
<thead>
<tr>
<th>Importance of Attribute</th>
<th>N</th>
<th>Mean Score</th>
<th>Standard Deviation</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>They have longer shelf life</td>
<td>133</td>
<td>3.26</td>
<td>1.09</td>
<td>33.31</td>
</tr>
<tr>
<td>Have higher nutritional value</td>
<td>132</td>
<td>2.55</td>
<td>1.09</td>
<td>42.90</td>
</tr>
<tr>
<td>Have a unique place of origin</td>
<td>126</td>
<td>2.10</td>
<td>1.20</td>
<td>56.95</td>
</tr>
<tr>
<td>They have special taste/colour</td>
<td>135</td>
<td>2.81</td>
<td>1.03</td>
<td>36.51</td>
</tr>
<tr>
<td>They have medical value</td>
<td>126</td>
<td>2.05</td>
<td>1.23</td>
<td>59.76</td>
</tr>
<tr>
<td>Use unique production method</td>
<td>134</td>
<td>2.09</td>
<td>1.22</td>
<td>58.52</td>
</tr>
<tr>
<td>They mature faster</td>
<td>129</td>
<td>2.35</td>
<td>1.12</td>
<td>48.41</td>
</tr>
<tr>
<td>Overall Average Score</td>
<td>132</td>
<td>2.459</td>
<td>1.139</td>
<td>48.051</td>
</tr>
</tbody>
</table>

Source: Primary data.

According to the results presented in Table 1, seven product attributes were mentioned as those that influenced consumer preference for FFV products. The product attributes with the highest mean scores were longer shelf life (mean score= 3.26, CV= 33.31), special taste/colour (mean score= 2.81, CV= 36.51) and higher nutritional value (mean score = 2.55, CV=42.90). The attributes rated highest in contributing to successful branding of Fresh Fruits and Vegetables are those the consumer is able to confirm such as colour/taste, shelf life and maturing period while the attributes that were more difficult to confirm such as production method, health value and place of origin were considered less important in contributing to successful branding of Fresh Fruits and Vegetables.

Summary on Performance of Commercial Farmers

The constructs used to measure performance of branded fresh fruits and vegetable products were price, volume, profitability and satisfaction achieved by the respondent farmers. Table 2 contains a summary of the individual indicators of the achieved performance.

Table 2: Summary on Performance of Branded Fresh fruits and Vegetables

<table>
<thead>
<tr>
<th>Overall summary of Performance of Farmers</th>
<th>N</th>
<th>Mean score</th>
<th>Standard Deviation</th>
<th>C.V (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price premium</td>
<td>99</td>
<td>1.25</td>
<td>0.493</td>
<td>39.41</td>
</tr>
<tr>
<td>Sales Volume</td>
<td>126</td>
<td>1.59</td>
<td>1.089</td>
<td>68.62</td>
</tr>
<tr>
<td>Profitability</td>
<td>124</td>
<td>1.51</td>
<td>0.917</td>
<td>60.68</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>140</td>
<td>2.72</td>
<td>0.619</td>
<td>22.77</td>
</tr>
<tr>
<td>Overall Average Score</td>
<td>-</td>
<td>1.77</td>
<td>0.780</td>
<td>44.11</td>
</tr>
</tbody>
</table>

Source: Primary data.

The summary results in Table 2 show low overall average levels of performance of branded Fresh Fruits and Vegetables (mean score=1.77, CV=44.11). Farmer satisfaction recorded the highest performance (mean score=2.72, CV=22.77) implying that on average, farmers were satisfied with their branding initiatives. Price premium had the lowest performance (mean score=1.25, CV=39.41) which indicated that the branded products were not earning the expected price premiums.

At an individual performance construct level, own products earned higher prices than competitor non-branded products from within and outside the county. Majority of the respondent farmers engaging in
branding practices indicated that they earned a premium price. Their numbers had increased progressively over the last three years. The results further revealed that even though in the minority, there was an increasing number of both small and large scale FFV farmers engaging in and benefiting from branding of fresh fruits and vegetables. The commercial farmers attributing profitability to branding of fresh fruits and vegetables increased progressively over the three previous years. Results on the extent to which the respondent farmers were satisfied with the achieved price, volume and profitability from their branded FFV products revealed average levels of satisfaction with the three indicators. However, volume harvested and price earned from branded FFV had slightly higher levels of satisfaction than profitability.

**Implications of the Study**
The results indicate an overall low adoption of branding of fresh fruits and vegetable products despite the availability of requisite product attributes. Longer shelf life and special taste/colour had the highest contribution to successful branding of FFV. The low levels of branding resulted in weak brand differentiation and therefore low motivation for consumers to pay a premium for any specific brands. The low prices resulted in low profitability. To attract premium prices and improve on financial performance the available attributes should be utilized to develop brands that clearly differentiate FFV products and remove them from the commodity classification. With the low adoption of branding FFV products, only a few farmers benefited from differentiating their products based on the available product attributes.

The policy makers in the agricultural sector should exploit the available FFV product attributes to encourage more farmers to brand their products. The results further revealed that when considered jointly, product attributes contributed significantly to branding of FFV. The farmers should adopted the most prominent product attribute(s) in branding their products.

**RECOMMENDATIONS**
Based on the findings of the study, the following recommendations are made to commercial FFV farmers and the government. Foremost, the study has established that even though branding influences the performance of FFV products, only a minority of the farmers utilize available product attributes to brand their FFV. It is recommended that all farmers should consider utilizing the available product attributes to differentiate their FFV products through branding. Investing in branding initiatives by FFV farmers is justified by the expected improvement in financial performance.

To achieve the aspirations in Kenya’s Vision 2030, the Ministry of Agriculture, Livestock and Fisheries has identified product branding among other initiatives as one of the targeted value addition initiatives. The findings of this study confirm that branding has significant influence on the performance of FFV. It is recommended that for the country to achieve the stated aspirations farmers should be encouraged to exploit the available product benefits to brand their FFV and achieve clear brand differentiation. The ministry should set up the requisite infrastructure and provide the facilitation and resources required to enlighten and support farmers in their branding initiatives. Qualified personnel on branding and marketing in general should be availed to enhance farmers’ branding initiatives.

This study established that product attributes can be utilized to successfully brand FFV products. The study focused only on FFV among all other agricultural products offered to the market in their fresh unprocessed form. To expand the scope of the study, future research should cover product attributes of other fresh agricultural products. The study considered seven constructs in the independent and four constructs in the dependent variable. The variables and constructs were not exhaustive and it is possible to extend the number of variables and constructs to expand the study’s scope and level of generalization.

The study population was limited to Kiambu County which has unique characteristics that favour the commercialization of the FFV sub-sector of the horticultural sector. While the findings of the study provide useful insight into the interrelationship among the study variables, the unique characteristics of the county may limit the extent of generalization to other counties. This calls for an extension of the study...
to other counties with differing social economic and climatic conditions to confirm the established relationships in the current study. The findings of the study revealed that only a small proportion of the farmers utilize the available product attributes to brand their FFV products. This limited the number of respondents who comprehensively contributed to most of the issues regarding utilization of product attributes for branding purposes. To get an in depth expose of the subject matter, a study targeting only farmers undertaking branding practices would be preferred.

The current study adopted a descriptive cross sectional survey design which involved collecting data once at a specific time. The study also relied on the data provided by the respondents to evaluate the contribution of different product attributes to successful branding of FFV products. Branding takes time to generate results. A time series design would enable the gathering of continuous data to demonstrate the application of product attributes in branding and the effect of branding throughout the life cycle of the product. A study should be designed to collect collaborative secondary data to confirm the self-reported data provided by the respondents. This would reduce the subjectivity in the provided data and strengthen the reliability of the study findings.

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ABSTRACT
Indigenous chicken production represents an important source of livelihood for the growing human population of Tharaka Nithi County. The increasing human population pressure, the need for high quality versatile foods especially protein, increasing levels of income and standards of living have created a tremendous demand for poultry products. Interventions aimed at improving productivity consequently improve incomes and knowledge of household members. Improvement programs therefore take advantage of the natural competitive advantages inherent in indigenous chicken production systems. In Tharaka-Nithi County, Agriculture Sector Development Support Program (ASDSP) is one such program. ASDSP, a SIDA funded program under the Ministry of Agriculture, Livestock and Fisheries has been working to improve the indigenous chicken value chain. Having been implemented for three years, it became necessary to evaluate the adoption of technologies by the value chain players. A survey was carried out to assess the adoption of indigenous chicken value chain technologies in Tharaka Nithi in June 2017. A random sample of 40 participants was drawn for the purpose of filling the questionnaire with 26 responses. The survey included age of respondents, education level, length of time in chicken rearing, number of chicken kept, progression in the chicken rearing reasons for increasing and disease control. The results found that that there were some farmers below 35 years of age although majority were over 46 years majority being of secondary level of education. Majority of the respondents practise indigenous chicken farming for over five years but it is also evident that many people are picking up the enterprise many having improved their flocks to over 50 birds. There has been positive progression in indigenous chicken value chain owing to adoption of innovative technologies.

Keywords: Livelihood, Innovative, Value Chain, Technologies

INTRODUCTION
Indigenous chicken production represents an important source of livelihood for the growing human population of Tharaka Nithi County. They are also a source of high quality protein and provide additional income to resource-poor small farmers, especially women (Guèye, 2009). According to FAO (2002), the increasing human population pressure, the need for high quality versatile foods especially protein, increasing levels of income and standards of living have created a tremendous demand for poultry products. According to Perry et al (2002) and Moreki et al (2010) chickens are the most widely kept livestock species in the world and also the most abundant. In addition, the Kenya economic report (KPPRA, 2010) identified poultry especially the indigenous chicken as a leading livestock enterprise that can contribute most towards attainment of the Sustainable Development Goals (SDGs). Indigenous chickens play an important role in income generation and food production. They are widely distributed in rural and peri-urban areas (Thornton et al. Moreki et al., 2010). They make up to 70 % of all chicken kept in Africa (FAO, 1986). About 90% of the small-scale farmers in Kenya rear indigenous poultry, majority of which are indigenous chicken (Gichohi and Maina, 1992). Poultry sub-sector creates employment and promotes overall economic development. Indigenous chicken have been used in cultural activities such as traditional medicine and for various rites (King’ori, 2004). In 2013 indigenous chicken comprised of over 90% of all the poultry kept in Tharaka Nithi County.

Interventions aimed at improving productivity consequently improve incomes and knowledge of household members. Improvement programs therefore take advantage of the natural competitive advantages inherent in indigenous chicken production systems. In Tharaka Nithi County, Agriculture Sector Development Support Program (ASDSP) is one such program. ASDSP, a SIDA funded program under the Ministry of Agriculture, Livestock and Fisheries has been working to improve the indigenous
chicken value chain. The poultry value chain was identified by stakeholders using the value chain prioritization tool matrix. This value chain was prioritized due its appeal to all gender, ages, ecological zones and across all economic statuses. Having been implemented for three years, it became necessary to evaluate the adoption of technologies by the value chain players.

**MATERIALS AND METHODS**
A survey was carried out to assess the adoption of indigenous chicken value chain technologies in Tharaka Nithi in June 2017. A pre-tested questionnaire was used to collect data from various indigenous chicken value chain players. The target population was those who participated in the ASDSP indigenous value chain supported activities such as technical trainings and demonstrations. The main criterion for inclusion was that they participated in most of the activities during the implementation period. A random sample of 40 participants was drawn for the purpose of filling the questionnaire. A total of 26 responses were received as some of the contacts could not be reached due to the limited time for the exercise. The questionnaires contained both structured and unstructured questions. Since the study was descriptive in nature, data was analysed using descriptive statistics like frequencies and tables. Information considered in this paper includes age of respondents, education level, length of time in chicken rearing, number of chicken kept, progression in the chicken rearing reasons for increasing and disease control.

**RESULTS AND DISCUSSION**

**General information**
The general information asked to the respondents include their names, there location, age bracket and level of education. Only the age and level of education are considered in this paper.

**Age of respondents**
The respondents were required to indicate their age bracket. Their age brackets are as shown below.

![Number of respondent](image)

Figure 1: Age of respondents

Although according to UNDP (n.d) the average age of a farmer is 60 years, this preposition is likely to change. It is evident from the survey that there were some farmers below 35 years of age although majority were over 46 years.
Education level

From the data it was found that 46% of the respondents had secondary level of education, 31% primary level and 23% have college level of education. Education level affects adoption in that the level of education may affect the rate of understanding the technologies delivered during technical trainings.

Length of time in rearing indigenous chicken
To find out whether any respondents had adopted indigenous chicken rearing within the period that ASDSP has been working to improve the indigenous chicken value chain, they were asked for how long they had been rearing indigenous chicken. The table below shows the period of time that the various respondents have been engaged in chicken rearing.

Table 1: Length of time in rearing indigenous chicken

<table>
<thead>
<tr>
<th>Number of years</th>
<th>Number of respondents</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 years</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>3-5 years</td>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td>More than 5 years</td>
<td>10</td>
<td>38</td>
</tr>
</tbody>
</table>

It was evident that majority of the respondents have been practising indigenous chicken farming for over five years. However it is also evident that many people are picking up the enterprise, implying that it is a profitable enterprise and also due to the continuous campaigns done through ASDSP.

Introduction to indigenous chicken rearing
To find out how the respondents got into rearing the indigenous chicken, they were asked who had introduced them to the same. The figure below shows their responses. It was found that most of the respondents practiced indigenous chicken farming out of their own individual motivation. However it was clear that agriculture extension still plays a big role in introducing enterprises to the community. It is also evident that research has direct link with the communities although to a small extent. It was also found that neighbour influence was low although farmer- to- farmer extension is termed as one of the most effective extension methodologies (Franzel et al 2015).
Number of chicken per household
It was also important to analyse if the number of indigenous chicken kept had changed. The table below shows the average number of birds kept when the respondents started keeping birds and the number during the time of survey.

**Table 2: Number of chicken per household**

<table>
<thead>
<tr>
<th>Average number of birds kept per household</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>At start of rearing</td>
<td>22.35</td>
</tr>
<tr>
<td>As at current</td>
<td>113.92</td>
</tr>
</tbody>
</table>

It was found that all those involved in the indigenous chicken value chain had increased the number of chicken kept. The number of birds kept by the respondents had more than quadrupled from the time they started the business, which ranged from less than one year to over ten years.

Progression in the chicken business
Respondents were asked to rate their progression in the number of birds kept with a view to find out if there was an increase in the number of birds kept. The graph below shows their responses.

The findings revealed that all the respondents have continually increased the number of birds they keep. The majority had between 10 and fifty birds when they started but currently majority have over 50 birds. In addition no respondent had less than 10 birds during the interview. This can be attributed to the acquisition of better management skills leading to reduced losses. It can also be attributed to the ever increasing demand for indigenous chicken.

Reasons for increased number of chicken per household
The respondents were asked to respond to why they had increased the number of their chicken. The respondents were free to provide more than one reason. The table below shows the reasons given and the number of respondents for each.
Proceedings of the Fourth International Research Conference

![Progression in Chicken business](image)

Figure 4: Progression in the chicken business

<table>
<thead>
<tr>
<th>Reason for increasing number of chicken</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved management &amp; disease control</td>
<td>20</td>
<td>77</td>
</tr>
<tr>
<td>Running as a business</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Biological incubation</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Predator control</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Home made ration</td>
<td>8</td>
<td>31</td>
</tr>
<tr>
<td>High demand in market</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Brooding</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3: Reasons for increased number of chicken per household

The main reason attributed to the increased indigenous chicken numbers is the improved management and disease control skills. 31% of the respondents also indicated the ability to make home-made chicken rations as having contributed greatly to increasing the number of chicken reared. It is evident therefore

**Number of vaccinations per year on farms**

Disease control is a very critical aspect in the management of poultry and especially indigenous chicken. Some diseases such as new castle can only be controlled by routine vaccination. To evaluate the adoption of routine vaccination in production of indigenous chicken the respondents were asked the number of times they vaccinate in a year. Over 80% of the respondent indicated that they vaccinate at least twice a year for Newcastle disease.

**CONCLUSION**

The survey assessed the adoption of indigenous chicken value chain technologies in Tharaka Nithi in June 2017. A random sample of 40 participants was drawn for the purpose of filling the questionnaire with 26 responses. The survey included age of respondents, education level, length of time in chicken rearing, number of chicken kept, progression in the chicken rearing reasons for increasing and disease control. The results found that that there were some farmers below 35 years of age although majority were over 46 years majority being of secondary level of education. Majority of the respondents have been practising indigenous chicken farming for over five years but it is also evident that many people are picking up the enterprise many having improved their flocks to over 50 birds. The study concluded that there has been positive progression in the indigenous chicken value chain owing to adoption of innovative technologies as promoted by ASDSP.
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FAO (2002). World agriculture towards 2015/2030. Rome, Italy
Undp n.d cultivating youth entrepreneurship through agribusiness available www.ke.undp.org accessed 20/9/2017
CONTRIBUTION OF PLASTIC TUBE DIGESTER (PTD) INNOVATIONS IN CLIMATE CHANGE MITIGATION AND IMPROVED RURAL LIVELIHOODS: CASE STUDY OF CENTRAL KENYA

Matiri, F. M. and Kiruiro, E.M.
KALRO-EMBU, P. O. Box 27-60100, EMBU
Email: francismatiri@yahoo.com or Francis.matiri@kalro.org, emkiruiro@yahoo.com

ABSTRACT
Most of the rural communities (over 80%) in the country highly depend on wood-fuel, charcoal and paraffin as the main sources of energy for cooking and lighting, with consequences of deforestation and water catchments degradation. Massive carbon dioxide (CO$_2$) production, due to tree burning, is associated with climate change world over. It is necessity to find promising innovations that contribute to countering these negative processes while improving household livelihoods. Plastic Tube Digester (PTD) Biogas technology was introduced among small-scale dairy farmers towards this effort. The main aim of this study was therefore to assess the socio-economic and environmental impacts of PTD, challenges to adoption and suggest way forward. Data was collected using formal survey, group and key informant interviews, and analysed by use of SPSS and qualitative tools. Results indicated that most households had small dairy herd sizes (an average of three animals) under zero grazing and low level of biogas awareness (20%). PTD adoption also reduced energy costs and labour requirement, and deforestation in all the households. There were improved ecosystems (63%), improved cooking environment (90%) and increased crop productivity (80%). The main challenge to improved adoption of PTD was inadequate skilled manpower to build farmers’ capacities to adopt and install the PTD technology. Hence a need to build the capacity of local community members to accelerate capacity building, installations and information sharing at the community level for improved PTD adoption.

Keywords: Adoption, change, climate, livelihoods, innovation, PTD.

INTRODUCTION
Over 80% of the rural communities in Kenya rely on wood-fuel, charcoal and paraffin as the main sources of energy for cooking and lighting, with over-reliance on the first two, causing negative environmental impacts (Minae and Nyamai, 1988, Kasson et al; 2004). There is great justification to seek alternative energy technologies/innovations to reduce these effects. Biogas, which is produced from anaerobic digestion of organic wastes, is considered as an appropriate renewable energy source that can contribute towards this end. Wood-fuel can be reduced by up to 60% by adopting PTD technology (Lekule, 1996).

Justification
The plastic-tube digesters were introduced in Kenya in early –mid 199s as a low-cost option to the conventional digesters (Karanja and Kiruiro, 2003). However, adoption was generally low initially until 2005 when it was re-introduced by the Kenya Agricultural Research Institute’s -Embu. Since then, upscaling has been on going through individual initiatives and some support from outside organisations. The adoption of the technology had increased to over 300 units in Central Kenya by 2007 (Kiruiro and Matiri, 2007). (KARI, 2006) showed that one Guernsey animal is able to supply adequate dung for one ten M PTD. In addition, conventional and PTD digester would cost Ksh.70, 000 and Ksh.10, 000 to install (Kiruiro and Matiri, 2009). This study was conducted in 2009 to assess socio-economic and environmental impacts of adopting the PTD technology and the challenges likely to affect adoption and scaling up.

Objectives
1. To assess the potential socio-economic and environmental impacts of PTD technologies
2. Identify challenges to adoption of PTDs.
3. Propose possible interventions/recommendations that would improve adoption of PTD technology.
METHODOLOGY
A sample frame of 300 households that have adopted PTD technology was developed with the assistance of the initial 15 adopters and key informants in the region. This was followed by a purposeful and random sampling to come up with a sample size of 60 households. Data was collected by use of a refined structured questionnaire with the selected 60 households. Data was collected through focused group interviews, secondary data review, participant observation and key informant interviews. Quantitative and qualitative data was analysed by use of SPSS software and qualitative tools respectively. Data was then analysed, report written and shared among the key stakeholders.

RESULTS
Socio-Economic Characteristics of the Households
The results showed that household sizes ranged between three to six members with an average of four, farming being the main source of income (90%). Level of education varied from primary (15%), secondary (70%) and post-secondary (15%). No clear relationship between income and level of education was identified. These results are as shown in Table one.

<table>
<thead>
<tr>
<th>Range in household sizes (persons)</th>
<th>(%): N=60</th>
<th>Level of Education</th>
<th>(%): N=60</th>
<th>Income Sources</th>
<th>(%): N=60</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>6 (10%)</td>
<td>Primary level</td>
<td>9 (15%)</td>
<td>Off-farm only</td>
<td>0 (0)</td>
</tr>
<tr>
<td>4-5</td>
<td>48 (80%)</td>
<td>Secondary level</td>
<td>42 (70%)</td>
<td>On-farm only</td>
<td>48 (80%)</td>
</tr>
<tr>
<td>Over 6</td>
<td>5 (8.9)</td>
<td>Post-secondary</td>
<td>9 (15%)</td>
<td>Both off-farm</td>
<td>12 (20%)</td>
</tr>
</tbody>
</table>

Land and herd sizes
Land sizes ranged between one and four acres, majority (65%) having one and half acres and below. Dairy is the main livestock, zero grazed, with an average of three animals per household.

Sources of Dung Utilized in PTD and Household Decision Making
Majority of households (56) utilise dung for PTD from on-farm while only four at times get dung from the neighbouring slaughterhouse. Results showed that the decision to install PTD was jointly done, despite men and women having different influencing factors, as shown in Table two.

Table 2: Reasons for considering installation of PTD by gender

<table>
<thead>
<tr>
<th>Most important consideration</th>
<th>Men: N =34</th>
<th>Percent (%)</th>
<th>Gender Women: N = 49</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced costs</td>
<td>34</td>
<td>100</td>
<td>29</td>
<td>100</td>
</tr>
<tr>
<td>Reduced tree cutting</td>
<td>26</td>
<td>74</td>
<td>14</td>
<td>29</td>
</tr>
<tr>
<td>Reduced labour</td>
<td>16</td>
<td>47</td>
<td>49</td>
<td>100</td>
</tr>
<tr>
<td>Increased cooking efficiency</td>
<td>12</td>
<td>35</td>
<td>44</td>
<td>90</td>
</tr>
<tr>
<td>Social satisfaction</td>
<td>10</td>
<td>29</td>
<td>21</td>
<td>43</td>
</tr>
</tbody>
</table>

NB: Gender responses were captured through group interviews

Biogas Awareness and Sources of Information on PTD
Only 10% of the initial 15 adopters were aware of conventional biogas and none about PTD. Main sources of biogas were as shown in Table three.
Table 3: Main sources of information on PTDs

<table>
<thead>
<tr>
<th>Source of information</th>
<th>No. of respondents N = 60</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KARI</td>
<td>40</td>
<td>(67%)</td>
</tr>
<tr>
<td>ASK demonstrations*</td>
<td>8</td>
<td>(18%)</td>
</tr>
<tr>
<td>Other farmers</td>
<td>2</td>
<td>(3%)</td>
</tr>
<tr>
<td>Brochures*</td>
<td>6</td>
<td>(9%)</td>
</tr>
<tr>
<td>Radio*</td>
<td>4</td>
<td>(4%)</td>
</tr>
</tbody>
</table>

* Predominantly done by KARI

Socio-Economic Impacts of PTDs

The results indicate that PTD technology had relatively high socio-economic impacts in all the indicators that were identified in a participatory process. The main socio-economic impact indicators that were identified and respondents that indicated they had impact at the household level are shown in Table four.

Table 4: Socio-economic impacts of PTD technology

<table>
<thead>
<tr>
<th>Indicator</th>
<th>No. of Households N = 60</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced costs/increased savings</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Increased crop productivity</td>
<td>48</td>
<td>80</td>
</tr>
<tr>
<td>Increased dairy productivity</td>
<td>40</td>
<td>62</td>
</tr>
<tr>
<td>Reduced workload/labour</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Social satisfaction and harmony</td>
<td>31</td>
<td>52</td>
</tr>
</tbody>
</table>

Environmental Impacts of PTDs

The results also showed that PTDs had environmental benefits/impacts. The main environmental impact indicators that were identified in a participatory process and the respondents that indicated that they have impacts at the household level are as shown in Table five.

Table 5: Environmental impacts of PTD technology

<table>
<thead>
<tr>
<th>Indicator</th>
<th>No. of Households N = 60</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced deforestation</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Improved cooking environment</td>
<td>54</td>
<td>90</td>
</tr>
<tr>
<td>Reduced respiratory discomforts</td>
<td>38</td>
<td>63</td>
</tr>
<tr>
<td>Improved ecosystem</td>
<td>38</td>
<td>63</td>
</tr>
</tbody>
</table>

Ranking of Socio-Economic and Environmental Impacts of PTD Technology by Gender

In order to capture whether there are perceived differences between gender on the importance of the identified socio-economic and environmental impacts, men and women did pairwise ranking of the socio-economic and environmental impacts in Tables four and five separately. According to the ranking results, men ranked reduced costs, reduced deforestation and reduced workload, while women ranked reduced workload, reduced costs and improved cooking environment in that order as the most important impacts due to PTD adoption. Through further probing from the group, it was explained that the ranking were different between men and women due to gender importance of the impacts. Men are more concerned on cost reduction because they are very influential on how finances/resources are allocated in the household and are the ones who buy fuel-wood and LPG gas when bought. On the other hand women were more concerned on reduced labour requirements because they used to go for long distances to fetch for firewood before installation of the PTD. In addition, men are more concerned about reduced deforestation compared to women. This is because men are the ones who plant the trees that the household depends on as a source of household energy and when saved, it becomes an important asset that can be sold when the household is in need of urgent cash. Improved crop and dairy production due to adoption of PTD was
associated with the better quality of slurry compared to the ordinary manure. Both men and women ranked improved crop production to be an important impact due to PTD adoption, compared to its impact on improved dairy production. This can be explained by the fact that despite the fact that the slurry comes from livestock, most of it goes to crop production other than fodder like Napier grass. However, there was a clear perception by both men and women that adoption of PTD reduces deforestation, hence mitigating against climate change. The results of the impact indicators’ ranking by men and women were as shown in Table six.

Table 6: Ranked PTD impacts by gender

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Rank by Men</th>
<th>Rank by Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced costs</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Increased crop production</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Increased dairy production</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Reduced workload</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Reduced deforestation</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Improved cooking environment</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Challenges to Adoption of PTD Technology

Results indicate that the demand of PTDs has been increasing tremendously since KARI – Embu started promoting it in 2005. The results indicate that the adoption of PTDs may have increased from the initial 15 in 2005 to over 600 units by the time of this study (September 2009). The projections of the number of PTDs in the region are as shown in table seven, based on the information from the main institutions (key informants) that are involved in training and installations of PTDs.

Table 7: Estimated number of PTDs in the region.

<table>
<thead>
<tr>
<th>Institution involved in training/installation</th>
<th>Estimated installation/year between 2005 – 2009 (5 yrs)</th>
<th>Estimated total installations/institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>KARI-Embu</td>
<td>80</td>
<td>400</td>
</tr>
<tr>
<td>Catholic Diocese</td>
<td>30</td>
<td>150</td>
</tr>
<tr>
<td>Kirinyaga Ecosystem Project</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td><strong>Estimated PTD Installations</strong></td>
<td></td>
<td><strong>600</strong></td>
</tr>
</tbody>
</table>

These estimations are based on the records from the three organisations and interviews with key informants. However, there are farmers that have installed PTDs through the assistance from other farmers. Hence, the number of PTDs in the region is higher than 600, implying the level of adoption is high. In addition, results indicate that KARI-Embu scientist has installed more PTDs outside the region including Transmara (1), Kitale (6), Nakuru (2), Kiambu (2) and Nyandarua (10) between May 2009 and February 2010, an indication that PTD technology’s demand is spreading outside the region.

Despite this, the results indicate that the technology faces a number of challenges for enhanced adoption. Through group discussions and key informant interviews, the key challenges that were identified included:

1. Lack of adequate manpower to train and install the required PTDs – as the results clearly shows, most of the farmers willing to utilise the technology depend on KARI scientists
2. Lack of technical information on the associated dung requirement, installation, costs, and expected benefits – there is a general perception that PTD requires a lot of dung, has high initial costs with little accruing benefits because few farmers have this technical information.
3. Lack of information sharing among farmers – it was observed that less than 10% of the farmers neighbouring those that have installed PTD have ever enquired about it from their neighbours.
4. **Donor dependency syndrome** – After demonstrations on PTD, some farmers expected free installations.

5. **Perceived short lifespan of the digester** – Three of the first 15 installations lasted for less than two years due to the plastic paper wearing out/getting torn.

6. **Perceived high cost of PTD installation** – Some farmers’ felt that cost of installing is high but without any information to that effect

**DISCUSSION**

The results show that average land size of most of the adopters is one and half acres with a herd size of three mature animals. Taking this to be a representative sample of the region and the estimated dung requirement per unit PTD, it implies that majority of the farmers in the region have the potential to utilise PTD technology. The level of education may influence adoption of PTD since majority of the adopters have at least secondary level of education. This may be due to their ability to grasp issues and being innovative. Although men and women have different reasons to adopt PTD technology, it is clear that their interests are not conflicting but complimentary and hence augmenting adoption of the technology. Consultative decision-making between wife and husband may also be an important factor in improving adoption once the households have the appropriate information relating to PTD and there is available manpower to train and install the technology.

PTD technology has enormous socio-economic and environmental impacts at both household and community levels. This is due to the fact that it reduces energy costs, labour requirement, increases household productivity and reduces deforestation among others. There are also challenges that may impend accelerated adoption of PTD technology with lack of manpower to train and install the PTDs where and when needed.

**CONCLUSION**

It is evident that PTD Biogas technology has the potential to highly contribute to socio-economic improvement of the households in the region and beyond. It also has the potential to mitigate against the negative processes of climate change. Reduced energy costs provide the household with resources that could be invested within or off-farm and hence increasing rural livelihoods and food security. Reduced deforestation counters CO₂ emissions, hence mitigating against global warming and climate change. In addition, resources saved from energy budget can also be invested in environmental conservation and social infrastructures like education and health, hence contributing to well being of the community and society at large. There is also need to develop mechanisms that would accelerate adoption of this technology by way of reducing the existing impediments.

**RECOMMENDATIONS**

The most impeccable limiting factor to adoption of PTD is lack of manpower for capacity building and installation of the PTDs when required. This is due to the fact that there is over reliance on only one KARI scientist in the region and most other parts of the country for both training and installation. Therefore, there is need to build capacities of other actors (NGOs, extension) as well as some local community members that would be the catalysts in training others, disseminating the appropriate information and providing feedback to the experts. The community also need to become more pro-active and have collective action in training and installation of the technology to accelerate dissemination and adoption. Farmers’ networks could also play an important role to accelerate accessing PTD information to enhance and sustain adoption. Further research need to be done to identify a plastic tube that would have a longer lifespan and hence encourage adoption. Donor support for those who have the expertise to build capacities (scientists, extension and skilled community members) is necessary for them to respond appropriately when needed and impart the required skills to others.
ACKNOWLEDGEMENT
We wish to acknowledge with a lot of gratitude the financial and logistical support by a team of Norwegian Environmentalists led by Mr. Gunnar Ronning that made the accomplishment of this survey possible. Special thanks goes to Mr. E.M. Kiruiro (Co-author) for tireless efforts he has put in capacity building and upscaling of PTD technology in the community within the region and beyond as well as technical support he offered during the study. We also thank Centre Director, KARI-Embu for logistical support and other facilitations that made accomplishment of this work possible. We also thank all the farmers and other stakeholders (key informants) that spared there precious time to provide us with this information and without their willingness, this work would not have succeeded.

REFERENCES
EFFECTS OF FARMYARD MANURE AND LEAF HARVESTING FREQUENCY ON KALE VEGETABLE LEAF YIELD

Gathungu, G. K., Omukoko, C. A., Sioma, M and Isutsa, D. K.
Department of Plant Sciences, Chuka University, P. O. Box 109-60400, Chuka
E-mail: gkgathungu@yahoo.com

ABSTRACT
Kale is the most consumed green leafy vegetable in Kenya as it is easy to prepare, is affordable to the consumer and it can be grown in every agro-ecological zone. Low kale productivity in Kenya occurs due to declining soil fertility and use of inorganic fertilizer sources. Farmyard manure (FYM) can be used as an alternative to commercial fertilizers to provide mineral nutrients important in kale growth. However, there exists no clear recommendations on the rate of FYM and leaf harvesting frequency to apply on kale vegetables and farmers tend to apply either too little or too much in the small plots or storeyed gardens used. Due to importance of kales in Kenyan households for nutrition, food and income security, a study was conducted to determine the effects of the rate of FYM application and leaf harvesting frequency on leaf number and yield. The treatments included four FYM rates [zero (0 kg/ha), low (7.5 t/ha), medium (15 t/ha), and high (22.5 t/ha)], and two leaf harvesting frequencies (one and twice every four weeks) with each treatment combination replicated three times. The FYM was applied and incorporated into the soil before planting. Data collected included number of leaves and leaf yield. The data collected in the field trial was subjected to analysis of variance and significantly different means separated using the Tukey’s Studentized Range Test. The analysis of variance showed there were significant differences \( P = 0.05 \) in number of leaves and leaf yield per plant after application of different levels of farmyard manure (M) and harvesting frequency (H). The number of leaves harvested progressively increased with the days after planting (DAP) from 36 DAP to 120DAP in all treatments. Harvesting once after four weeks (H2) recorded more number of leaves per harvest. Number of leaves increased from 1.67 and 3.67 to 4.92 and 7.58 at 64 DAP; 2.5 and 5.5 to 5.67 and 10.92 at 92 DAP; 3.3 and 7.58 to 9.17 and 17.75 at 120 DAP and 0.5 and 2.75 to 6.25 at 148 DAP with zero manure (0 kg/ha) [M1] compared with application of high (22.5 t/ha) [M4] farmyard manure both with harvesting twice (H1) and once (H2) every four weeks in trial I respectively. Leaf weight per plant increased from 0.32 gm and 0.44 gm and 0.99 and 1.38 gm at 36 DAP to 28.03 and 39.28 g and 42.18 and 59.06 g at 92 DAP to 43.98 and 61.57 g and 83.13 and 116.38 g at 120 DAP with application of zero farmyard manure and when harvesting twice (H1) and once (H2) in every four weeks both in trials I and II respectively. Overall harvesting once compared to twice weeks every four weeks resulted in more leaves and greater leaf weight regardless of the rate of manure applied. Farmers should be advised to apply farmyard manure and avoid frequent harvesting to improve the number of leaves and kale leaf yields.

Keywords: Kales, farmyard manure, harvesting frequency, leaf number, leaf yield

INTRODUCTION
Horticulture production especially of vegetables is an important source of income for the smallholders in most parts of Kenya. Vegetables play an important role in human nutrition, providing vitamins, micronutrients, proteins, fibre and sugars. Their role in nutrition is especially critical in rural communities, where access to alternative sources of these nutritional elements is limited. Vegetables are grown by over 90 per cent of Kenyan small-scale farmers with kale \((Brassica oleracea\ var. Acephala\ D.C.)\) being the most important by area and production (BDA, 2010). In Kenya, kale is a popular and nutritious leaf vegetable eaten by many families (Agfax, 2006). Most farmers would prefer a kale crop that yields more and stays longer in the field for sustained vegetable production both for purposes of food security and income generation.

Kales are frequently being used in most of the households to complement other food sources such as Ugali or Githeri. Kale is the most consumed green leafy vegetable in Kenya as it is easy to prepare and affordable to the consumer, it can be grown in every agro-ecological zone and has a preferential taste.
when compared to cabbage and many exotic vegetables (Mogeni, 2011). Kales helps feed the community and diversify its diet while providing an opportunity to generate extra income. The yield per unit area of kales production depends on the quantity and the size (quality) of the individual leaves which are dependent on the nutrition and the harvesting frequency. With proper crop husbandry practices that improve on the longevity of the kales in kitchen garden, farmers can make considerable profits. Though kales are the most important vegetable in Kenya its production is hampered by low soil fertility particularly Nitrogen and Phosphorus (Abukutsa and Onyango, 2002). Application of farmyard manure which is a source of organic matter can be one of the best practices that can lead to increased kale productivity per unit area. The organic matter improves the physical, chemical and biological condition of soil which provides binding action to soil aggregates, increases water holding capacity and improve buffering capacity of soils (Kanwar et al., 2017).

Low productivity and cropping duration (longevity) of most kales kitchen gardens has been a problem for farmers due to lack of information on the importance of crop nutrition and harvesting intervals. Most of the farmers plant kales either without or with little farmyard manure, and frequently harvest the crop without consideration of the effects of these practices on the long-term yield and longevity of the kales kitchen garden. Probably these improper practices may accelerate the aging of the crop resulting to early flowering and production of relatively small leaves hence a poor yielding kitchen garden. There is need therefore need to test the effects of application of farmyard manure so as to increase yield and the ability of kales in kitchen garden to resist or withstand insect pest damage owing to improved health. This study was conducted to increase kitchen garden kale productivity and longevity through integration of mixed (cattle manure + beddings) farmyard manure application and proper harvesting frequencies.

MATERIALS AND METHODS

Experimental Site and Soil Characteristics
The experiment was conducted in Chuka University Field Research Farm at Ndagani and the soil nutrient contents was determined before and after planting, and rainfall and temperature patterns obtained from the nearest weather station.

Treatments, Experimental Layout and Design
The treatments included integration of different mixed (cattle manure + beddings) farmyard manure application rates and harvesting frequencies (duration). The four rates of FYM included zero (0 kg/ha) [M1], low (7.5 t/ha) [M2], medium (15 t/ha) [M3], and high (22.5 t/ha) [M4]. Two harvesting frequencies, were once (H2) and twice (H1) per 4 week duration throughout the kale growth period. This resulted to a total of eight treatments (M1H1, M1H2, M2H1, M2H2, M3H1, M3H2, M4H1 and M4H2). The experiment was laid out in a randomized complete block design (RCBD) in a split plot arrangement, where organic manure rates were assigned to main plots and harvesting frequency to subplots. The treatments were replicated three times and the experiment was repeated once in plots measuring 1.8 m x 2.4 m. Paths between main plots and subplots was 1 m wide, while those between sub-subplots was 0.7 m wide. Each plot had 4 rows each with 6 kale plants, giving 24 plants per treatment. The first and last rows including the first and last plants per row formed the guard rows. Data was taken on the 4 middle plants.

Plant Material, Manure and Planting
Certified kale seed variety thousand headed was sown in a nursery and after one month seedlings obtained were planted at a spacing of 0.3m x 0.6m within and between rows, respectively, giving a kale population density of 55,555 per hectare or 24 per plot. Mixed (cattle manure + beddings) farmyard manure from the livestock unit within the Chuka University farm was used as the source of organic manure. A standard application of 200 kg DAP was done across all treatments to act as starter nitrogen and phosphorus source as a single dose at planting.
Crop Maintenance in the Field
Routine field maintenance practices such as weeding and spraying against diseases and insect pests was done using appropriate fungicides and insecticides when necessary. Weeding was done any time weeds were visible.

Data Collection
Three soil samples were collected from the top 0 cm - 30 cm of the soil profile using a soil auger and analyzed for available soil nutrients especially total N and P before planting and at the end of the kale cropping duration to determine nutrient dynamics. Total nitrogen was determined using the Kjeldahl method (Bremner and Mulvaney, 1982). Olsen and Sommers (1982) method was used to determine P content. Plant data was taken on number of leaves and leaf yield per harvesting.

Number of leaves per plant: The leaves harvested were placed separately on laboratory benches and counted to facilitate determination of their number per individual plant within the treatment.

Leaf weight: The weight of the leaves harvested was determined every harvest at 36, 50, 64, 78, 92, 106, 120, 148, 162, 176 and 198 Days after planting (DAP) using a weighing scale. The total leaf yield was determined by addition of individual weights at all harvests which was later transformed to yield in t/ha.

Data Analysis
Data collected values were subjected to analysis of variance using the SAS system for windows V8 1999-2001 by SAS Institute Inc., Cary, NC, USA (SAS, 2011) and significantly different means separated using Tukey’s Studentized Range Test at $P \leq 0.05$.

RESULTS
Soil analysis
Before planting eight soil samples were collected from the top soil (0-15cm) and four of subsoil (15-30cm). The samples were analysed at KALRO Kabete laboratories in May 2016. The results showed that most of the nutrient status had improved compared to when samples were collected during Trial I (Table 1). On the subsoil phosphorus had improved from 2.32 to 10.9%, Organic matter from 4.83 to 5.07%, CEC from 12.4 to 17.5% (Table 2). This may indicate that application of farmyard manure improved the status of the soil. The subsoil has low contents of most nutrients than the topsoil (Table 3). The subsoil had very low potassium that can probably be corrected by application of FYM

Table 2: Results of farmyard manure analysis in trials I and II

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Trial I</th>
<th>Trial II</th>
<th>Guide low</th>
<th>Guide high</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>8.04</td>
<td>8.26</td>
<td>6.00</td>
<td>8.50</td>
</tr>
<tr>
<td>EC (Salts)</td>
<td>mS/cm</td>
<td>8.32</td>
<td>5.79</td>
<td>0.75</td>
<td>1.20</td>
</tr>
<tr>
<td>Dry matter</td>
<td>%</td>
<td>88.2</td>
<td>89.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>%</td>
<td>24.1</td>
<td>22.3</td>
<td>13.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>%</td>
<td>1.73</td>
<td>1.73</td>
<td>0.80</td>
<td>1.50</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>%</td>
<td>0.46</td>
<td>0.29</td>
<td>0.20</td>
<td>0.75</td>
</tr>
<tr>
<td>Potassium</td>
<td>%</td>
<td>1.59</td>
<td>1.11</td>
<td>0.40</td>
<td>2.00</td>
</tr>
<tr>
<td>Calcium</td>
<td>%</td>
<td>2.01</td>
<td>1.30</td>
<td>0.60</td>
<td>1.50</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>0.60</td>
<td>0.48</td>
<td>0.20</td>
<td>0.80</td>
</tr>
<tr>
<td>Sulphur</td>
<td>%</td>
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<td>0.25</td>
<td>0.20</td>
<td>0.50</td>
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<td>Manganese</td>
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<td>2750</td>
<td>200</td>
<td>800</td>
</tr>
<tr>
<td>Iron</td>
<td>ppm</td>
<td>36600</td>
<td>24600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>ppm</td>
<td>263</td>
<td>157</td>
<td>40.0</td>
<td>300</td>
</tr>
<tr>
<td>Copper</td>
<td>ppm</td>
<td>49.0</td>
<td>17.1</td>
<td>8.00</td>
<td>400</td>
</tr>
<tr>
<td>Boron</td>
<td>ppm</td>
<td>60.9</td>
<td>60.3</td>
<td>20.0</td>
<td>140</td>
</tr>
<tr>
<td>Sodium</td>
<td>ppm</td>
<td>366</td>
<td>477</td>
<td>&lt;3000</td>
<td></td>
</tr>
<tr>
<td>C/N ratio</td>
<td></td>
<td>13.9</td>
<td>12.9</td>
<td>10.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>
Table 3: Results of top soil analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Trial I</th>
<th>Trial II</th>
<th>Guide low</th>
<th>Guide high</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (H2O)</td>
<td></td>
<td>5.63</td>
<td>4.99</td>
<td>6.00</td>
<td>7.00</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>ppm</td>
<td>2.32</td>
<td>10.9</td>
<td>40.0</td>
<td>100</td>
</tr>
<tr>
<td>Potassium</td>
<td>ppm</td>
<td>103</td>
<td>213</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>ppm</td>
<td>1250</td>
<td>1120</td>
<td>1480</td>
<td>1730</td>
</tr>
<tr>
<td>Magnesium</td>
<td>ppm</td>
<td>206</td>
<td>233</td>
<td>148</td>
<td>267</td>
</tr>
<tr>
<td>*Sodium</td>
<td>ppm</td>
<td>32.7</td>
<td>46.5</td>
<td>&lt; 142</td>
<td></td>
</tr>
<tr>
<td>*Organic Matter</td>
<td>%</td>
<td>4.83</td>
<td>5.07</td>
<td>3.00</td>
<td>8.00</td>
</tr>
<tr>
<td>*Nitrogen</td>
<td>%</td>
<td>0.24</td>
<td>0.23</td>
<td>0.20</td>
<td>0.50</td>
</tr>
<tr>
<td>*C.E.C</td>
<td>meq/100g</td>
<td>12.4</td>
<td>17.5</td>
<td>15.0</td>
<td>30.0</td>
</tr>
</tbody>
</table>

PERCENTAGES AND RATIOS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>%</th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td></td>
<td>50.6</td>
<td>32.0</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td>13.9</td>
<td>11.1</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
<td>2.14</td>
<td>3.12</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Sodium % (ESP)</td>
<td>%</td>
<td>1.15</td>
<td>1.16</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Other Bases %</td>
<td>%</td>
<td>6.14</td>
<td>7.42</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Hydrogen %</td>
<td>%</td>
<td>26.1</td>
<td>45.2</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Ca:Mg Ratio</td>
<td>%</td>
<td>3.64</td>
<td>2.88</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 4: Results of sub soil analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Trial I</th>
<th>Trial II</th>
<th>Guide low</th>
<th>Guide high</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (H2O)</td>
<td></td>
<td>5.77</td>
<td>5.58</td>
<td>6.00</td>
<td>7.00</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>ppm</td>
<td>0.48</td>
<td>0.25</td>
<td>40.0</td>
<td>100</td>
</tr>
<tr>
<td>Potassium</td>
<td>ppm</td>
<td>46.2</td>
<td>82.2</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>ppm</td>
<td>1210</td>
<td>1380</td>
<td>1310</td>
<td>1530</td>
</tr>
<tr>
<td>Magnesium</td>
<td>ppm</td>
<td>197</td>
<td>238</td>
<td>131</td>
<td>237</td>
</tr>
<tr>
<td>*Sodium</td>
<td>ppm</td>
<td>24.2</td>
<td>34.5</td>
<td>&lt; 126</td>
<td></td>
</tr>
<tr>
<td>*Organic Matter</td>
<td>%</td>
<td>6.52</td>
<td>3.97</td>
<td>3.00</td>
<td>8.00</td>
</tr>
<tr>
<td>*Nitrogen</td>
<td>%</td>
<td>0.27</td>
<td>0.21</td>
<td>0.20</td>
<td>0.50</td>
</tr>
<tr>
<td>*C.E.C</td>
<td>meq/100g</td>
<td>11.0</td>
<td>14.0</td>
<td>15.0</td>
<td>30.0</td>
</tr>
</tbody>
</table>

PERCENTAGES AND RATIOS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>%</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td></td>
<td>55.2</td>
<td>49.4</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td>15.0</td>
<td>14.2</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
<td>1.08</td>
<td>1.51</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Sodium % (ESP)</td>
<td>%</td>
<td>0.96</td>
<td>1.07</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Other Bases %</td>
<td>%</td>
<td>5.86</td>
<td>6.24</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Hydrogen %</td>
<td>%</td>
<td>21.9</td>
<td>27.6</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Ca:Mg Ratio</td>
<td>%</td>
<td>3.69</td>
<td>3.48</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

Number of leaves per plant
The analysis of variance showed there were significant differences \((P=0.05)\) in number of leaves per plant after application of different levels of farmyard manure (M) and harvesting frequency (H). Where high rate of farmyard manure compared to low rates were applied more leaves per plant, were observed (Tables 4 and 5). The number of leaves harvested progressively increased with the days after planting (DAP) from 36 DAP to 120DAP in all treatments.
Table 5: Effect of manure application and harvesting frequency on number of leaves per plant at different days after planting

<table>
<thead>
<tr>
<th>Days After Planting (Trial I)</th>
<th>FYM</th>
<th>H1</th>
<th>H2</th>
<th>H1</th>
<th>H2</th>
<th>H1</th>
<th>H2</th>
<th>H1</th>
<th>H2</th>
<th>H1</th>
<th>H2</th>
<th>H1</th>
<th>H2</th>
<th>H1</th>
<th>H2</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td></td>
<td>0.33a</td>
<td>0.41a</td>
<td>0.42a</td>
<td>1.67a</td>
<td>3.67a</td>
<td>1.75a</td>
<td>2.58a</td>
<td>5.58a</td>
<td>3.0a</td>
<td>7.5b</td>
<td>12.42a</td>
<td>3.33a</td>
<td>8.42a</td>
<td>1.25a</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>0.42a</td>
<td>0.2a</td>
<td>0.92a</td>
<td>2.83a</td>
<td>4.4a</td>
<td>4.25b</td>
<td>5.14b</td>
<td>5.28a</td>
<td>6.83b</td>
<td>7.58b</td>
<td>14.0a</td>
<td>5.58b</td>
<td>9.25ab</td>
<td>2.92b</td>
</tr>
<tr>
<td>64</td>
<td></td>
<td>0.58a</td>
<td>0.5a</td>
<td>1.5b</td>
<td>4.25b</td>
<td>6.58b</td>
<td>5.17c</td>
<td>5.41b</td>
<td>7.83c</td>
<td>8.0c</td>
<td>9.58b</td>
<td>24.0b</td>
<td>6.25bc</td>
<td>10.42bc</td>
<td>3.41bc</td>
</tr>
<tr>
<td>78</td>
<td></td>
<td>0.75a</td>
<td>0.58a</td>
<td>2.25c</td>
<td>4.92b</td>
<td>7.58b</td>
<td>5.75c</td>
<td>5.67b</td>
<td>10.92d</td>
<td>7.83bc</td>
<td>4.0a</td>
<td>24.25b</td>
<td>7.42c</td>
<td>20.75c</td>
<td>4.58c</td>
</tr>
<tr>
<td>92</td>
<td></td>
<td>0.49</td>
<td>0.41</td>
<td>1.31</td>
<td>0.86</td>
<td>1.77</td>
<td>1.31</td>
<td>3.54</td>
<td>1.99</td>
<td>0.79</td>
<td>1.11</td>
<td>0.94</td>
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</tr>
<tr>
<td>106</td>
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<td>0.87</td>
<td>0.78</td>
<td>1.75</td>
<td>1.58</td>
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<td>0.75a</td>
<td>3.83a</td>
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<td>10.5a</td>
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<td>1.58a</td>
<td>9.0a</td>
</tr>
<tr>
<td>120</td>
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<td>0.5</td>
<td>1.84</td>
<td>1.30</td>
<td>2.54</td>
<td>1.85</td>
<td>5.70</td>
<td>3.08</td>
<td>2.01</td>
<td>2.91</td>
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<td>148</td>
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<td>0.99</td>
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<td>0.99</td>
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<td>0.70</td>
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<td>0.95</td>
<td>0.70</td>
<td>1.90</td>
<td>1.07</td>
<td>0.79</td>
<td>1.11</td>
<td>0.94</td>
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<td>0.53</td>
<td>1.93</td>
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<td>2.97</td>
<td>1.86</td>
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<td>3.04</td>
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<td>0.99</td>
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<td>1.61</td>
<td>1.14</td>
<td>1.58</td>
<td>1.34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NB: Means with the same letter along the column are not significantly different for interaction between level of farmyard manure and harvesting frequency on the number of leaves per plant per harvest. FYM=Farmyard Manure; M1-M4 are levels of farmyard manure; H1 and H2 are harvesting frequency of harvesting once every two weeks and harvesting once every four weeks; MSDH and MSDM are minimum significant difference of Harvesting frequency and level of farmyard manure respectively.

Table 6: Overall average number of leaves per plant as affected by manure application and harvesting frequency

<table>
<thead>
<tr>
<th>Trial I</th>
<th>FYM</th>
<th>H1</th>
<th>H2</th>
<th>Mean</th>
<th>Trial II</th>
<th>FYM</th>
<th>H1</th>
<th>H2</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
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<td>2.81</td>
<td>3.25a</td>
<td>4.49a</td>
<td>3.87</td>
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<td>50</td>
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<td>3.87b</td>
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<td>3.76</td>
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<td>5.15a</td>
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<tr>
<td>64</td>
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<td>4.90</td>
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<td>78</td>
<td></td>
<td>4.93b</td>
<td>6.56c</td>
<td>5.75</td>
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</tr>
<tr>
<td>92</td>
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<td>3.96</td>
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<td>6.49</td>
<td>7.27</td>
<td>1.57</td>
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</tr>
</tbody>
</table>

NB: Means with the same letter along the column are not significantly different for interaction between level of farmyard manure and harvesting frequency on the average number of leaves per plant per harvest. FYM=Farmyard Manure; M1-M4 are levels of farmyard manure; H1 and H2 are harvesting frequency of harvesting once every two weeks and harvesting once every four weeks; MSDH and MSDM are minimum significant difference of Harvesting frequency and level of farmyard manure respectively.
For example the number of leaves increased from 0.33 and 0.41 to 7.5 and 12.42 with application of zero farmyard manure by harvesting twice and once in every four weeks respectively. However, the number of leaves harvested constantly declined after 120 DAP regardless of the treatment (Table 4). Harvesting once after four weeks (H2) recorded more number of leaves per harvest. The number of leaves harvested significantly increased also with the level of farmyard manure applied. For example the number of leaves increased from 1.67 and 3.67 to 4.92 and 7.58 at 64 DAP; 2.5 and 5.5 to 5.67 and 10.92 at 92 DAP; 3.3 and 8.42 to 7.42 and 20.75 at 148 DAP and 0.5 and 2.75 to 2.67 and 6.25 at 198 DAP with zero manure (0 kg/ha) [M1] compared with application of high (22.5 t/ha) [M4] farmyard manure both with harvesting twice (H1) and once (H2) every four weeks in trial I respectively (Table 4). Further, the highest number of leaves was recorded at 120 DAP with 9.58 and 16.4 and 24.25 and 33.92 when farmyard manure was applied at 15 t/ha (M3), and 22.5 t/ha (M4) and the harvesting done twice and once every four weeks in Trial I and II respectively (Table 4). This shows there was increase in number of leaves if harvesting was delayed. Also, the increase in the number of leaves was recorded progressively with increase in the rate of farmyard manure regardless of the harvesting frequency (Table 5).

**Leaf weight per plant**

The analysis of variance showed there were significant differences ($P=0.05$) in leaf weight/yield per plant after application of different levels of farmyard manure (M) and harvesting either twice (H1) or once (H2) every four weeks. Where higher rate of farmyard manure compared to low rates were applied significantly greater leaf yield was observed (Tables 6). Leaf yield progressively increased with the days after planting (DAP) from 36 DAP to 120 DAP and up to 148 DAP when harvesting was done twice (H1) or once (H2) every four weeks respectively. For example leaf weight per plant increased from 0.32 gm and 0.44 gm and 0.99 and 1.38 gm at 36 DAP to 28.03 and 39.28 gms and 42.18 and 59.06 gms at 92 DAP to 43.98 and 61.57 gms and 83.13 and 116.38 gms at 120 DAP with application of zero farmyard manure and when harvesting twice (H1) and once (H2) every four weeks in trials I and II respectively. However, the leaf yield constantly declined after 120 DAP regardless of the treatment (Table 6). Harvesting once (H2) had the greatest leaf yield regardless of the rate of farmyard manure applied. The highest leaf yield of 109.22 and 172.09 gms and 148.22 and 216.62 gms was observed with application of 15t/ha (M3) and 22.5 t/ha (M4) of farmyard manure at 120 and 140 DAP and when harvesting was done twice (H1) and once (H2) every four weeks both in trials I and II respectively. This showed there was maintained increase in leaf yield when more farmyard manure was applied and the harvesting was delayed and done once in every 4 weeks. Also, the increases in the leaf yield was recorded progressively with increase in the rate of farmyard manure regardless of the harvesting frequency (Table 5).

**Table 7: Average leaf yield per plant as affected by manure application and harvesting frequency**

<table>
<thead>
<tr>
<th>FYM</th>
<th>H1</th>
<th>H2</th>
<th>Mean</th>
<th>H1</th>
<th>H2</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>17.99a</td>
<td>21.77a</td>
<td>19.88</td>
<td>25.19a</td>
<td>30.47a</td>
<td>27.83</td>
</tr>
<tr>
<td>M2</td>
<td>32.19b</td>
<td>31.29b</td>
<td>31.74</td>
<td>45.07b</td>
<td>43.81b</td>
<td>44.44</td>
</tr>
<tr>
<td>M3</td>
<td>46.0c</td>
<td>40.13c</td>
<td>43.06</td>
<td>64.4c</td>
<td>56.13c</td>
<td>60.26</td>
</tr>
<tr>
<td>M4</td>
<td>55.66d</td>
<td>55.04d</td>
<td>55.35</td>
<td>76.93d</td>
<td>77.83d</td>
<td>77.38</td>
</tr>
<tr>
<td>Mean</td>
<td>37.96</td>
<td>37.06</td>
<td>37.51</td>
<td>52.89</td>
<td>52.06</td>
<td></td>
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<tr>
<td>MSDM</td>
<td>8.86</td>
<td>12.42</td>
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</tr>
<tr>
<td>MSDH</td>
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<tr>
<td>CVM</td>
<td>3.64</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CVH</td>
<td>2.77</td>
<td></td>
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</tr>
</tbody>
</table>

NB: Means with the same letter along the column are not significantly different for interaction between level of farmyard manure and harvesting frequency on the leaf weight per plant. FYM=Farmyard Manure; M1-M4 are levels of farmyard manure; H1 and H2 are harvesting frequency of harvesting once every two weeks and harvesting once every four weeks; MSDH and MSDM are minimum significant difference of Harvesting frequency and level of farmyard manure respectively
Table 8: Effect of manure application and harvesting frequency on kales leaf yield per plant (gm) at different days after planting

<table>
<thead>
<tr>
<th>Days After Planting</th>
<th>36</th>
<th>50</th>
<th>64</th>
<th>78</th>
<th>92</th>
<th>106</th>
<th>120</th>
<th>148</th>
<th>162</th>
<th>176</th>
<th>198</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(Trial I)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>FYM</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1</td>
<td>0.32a</td>
<td>0.99a</td>
<td>4.83a</td>
<td>10.26a</td>
<td>13.7a</td>
<td>17.37a</td>
<td>28.03a</td>
<td>42.18a</td>
<td>31.7a</td>
<td>43.98a</td>
<td>83.13a</td>
</tr>
<tr>
<td>H2</td>
<td>2.24ab</td>
<td>1.66a</td>
<td>6.13a</td>
<td>16.82ab</td>
<td>23.96b</td>
<td>33.06b</td>
<td>55.35ab</td>
<td>48.14b</td>
<td>72.24b</td>
<td>151.32b</td>
<td>50.94b</td>
</tr>
<tr>
<td>M1</td>
<td>3.5ab</td>
<td>1.99a</td>
<td>9.43b</td>
<td>19.58b</td>
<td>50.06b</td>
<td>65.62b</td>
<td>83.55c</td>
<td>109.22c</td>
<td>147.95b</td>
<td>104.38b</td>
<td>42.61bc</td>
</tr>
<tr>
<td>M2</td>
<td>3.89bc</td>
<td>2.33bc</td>
<td>19.35c</td>
<td>36.46c</td>
<td>99.58c</td>
<td>64.75c</td>
<td>61.15c</td>
<td>9.43b</td>
<td>19.58b</td>
<td>50.06b</td>
<td>65.62b</td>
</tr>
<tr>
<td>M3</td>
<td>2.2</td>
<td>3.4</td>
<td>7.75</td>
<td>7.31</td>
<td>14.83</td>
<td>13.67</td>
<td>19.1</td>
<td>11.83</td>
<td>16.95</td>
<td>17.18</td>
<td>16.36</td>
</tr>
<tr>
<td>M4</td>
<td>3.89bc</td>
<td>2.33bc</td>
<td>19.35c</td>
<td>36.46c</td>
<td>99.58c</td>
<td>64.75c</td>
<td>61.15c</td>
<td>9.43b</td>
<td>19.58b</td>
<td>50.06b</td>
<td>65.62b</td>
</tr>
<tr>
<td>MSDM 2.2</td>
<td>1.18</td>
<td>1.82</td>
<td>4.15</td>
<td>3.92</td>
<td>7.95</td>
<td>7.33</td>
<td>10.24</td>
<td>6.34</td>
<td>9.09</td>
<td>9.21</td>
<td>8.77</td>
</tr>
<tr>
<td>MSDH 2.2</td>
<td>3.72</td>
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<td>CVM 3.72</td>
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<td>CVH 2.82</td>
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</table>

(NB: Means with the same letter along the column are not significantly different for interaction between level of farmyard manure and harvesting frequency on leaf weight per plant per harvest. FYM=Farmyard Manure; M1-M4 are levels of farmyard manure; H1 and H2 are harvesting frequency of harvesting once every two weeks and harvesting once every four weeks; MSDH and MSDM are minimum significant difference of Harvesting frequency and level of farmyard manure respectively.)
DISCUSSION
The results obtained in the study showed that the application of farmyard manure and harvesting at different times significantly affected the number of leaves and the leaf yield in kales. Lack of application of farmyard manure led to less number of leaves regardless of the harvesting frequency. Organic manure has been reported to enhance the vegetative and reproductive growth of the plant such as leaf size, number of leaf per plant, fresh leaf weight, plant height, leaf area, root depth and number of root per plant and days taken to harvest (Ahmed et al., 2017; Melese, 2016). Low soil fertility resulting from continuous monocropping, crop residue removal and limited fertilizer use has been reported as the key challenges to produce surplus food for the ever increasing population (Zerihun and Haile, 2017). The application of FYM probably potentially improved soil fertility and enhanced growth in the plots it was supplied which in return positively increased the number of leaves harvested and the leaf yield per plant. Prasad et al. (2017) reported that farm yard manure act directly by increasing crop yield either by acceleration of respiratory process by cell permeability or by hormone growth action and it also supplies N, P and K in available forms to plants through biological decomposition. In this study probably application of farmyard manure resulted to increased photosynthetic activity which increased photosynthates available for leaf expansion and consequently greater leaf numbers and yield.

Frequent harvesting twice compared to once every four weeks did not increase the overall number of leaves and leaf yield per plant. Actually where harvesting was delayed greater number of leaves and the leaf yield was observed. It was observed that leaf number and yield declined at a greater rate where harvesting was done severally. This can be attributed to increased disturbances and resulting utilization of most of the photoassimilates towards maintenance of the crop. Where there was harvesting delayed probably the plant used most on the photoassimilates towards production of more leaves that contributed to increased leaf yield. The higher leaf weight can also be attributed to greater leaf expansion due the longer growth season. The increased number of leaves and leaf yield when more farmyard manure was applied and the harvesting was delayed and done once in every 4 weeks could also have resulted from maintenance of the crop stand for a longer duration of time. This probably can be interpreted to have enhanced the longevity of the plant stand.

CONCLUSION AND RECOMMENDATIONS
Based on the findings, application of farmyard manure and reducing the harvesting frequency can be adopted to increase kitchen garden kales productivity. Farmers should be advised to apply farmyard manure and avoid frequent harvesting that may compromise the growth and productivity in terms of number of leaves and leaf yield.

ACKNOWLEDGEMENT
The author would like to thank Chuka University for providing the internal research funds grant to undertake the study.

REFERENCES


GENETIC DIVERSITY OF PUMPKIN ACCESSIONS IN KENYA REVEALED USING MORPHOLOGICAL CHARACTERS, DIVERSITY INDEX, CATPCA AND FACTOR ANALYSIS

Kiramana, J.K.1, Isutsa, D.K.1,2, and Nyende, A. B.3
1Chuka University, P. O. Box 109-60400, Chuka, Kenya
2Egerton University, P. O. Box 536-20115, Egerton, Kenya
3Jomo Kenyatta University of Agriculture and Technology, P. O. Box 62000-00200, Nairobi
Email: kirimijk@yahoo.com, dorcaski@yahoo.com

ABSTRACT
Pumpkin is one of the most morphologically variable genera in the entire plant kingdom. In Kenya, its genetic diversity is undocumented and distribution is haphazard. An expedition was done in Kakamega and Nyeri regions in 2012 using purposive sampling and IPGRI descriptors that led to collection of 155 accessions. The accessions were planted and replicated three times at the Chuka University farm. The character ranges were green to orange for mature fruit rind, speckled to striped secondary fruit rind, smooth to warty fruit surface, and white to yellow internal flesh, and yellow to pink-red inner flesh and outer flesh. Sex type was monoecious, with most flowers being male and flowering early; only 9 accessions had female flowers appearing early. Most accessions had globular fruits and second fruit cycle. All the accessions had fruit vein tracks and peduncles that abscised when overripe. Deep fruit ribbing was in 40, while small blossom scars were in 69 accessions. Shannon diversity index based on qualitative traits ranged 0.49 to 1.79, with average of 0.97. Fruit shape and seed coat surface displayed high and low indices, respectively. Nyeri accessions had the highest diversity index. CATPCA, factor and cluster analysis determined relationships of the accessions based on the dissimilarity of qualitative characters. CATPCA and factor analysis reduced the dimensionality of the characters to 13 PCs and factors, respectively. CATPCA captured 78.3% and factor analysis 72.1% of the total variation. The two methods jointly identified second fruiting cycle, central leaf lobes, leaf pubescence type, leaf glossiness, and plant growth habit, leaf and flower colour contributing most to divergence of the accessions. The communalities were mostly high except for few characters exhibiting high specificity. Configuration by scatter Bi-plot along the first two PC axes grouped 124 accessions into variegated and green-leafed. Cluster analysis identified four groups with 59, 40, 24 and 1 accessions in clusters one, two, three and four, respectively. The green-leafed accessions were grouped in clusters 3 and 4, and the variegated in clusters 1 and 2. The morphological qualitative characters with high discrimination can be useful in identifying variation that can be used for direct selection and in assisting breeders identify pumpkin germplasm with desirable traits for inclusion in breeding and improvement programmes.

Keywords: Accessions, Morphological qualitative characters, Categorical Principal Component Analysis, Agrobiodiversity, Kakamega, Nyeri

INTRODUCTION
Pumpkin belongs to the family Cucurbitaceae (Jeffrey, 1990). It is one of the most morphologically variable genera in the entire plant kingdom (Aruah et al., 2010). Its genetic diversity and distribution are essential for rational utilization in crop improvement (Padmini et al., 2013). Distinction of pumpkin cultivars is easiest by observing fruit shape, size, stalk, stems and leaves (Paris, 2000). Fruits are variable in size, colour and shape (Robinson and Decker-Walters, 1997). Morphological qualitative traits provide information on genetic variability, identification and classification (Lima et al., 2012), and determine divergence of pumpkins to a greater degree (Borges, et al., 2011). The traits are also used to assess variation between and within accessions (Balkaya et al., 2010). These diagnostic features are useful in assessing relationships (Radford 1986), by measuring, counting, differentiating and documenting various morphological characteristics (Xolisa, 2002), using the minimum list of descriptors (Kristkova et al., 2003) among pumpkin accessions. The process makes available information collected to prospective breeders and end users that lead to development of new cultivars as well as strengthening the existing ones (Xolisa, 2002).
Principal component analysis (PCA) reveals patterns of variation, eliminates redundancy and identifies unknown trends in a multi-dimensional data set (Maji and Shaibu, 2012). Categorical Principal Component Analysis (CATPCA) is performed when variables are measured on a nominal or ordinal scale. These variables show a fixed a priori order and nonlinear relationships. This method is the nonlinear equivalent of standard PCA, and reduces the observed variables to a number of uncorrelated principal components (Linting et al., 2007). The use of linear or standard PCA is not appropriate, only after linearity in nominal or ordinal variables has been verified (Vilela et al., 2015). The most important advantages of nonlinear over linear PCA are that it incorporates nominal and ordinal variables, and that it can handle and discover nonlinear relationships between variables. Also, non-linear PCA can deal with variables at their appropriate measurement level. Every observed value of a variable is referred to as a category. CATPCA converts every category to a numeric value, in accordance with the variable’s analysis level, using optimal quantification (Linting et al., 2007). Categorical quantifications of categorical variables by optimal scaling ensures the overall variance accounted for in the transformed variables, given the number of components is maximized. This ensures information in the original categorical data is retained, depending upon the optimal scaling level chosen for each variable separately (Vilela et al., 2015). Factor analysis identifies the underlying relationships that exist within a set of variables. Large datasets are reduced into groups of factors that underlie the quality of characteristics of the original variables (Yong and Pearce, 2013). The dimensionality of measurable and observable variables is reduced by regrouping the variables into a limited set of descriptive categories and clusters, and to fewer latent variables that share a common variance and are unobservable. These make it easier to focus on key factors rather than having to consider too many variables that may be trivial. It also summarizes the data into relationships and patterns that can be easily interpreted and understood (Yong and Pearce, 2013).

Cluster analysis (CA) is used in assessing genetic diversity (Lima et al., 2012; Maji and Shaibu, 2012). CA group’s accessions showing dissimilarity in several traits by displaying similarity or differences between pairs of subjects (Goda et al., 2007). CA also defines homogeneous subgroups of a given measure of dissimilarity or similarity from heterogeneous sets of items (Downs and Barnard, 2002). The ward’s clustering method is useful in producing desirable compact clusters (Zewdie and Zeven, 1997). The unweighted pair group method of arithmetic averages (UPGMA) minimizes within cluster variance (Hintze, 2001). The Euclidean distance measures dissimilarity and partitions genotypes into exclusive groups according to genetic distance (Lima et al., 2012). Kenya being a secondary centre of genetic diversity has a wide array of pumpkin genotypes that require detailed characterization (Karuri et al., 2010). They are referred as “orphaned”, which connotes that they receive very little research and development attention (Naluwairo, 2011). Presently, no information is available that can be used to delineate and standardize the pumpkin accessions in Kenya (Ahamed et al., 2011; Isutsa and Mallowa, 2013; Mwaura et al., 2014; Kiharason et al., 2015). The present study was undertaken to characterize phenotypically pumpkin accessions collected among smallholder farmers in Kakamega and Nyeri regions of Kenya. This was aimed at providing useful information on pumpkin accessions qualitative morphological characteristics based on their phenotypic differences, PCA, Shannon diversity index and their dissimilarity using Phylogenetic analysis.

**MATERIALS AND METHODS**

**Research Site**

The collected accessions (155) from Kakamega and Nyeri were planted on 23rd May, 2012, in a Complete Randomized Design (CRD) in three replications at Chuka University (CU) farm. The farm lies at 0° 19' S, 37° 38' E and 1535 m above sea level. Rainfall is about 1,200 mm annually and bimodally distributed. Annual mean temperature is about 20°C. Soils are mainly humic nitisols, deep, well weathered with moderate to high inherent fertility (Jaetzold & Schmidt, 1983). Land was ploughed and pulverized to fine tilth. Planting holes measuring 2 ft squared on the top and a depth of 2 ft were dug. During digging, top soil was separated from the subsoil. Top soil was then mixed thoroughly with 24 kg of well decomposed farm yard manure (FYM) and returned back to the hole without the subsoil. A six inch unfilled portion of
the hole was left (Muyekho et al., 2003) to act as a basin for water holding during irrigation to avoid wastage. These holes referred as “Tumbukiza”, were spaced at 2m x 2m. Five plants/accession were planted in each hole using rainfall. Twenty litres of water was applied in two splits in each hole using a calibrated watering jar when there were no rains. Chemical sprays to control insects and diseases were applied. Moles destroying the accessions were trapped manually. Weeding was done during all stages of the accessions growth.

**Data Analysis**

Data recording on vegetative characteristics began 20 days after emergence up to fruit maturity. Five plants per accession and a total 775 plants were selected and tagged, for morphological data recording using IPGRI descriptors (IPGRI, 2003). Qualitative characteristics were recorded of leaf, stem, root and inflorescence on 146 accessions, and on 126 and 124 accessions on fruit and seed traits, respectively. Each accession represented a research plot, and at fruit maturity each of the accessions were harvested separately. The colour of fruits, leaves, stems and flowers of the accessions were matched using a colour chart. Qualitative data was numerically coded and expressed as modes and frequencies. Frequency of mode indicated variation within accessions. Statistical analysis system generated modes and frequencies.

Shannon diversity index (HS) was used to determine accessions richness and abundance (Equation 1) (Shannon, 1983). Evenness was calculated using the ratio of Shannon diversity index and the natural logarithm of species richness (Equation 2) (Aruah et al., 2010).

\[
\text{Shannon Diversity Index (HS)} = \sum_{i=1}^{s} - [p_i \ln p_i] \tag{1}
\]

Where: \(p_i\) = relative abundance of species, \(s\) = the number of species in the sample and \(\ln\) = natural logarithm:

\[
\text{Evenness (J)} = \frac{\text{HS}}{\ln S} \tag{2}
\]

Where: HS = Shannon diversity index and \(\ln S\) = natural logarithm of the Species richness.

Qualitative characters that contributed significantly to the total variation of the accessions were identified using CATPCA. The CATPCA estimated correlations between the qualitative characters, and generated Eigen values, percentage of variation accumulated by the principal components (PCs), the corresponding load coefficients and the scatter bi-plots. CATPCA was used to extract maximum variance from qualitative data set with each component reducing the large number of variables into smaller number of components. Factor analysis (FA) was used to reduce the measured and observed variables to fewer latent variables that shared a common variance, in order to reduce the dimensionality of variables to the most discriminating qualitative characters. This enabled regrouping of the variables into a limited set of clusters. Factor analysis also helped summarize qualitative data into relationships and patterns that could be easily interpreted and understood (Yong and Pearce, 2013).

The number of PCs and factors that were retained was based on the Eigen value greater than one criterion. The Eigen values were used to estimate the relative contribution of each PC to the total variance of all the variables. The load coefficients were used to generate the correlations of each variable with its relevant PC. The internal consistency of qualitative data was tested using Cronbach’s alpha. The data with Cronbach’s alpha greater than 0.7, indicated an acceptable internal consistency (Sartipi et al., 2016). Qualitative characters with load coefficients and factor load rotations \(\geq 0.20\) in the correlation matrix were considered significant contributors to the variability of the accessions and were considered to be highly relevant to that PC or factor. The significant level for retaining discriminative qualitative character was \(\alpha = 0.05\). CATPCA and factor analysis were performed using SPSS version 16. Cluster analysis generated dendrograms to infer relationships among accessions based on Euclidean distance matrices, ward and UPGMA methods. Cluster analysis was performed using XLstat.

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RESULTS

Morphological Qualitative Characters

All the accessions had leaf veins, large sized leaves, dense and intermediate leaf pubescence adaxial and abaxial, and roots at the internodes. The leaves were pentalobate with cordate base and shallow lobes. Leaf outline was broadly ovate and very broadly ovate in 108 and 38 accessions, respectively. The accession leaves were variegated in 102 and plain green leafed in 44 accessions, leaf senescence when fruits matured moderate in 88, and conspicuous and concurrent in 44 accessions. The flowers of all accessions were monoecious, with most being male and appearing early, than female flowers. Female flowers appeared early in only 9 accessions. The colour of flowers was orange, and the predominant fruit shape globular in most accessions (Table 1).

The second fruiting cycle was observed in 99 accessions, with 27 accessions showing no sign of second fruit cycle. Predominant fruit skin ranged from green to orange and secondary skin pattern from speckled to stripe. The fruit surfaces at maturity were either smooth or wart. Internal fruit flesh colour ranged from white to yellow, and main and outer layer flesh from yellow to salmon (Table 1). Fruit vein tracks and peduncles abscising when overripe, unwinged seeds and no seed coat pattern was observed in all accessions. Predominant seed coat colour ranged from white to cream yellow. The seeds were either sharply or bluntly pointed at the hilum end.

Table 1: Qualitative morphological traits displaying the highest distribution frequency of accessions

<table>
<thead>
<tr>
<th>Characters</th>
<th>Score code</th>
<th>Descriptor state</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
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<td>Flower colour</td>
<td>2</td>
<td>Yellow-cream</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Yellow</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Dark-yellow</td>
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<tr>
<td></td>
<td>5</td>
<td>Orange</td>
<td>101</td>
</tr>
<tr>
<td>Fruit shape</td>
<td>1</td>
<td>Globular</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Flattened</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Elliptical</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Pyriform (pear-like)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Oval</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Acorn</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Elongate</td>
<td>6</td>
</tr>
<tr>
<td>Predominant fruit skin colour</td>
<td>3</td>
<td>Cream</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Pale green</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Green</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Dark green</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Blackish-green</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Grey</td>
<td>10</td>
</tr>
<tr>
<td>Secondary fruit skin colour</td>
<td>2</td>
<td>Light-yellow</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Cream</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Pale green</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Green</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Orange</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Grey</td>
<td>4</td>
</tr>
<tr>
<td>Design produced by secondary fruit skin colour</td>
<td>1</td>
<td>Speckled (spots &lt;0.5 cm)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Spotted, blotchy (spots &gt;0.5 cm)</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Striped (bands run from peduncle to blossom scar)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Short streaked (elongated marks and &lt;4 cm)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Long streaked (as 4 but &gt;4 cm)</td>
<td>15</td>
</tr>
</tbody>
</table>
Fruit surface
1 Smooth 39
2 Grainy 9
3 Finely wrinkled 11
4 Deeply wrinkled 2
5 Shallowly wavy 50
6 Rare warts 7
7 Numerous warts 8

Blossom end shape
1 Depressed 33
2 Flattened 23
3 Rounded 60
4 Pointed 10

Stem end shape
1 Depressed 31
2 Flattened 56
3 Rounded 11
4 Pointed 28

Main color of flesh
2 Yellow 54
4 Pale green 1
7 Orange 61
8 Salmon 10

Predominant seed coat colour
1 1 white 2
2 2 yellow-white 28
3 3 cream yellow 70
5 5 light brown or tan 12
6 6 brown 14

NB - Only qualitative characteristics with more than three descriptor states are displayed in Table 2

Shannon Diversity Index
The genetic diversity of the accessions based on morphological qualitative traits was 0.91 and 1.05, in Kakamega and Nyeri accessions, respectively, with a mean of 0.97 in both regions. The diversity ranged from 0.49 to 1.79, with fruit shape and seed coat surface displaying the highest and lowest indices, respectively. Highest diversity (HS) and evenness (J) were observed in fruit and seed characters. The diversity was positively correlated to evenness. Fruit shape and surface, and predominant fruit skin colour indicated high diversity as attributed to their high evenness (Table 2).

Table 2: Shannon diversity index and evenness of pumpkin accessions based on qualitative traits

<table>
<thead>
<tr>
<th>Character</th>
<th>Kakamega accessions</th>
<th>Nyeri accessions</th>
<th>Kakamega and Nyeri accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HS</td>
<td>J</td>
<td>HS</td>
</tr>
<tr>
<td>Fruit shape</td>
<td>1.78</td>
<td>0.43</td>
<td>1.72</td>
</tr>
<tr>
<td>Predominant fruit skin colour</td>
<td>1.35</td>
<td>0.33</td>
<td>1.60</td>
</tr>
<tr>
<td>Secondary fruit skin colour</td>
<td>1.20</td>
<td>0.29</td>
<td>1.39</td>
</tr>
<tr>
<td>Primary colour of immature fruit</td>
<td>0.90</td>
<td>0.22</td>
<td>1.03</td>
</tr>
<tr>
<td>Secondary colour of immature fruit</td>
<td>0.86</td>
<td>0.21</td>
<td>0.90</td>
</tr>
<tr>
<td>Fruit skin glossiness</td>
<td>1.04</td>
<td>0.25</td>
<td>1.09</td>
</tr>
<tr>
<td>Fruit surface</td>
<td>1.13</td>
<td>0.27</td>
<td>1.59</td>
</tr>
<tr>
<td>Fruit ribbing</td>
<td>1.15</td>
<td>0.28</td>
<td>1.07</td>
</tr>
<tr>
<td>Blossom scar appearance</td>
<td>0.90</td>
<td>0.23</td>
<td>0.96</td>
</tr>
<tr>
<td>Blossom scar size</td>
<td>0.80</td>
<td>0.19</td>
<td>0.93</td>
</tr>
<tr>
<td>Blossom end shape</td>
<td>1.11</td>
<td>0.27</td>
<td>1.24</td>
</tr>
<tr>
<td>Stem end shape</td>
<td>1.26</td>
<td>0.30</td>
<td>1.24</td>
</tr>
<tr>
<td>Fruit stem/peduncle colour</td>
<td>1.01</td>
<td>0.24</td>
<td>0.99</td>
</tr>
<tr>
<td>Main colour of flesh</td>
<td>0.95</td>
<td>0.23</td>
<td>0.85</td>
</tr>
<tr>
<td>Flesh colour of outer layer</td>
<td>0.79</td>
<td>0.19</td>
<td>1.03</td>
</tr>
<tr>
<td>Seed shape</td>
<td>0.90</td>
<td>0.22</td>
<td>1.06</td>
</tr>
<tr>
<td>Predominant seed coat colour</td>
<td>1.14</td>
<td>0.28</td>
<td>1.16</td>
</tr>
<tr>
<td>Seed glossiness</td>
<td>0.96</td>
<td>0.23</td>
<td>1.08</td>
</tr>
</tbody>
</table>

**Only morphological qualitative characters with diversity index values above 0.9 are displayed in Table 2**
Categorical Principal Component Analysis (CATPCA)

Total Cronbach’s alpha was greater than 0.7 in PC 1 and 2 (Table 3). The characters with Eigen values greater than one were reduced to 13 PCs that explained 78.2% of the total variation. The first four PCs with eigen-values greater than 2.0 explained more than half of total variation (Table 3). The first PC had the highest Eigen-value and accounted for the greatest amount of total variation (35.5%) in the original data (Table 3). It was highly and positively loaded with second fruiting cycle, central leaf lobes, leaf glossiness, leaf pubescence type, leaf senescence and predominant seed coat colour. It was highly and negatively loaded with plant growth habit, leaf and flower colour (Table 4). The second PC 2 accounted for 6.4% of the residual variation unaccounted for by PC 1, and was highly and positively loaded with predominant and secondary fruit skin colour, and primary colour of immature fruit. It was highly and negatively loaded with seedling vigour, plant size, blossom scar appearance and size. The third PC accounted for 5.0% of the residual variation unaccounted for by PC 2, and was highly and positively loaded with fruit shape. It was highly and negatively loaded with blossom scar appearance and size. The fourth PC accounted for 4.4% of the residual variation unaccounted for by PC 3, and was positively loaded with seedling vigour and earliness of male flowers. It was highly and negatively loaded with earliness female flowers (Table 3 and 4). The same process unfolded for PC 5 up to 13 (Balkaya et al., 2010). The first PC was defined by plant, leaf, flower, fruit and seed characters, PC 2 and PC 3 were mainly delineated by fruit characters, while PC 4 was mainly outlined by flower characters (Table 4).

Table 3: Categorical principal components, Cronbach's alpha, Eigen values and percent variation

<table>
<thead>
<tr>
<th>Principal components (PCs)</th>
<th>Cronbach's Alpha</th>
<th>Total (Eigen value)</th>
<th>% Proportion of Variance</th>
<th>Cumulative % variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC 1</td>
<td>1.0</td>
<td>16.7</td>
<td>35.5</td>
<td>35.5</td>
</tr>
<tr>
<td>PC 2</td>
<td>0.7</td>
<td>3.0</td>
<td>6.4</td>
<td>42.0</td>
</tr>
<tr>
<td>PC 3</td>
<td>0.6</td>
<td>2.3</td>
<td>5.0</td>
<td>46.9</td>
</tr>
<tr>
<td>PC 4</td>
<td>0.5</td>
<td>2.1</td>
<td>4.4</td>
<td>51.3</td>
</tr>
<tr>
<td>PC 5</td>
<td>0.5</td>
<td>1.9</td>
<td>4.1</td>
<td>55.4</td>
</tr>
<tr>
<td>PC 6</td>
<td>0.4</td>
<td>1.7</td>
<td>3.7</td>
<td>59.1</td>
</tr>
<tr>
<td>PC 7</td>
<td>0.4</td>
<td>1.6</td>
<td>3.3</td>
<td>62.5</td>
</tr>
<tr>
<td>PC 8</td>
<td>0.3</td>
<td>1.5</td>
<td>3.1</td>
<td>65.6</td>
</tr>
<tr>
<td>PC 9</td>
<td>0.2</td>
<td>1.3</td>
<td>2.8</td>
<td>68.3</td>
</tr>
<tr>
<td>PC 10</td>
<td>0.2</td>
<td>1.3</td>
<td>2.1</td>
<td>71.1</td>
</tr>
<tr>
<td>PC 11</td>
<td>0.2</td>
<td>1.2</td>
<td>2.2</td>
<td>73.6</td>
</tr>
<tr>
<td>PC 12</td>
<td>0.1</td>
<td>1.2</td>
<td>2.4</td>
<td>76.0</td>
</tr>
<tr>
<td>PC 13</td>
<td>0.0</td>
<td>1.0</td>
<td>2.1</td>
<td>78.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36.7</strong></td>
<td><strong>78.2</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Categorical principal component loadings (Eigen vectors) for the first four PCs with Eigen values ≥ 2

<table>
<thead>
<tr>
<th>Characters</th>
<th>PC 1</th>
<th>PC 2</th>
<th>PC 3</th>
<th>PC 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling vigour</td>
<td>0.08</td>
<td>-0.41</td>
<td>-0.05</td>
<td>0.51</td>
</tr>
<tr>
<td>Plant growth rate before flowering</td>
<td>-0.13</td>
<td>-0.34</td>
<td>-0.08</td>
<td>0.44</td>
</tr>
<tr>
<td>Plant growth rate after flowering</td>
<td>-0.61</td>
<td>-0.06</td>
<td>-0.28</td>
<td>0.07</td>
</tr>
<tr>
<td>Plant growth habit</td>
<td>-0.96</td>
<td>-0.02</td>
<td>0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td>Plant size</td>
<td>0.07</td>
<td>-0.47</td>
<td>-0.20</td>
<td>0.44</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>-0.25</td>
<td>0.01</td>
<td>0.10</td>
<td>-0.07</td>
</tr>
<tr>
<td>Internode length</td>
<td>-0.03</td>
<td>-0.23</td>
<td>-0.11</td>
<td>-0.03</td>
</tr>
<tr>
<td>Stem colour</td>
<td>-0.61</td>
<td>0.35</td>
<td>-0.11</td>
<td>0.04</td>
</tr>
<tr>
<td>Leaf outline</td>
<td>0.86</td>
<td>0.13</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Central leaf lobe shape</td>
<td>0.99</td>
<td>0.05</td>
<td>-0.03</td>
<td>0.00</td>
</tr>
<tr>
<td>Leaf pubescence type</td>
<td>0.99</td>
<td>0.04</td>
<td>-0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Leaf colour</td>
<td>-0.98</td>
<td>-0.05</td>
<td>0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td>Leaf glossiness</td>
<td>0.97</td>
<td>0.04</td>
<td>-0.05</td>
<td>-0.03</td>
</tr>
<tr>
<td>Leaf senescence</td>
<td>0.96</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Earliness of male flowers</td>
<td>-0.08</td>
<td>0.19</td>
<td>-0.29</td>
<td>0.68</td>
</tr>
</tbody>
</table>
Configuration of Accessions
The configuration along the first two PCs (1 and 2) grouped the accessions into two distinct groups (Figure 1). On the positive end of PC 1 axis after the truncation line are the green leafed accessions, and on the negative end of PC 1 are the local variegated accessions. The local variegated accessions KK-63, KK-51, NY-94, NY-95 and NY-117 on the positive end of PC 2 axis, and KK-60, KK-46 and NY-144 on the negative end of PC 2 axis, and green leafed KK-19 on the positive end of PC 1 of the configuration were placed a distant away from the other accessions (Figure 1). The accessions were mainly discriminated on the basis of plant growth habit, second fruiting cycle, leaf outline, central leaf lobes, leaf glossiness, leaf pubescence type, leaf senescence, leaf and flower colour, fruit surface, predominant and secondary fruit skin colour, fruit stem peduncle length, predominant seed coat colour, seed coat surface and seed surface glossiness.

Factor Analysis
Factor analysis based on principal components reduced qualitative traits into 13 factors, which explained 72.1% of total variation. Three factors with eigen-values ≥ 2.0 explaining more than half of total variation were retained (Norman et al., 2011). The degree of association of qualitative characters within the first three factors was given as factor scores. This information was used to construct three dimensional ordinations for morphological qualitative traits that explained 38.7 % of the total variation (Figure 2).
Figure 1: Scatter bi-plot showing the distribution of 124 accessions under PC 1 and 2 axis, 1-70 – Kakamega (KK) and 71-155- Nyeri (NY) - 1 - 155 accessions codes

Figure 2: Three dimensional ordination for morphological qualitative traits contributing 38.7 % of the total variation

Growthb-plant growth rate before flowering; Growtha- plant growth rate after flowering; Vigour-seedling vigour; Psize- plant size; Habit-plant growth habit; Stemc-stem colour; Loutline-leaf outline; Clobes=central leaf lobes; Ptype-leaf pubescence type; Nnodes-number of nodes; Ilength-internode length; Lcolor-leaf colour; Lglos-leaf glossiness; Sene-leaf senescence; Emflo-earliness of male flowers; Efflo- earliness of female flowers; Fcolor-flower colour; Fsize-fruit size; Fshap-fruit shape; Sfcycle-second fruit cycle; Pfcol-predominant fruit skin colour; Sfcol-secondary fruit skin colour; Pcimm-primary colour of immature fruit; Scimm- secondary colour of immature fruit; Fglos-fruit skin glossiness; Sfcol-secondary skin colour; Fsurf-fruit surface; Frib-fruit ribbing; Sribs-shape of fruit ribs; Vcolor-vein track colour; Bsapp-blossom scar appearance; Bsize-blossom scar size; Bshap-blossom end shape; Sshap-stem end shape; Pfcol-fruit stem peduncle colour; Pleng-fruit stem peduncle length; Iskinc-internal colour of skin; Mcfles-main colour of flesh; Fvar-fruit size variability; Fclay-flesh colour of outer layer; Seshap-seed shape; Shilum-seed shape at the hilum end; Secol-predominant seed coat colour; Ssurf-seed coat surface; Sglos-seed surface glossiness; Nseeds-number of seeds per fruit

The first factor accounted for the greatest amount (29.3%) of total variation in the original data. It was highly and positively loaded with plant growth habit, leaf and flower colour, and seed coat surface, and
was highly and negatively loaded with second fruit cycle, central leaf lobes, leaf glossiness, leaf pubescence type, leaf outline, leaf senescence and predominant seed coat colour. The second factor accounted for 4.8%, and was highly and positively loaded with blossom scar size and appearance. The third factor accounted for 4.6% of the total variation, was moderately and positively loaded with secondary fruit skin colour, fruit vein track colour and fruit surface, and moderately and negatively loaded with fruit skin glossiness (Table 5). The communalities were all high except for number of nodes, internode length and fruit skin glossiness which exhibited low communality and high specificity. The first factor was mainly associated with plant, leaf, flower, fruit and seed characters. Factor 2 and 3 were mainly delineated by fruit characters (Table 5).

**Table 5:** Factor loadings for the first three factors with Eigen values ≥ 2, communality and specificity of qualitative characters

<table>
<thead>
<tr>
<th>Characters</th>
<th>F 1</th>
<th>F 2</th>
<th>F 3</th>
<th>Communalities</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling vigour</td>
<td>-0.07</td>
<td>0.06</td>
<td>-0.05</td>
<td>0.78</td>
<td>0.22</td>
</tr>
<tr>
<td>Plant growth rate before flowering</td>
<td>0.14</td>
<td>-0.03</td>
<td>-0.08</td>
<td>0.81</td>
<td>0.19</td>
</tr>
<tr>
<td>Plant growth rate after flowering</td>
<td>0.64</td>
<td>0.23</td>
<td>0.11</td>
<td>0.65</td>
<td>0.35</td>
</tr>
<tr>
<td>Plant growth habit</td>
<td>0.95</td>
<td>-0.09</td>
<td>-0.08</td>
<td>0.92</td>
<td>0.08</td>
</tr>
<tr>
<td>Plant size</td>
<td>0.00</td>
<td>0.25</td>
<td>-0.04</td>
<td>0.69</td>
<td>0.31</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>0.24</td>
<td>0.06</td>
<td>-0.38</td>
<td>0.47</td>
<td><strong>0.53</strong></td>
</tr>
<tr>
<td>Internode length</td>
<td>0.08</td>
<td>-0.03</td>
<td>0.19</td>
<td>0.45</td>
<td><strong>0.55</strong></td>
</tr>
<tr>
<td>Stem colour</td>
<td><strong>0.60</strong></td>
<td>-0.08</td>
<td>0.08</td>
<td>0.65</td>
<td>0.35</td>
</tr>
<tr>
<td>Leaf outline</td>
<td>-0.86</td>
<td>0.00</td>
<td>0.07</td>
<td>0.81</td>
<td>0.19</td>
</tr>
<tr>
<td>Central leaf lobe shape</td>
<td>-0.92</td>
<td>0.11</td>
<td>0.07</td>
<td>0.89</td>
<td>0.11</td>
</tr>
<tr>
<td>Leaf pubescence type</td>
<td>-0.91</td>
<td>0.02</td>
<td>0.05</td>
<td>0.86</td>
<td>0.14</td>
</tr>
<tr>
<td>Leaf colour</td>
<td><strong>0.94</strong></td>
<td>-0.02</td>
<td>-0.07</td>
<td>0.91</td>
<td>0.09</td>
</tr>
<tr>
<td>Leaf glossiness</td>
<td>-0.92</td>
<td>0.10</td>
<td>0.06</td>
<td>0.88</td>
<td>0.12</td>
</tr>
<tr>
<td>Leaf senescence</td>
<td>-0.83</td>
<td>0.11</td>
<td>0.03</td>
<td>0.78</td>
<td>0.22</td>
</tr>
<tr>
<td>Earliness of male flowers</td>
<td>0.06</td>
<td>-0.03</td>
<td>0.09</td>
<td>0.71</td>
<td>0.29</td>
</tr>
<tr>
<td>Earliness of female flower</td>
<td>-0.03</td>
<td>0.02</td>
<td>-0.04</td>
<td>0.80</td>
<td>0.20</td>
</tr>
<tr>
<td>Flower colour</td>
<td><strong>0.85</strong></td>
<td>-0.09</td>
<td>-0.03</td>
<td>0.79</td>
<td>0.21</td>
</tr>
<tr>
<td>Fruit shape</td>
<td>-0.29</td>
<td>-0.12</td>
<td>-0.02</td>
<td>0.68</td>
<td>0.32</td>
</tr>
<tr>
<td>Fruit size</td>
<td>0.29</td>
<td>0.18</td>
<td>-0.07</td>
<td>0.72</td>
<td>0.28</td>
</tr>
<tr>
<td>Fruit size variability</td>
<td><strong>0.53</strong></td>
<td>-0.04</td>
<td>0.04</td>
<td>0.60</td>
<td>0.40</td>
</tr>
<tr>
<td>Second fruit cycle</td>
<td>-0.98</td>
<td>0.09</td>
<td>0.07</td>
<td>0.98</td>
<td>0.02</td>
</tr>
<tr>
<td>Predominant fruit skin colour</td>
<td>-0.38</td>
<td>0.17</td>
<td>0.18</td>
<td>0.74</td>
<td>0.26</td>
</tr>
<tr>
<td>Secondary fruit skin colour</td>
<td>-0.05</td>
<td>0.04</td>
<td><strong>0.69</strong></td>
<td>0.64</td>
<td>0.36</td>
</tr>
<tr>
<td>Primary colour of immature fruit</td>
<td>0.41</td>
<td>-0.17</td>
<td>0.43</td>
<td>0.73</td>
<td>0.27</td>
</tr>
<tr>
<td>Secondary colour of immature fruit</td>
<td>0.28</td>
<td>0.07</td>
<td>0.13</td>
<td>0.83</td>
<td>0.17</td>
</tr>
<tr>
<td>Fruit skin glossiness</td>
<td>0.21</td>
<td>-0.01</td>
<td><strong>-0.56</strong></td>
<td><strong>0.47</strong></td>
<td><strong>0.53</strong></td>
</tr>
<tr>
<td>Secondary skin colour</td>
<td>0.38</td>
<td>-0.11</td>
<td>0.16</td>
<td>0.56</td>
<td>0.44</td>
</tr>
<tr>
<td>Fruit surface</td>
<td>0.08</td>
<td>-0.17</td>
<td><strong>0.55</strong></td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td>Fruit ribbing</td>
<td>0.48</td>
<td>0.07</td>
<td>0.09</td>
<td>0.74</td>
<td>0.26</td>
</tr>
<tr>
<td>Shape of fruit ribs</td>
<td>0.20</td>
<td>0.01</td>
<td>0.17</td>
<td>0.63</td>
<td>0.37</td>
</tr>
<tr>
<td>Vein track colour</td>
<td>-0.06</td>
<td>0.04</td>
<td><strong>0.64</strong></td>
<td>0.51</td>
<td>0.49</td>
</tr>
<tr>
<td>Blossom scar appearance</td>
<td>-0.30</td>
<td><strong>0.89</strong></td>
<td>-0.05</td>
<td>0.91</td>
<td>0.09</td>
</tr>
<tr>
<td>Blossom scar size</td>
<td>-0.23</td>
<td><strong>0.90</strong></td>
<td>0.00</td>
<td>0.88</td>
<td>0.12</td>
</tr>
<tr>
<td>Blossom end shape</td>
<td>-0.16</td>
<td>-0.18</td>
<td>-0.12</td>
<td>0.78</td>
<td>0.22</td>
</tr>
<tr>
<td>Stem end shape</td>
<td>0.21</td>
<td>0.00</td>
<td>0.00</td>
<td>0.71</td>
<td>0.29</td>
</tr>
<tr>
<td>Fruit stem peduncle colour</td>
<td>-0.08</td>
<td>-0.11</td>
<td>0.00</td>
<td>0.69</td>
<td>0.31</td>
</tr>
<tr>
<td>Fruit stem peduncle length</td>
<td><strong>0.67</strong></td>
<td>0.11</td>
<td>0.13</td>
<td>0.62</td>
<td>0.38</td>
</tr>
<tr>
<td>Internal colour of skin</td>
<td>0.07</td>
<td>-0.01</td>
<td>0.13</td>
<td>0.73</td>
<td>0.27</td>
</tr>
<tr>
<td>Main colour of flesh</td>
<td>0.48</td>
<td>-0.03</td>
<td>0.17</td>
<td>0.70</td>
<td>0.30</td>
</tr>
<tr>
<td>Flesh colour of outer layer</td>
<td><strong>0.56</strong></td>
<td>-0.02</td>
<td>0.09</td>
<td>0.79</td>
<td>0.21</td>
</tr>
<tr>
<td>Seed size</td>
<td><strong>-0.65</strong></td>
<td>0.12</td>
<td>0.03</td>
<td>0.62</td>
<td>0.38</td>
</tr>
<tr>
<td>Seed shape</td>
<td><strong>-0.56</strong></td>
<td>0.06</td>
<td>0.06</td>
<td>0.66</td>
<td>0.34</td>
</tr>
</tbody>
</table>
Phylogenetic analysis
Cluster analysis clustered the accessions into 4 groups. Group I (GI) and GII consisted of 59 and 40 variegated accessions, GIII and GIV consisted of 24 and 1 green leafed accession, respectively (Figure 3).

Figure 3: A dendrogram portraying relationships among 124 accessions using qualitative characters. G - Groups I – IV.

The dissimilarity among the accessions was attributed mainly to stem colour, leaf glossiness, leaf senescence; earliness of male and female flowers, flower colour; fruit shape, predominant and secondary fruit skin colour, primary and secondary colour of immature fruit, fruit skin glossiness, secondary skin colour, fruit surface, fruit ribbing and shape of the ribs, fruit vein track colour; blossom scar appearance and size, blossom and stem end shape, fruit stem peduncle colour and length, internal colour of skin, main and outer layer colour of flesh, separation of seed and placenta from the fruit, seed shape, seed shape at the hilum end, predominant seed coat colour, seed coat surface and glossiness. Group I (GI) accessions were delineated by stem colour, earliness of female flowers, primary and secondary colour of immature fruits, secondary skin colour, fruit ribbing, internal colour of skin, main and outer layer colour of flesh. They were further clustered into three sub groups. Group II (GII) were differentiated by flower colour, fruit skin glossiness, shape of the ribs and seed coat surface, and further clustered into two sub groups. Group III (GIII) were qualified by leaf glossiness, fruit shape, fruit stem peduncle colour, seed shape at the hilum end and predominant seed coat colour, and were further divided into three sub groups. In group IV (GIV), one green leafed accession was clustered in simplifolious. It was delineated by leaf senescence; earliness of female flowers, predominant and secondary fruit skin colour, fruit vein track colour; blossom scar appearance and size, blossom and stem end shape, fruit stem peduncle length, separation of seed and placenta from the fruit, seed shape and seed surface glossiness.

DISCUSSION
a) Phenotypic Variation of the Accessions
i. **Vegetative, stem and root characters**

The growth habit in most of the accessions was bushy and multilateral. Maynard (2007) reported multilateral branches forming at nodes and following the same general pattern of growth as the main stem. Multilateral branching creates more locations for flowering and fruit development (Gichimu et al., 2008). The variations in internode length among accessions was attributed to genetic effects which induce reduced internode length and shorter vines “bush”, or “semi-bush”, or “restricted vine” (Maynard, 2007). The stems in most accessions were dark-green. Ajuru and Okoli (2013) reported light-green, highly pubescent stems. All the accessions had tendrils at the nodes. Saboo et al. (2013) reported branched tendrils arising in the axial or opposite to the leaf at the node. All the accessions had roots at the internodes. Internodal roots improve nutrient absorption (Aderi et al., 2011).

ii. **Leaf characters**

Most of the accessions had soft leaf pubescence. Ajuru and Okoli (2013) reported highly pubescent, hairs forming a cushion on the adaxial surface of leaves. Agbagwa et al. (2007) reported large pilose leaves, and Nesom (2011) moderately hirsutulous to puberulent and moderately villous to unicellular-based hairs. The leaves were variable with green and silvery variegation in most of the accessions. Xiaohua et al. (2011) reported leaf colour ranges from light-green to dark-green. Ajuru and Okoli (2013) reported light-green leaves, and Agbagwa et al. (2007) white blotched leaves. The variegation in leaves of pumpkins is controlled by dominant M gene for silver-gray areas in axils of leaf veins, which are dominant to m for absence of silver-gray (Paris and Brown, 2005). The silverying is caused by air spaces within the palisade cell layer and between that layer and the epidermis (Brown, 2002). Leaf senescence among accessions was slightly visual, moderately, to conspicuous when fruits matured. Precocious yellowing of leaves, under certain environmental conditions is caused by B (Bicolor) genes. Dominant selective suppressor of B (Ses-B) gene prevents leaf yellowing in the presence of B (Bicolor) gene (Brown, 2002). The slight to moderate senescence of local variegated accessions was attributed to segregation of Ses-B with age of plants as the fruits matured (Brown, 2002).

Conspicuous concurrent senescence, just after flowering was observed in green leaved accessions. Early senescence is a genetically programmed self-attrition program accompanied by recycling of nutrition released during degradation of macromolecules such as proteins (Gan, 2014), and due to the presence of B (Bicolor) genes (Brown, 2002). The leaves were large, pentalobate and cordate, broadly to very broadly ovate in all the accessions. Saboo et al. (2013) reported large leaves shallowly 5 lobed, alternate broad, palmately-veined and reticulate, with long hollow petiole and different shapes. Agbagwa et al. (2007) reported large, cordate and shallowly 5-lobed leaves, and Ajuru and Okoli (2013) simple, alternate, broadly ovate, roughly serrate, broadly cordate and palmately lobed leaves. Leaf shape and margin are useful in distinguishing cultivated Cucurbitaceae from others (Agbagwa and Ndukwu, 2004).

iii. **Inflorescence characters**

The flower colour was orange in most accessions. Ahamed et al. (2011) reported yellow flowers in all accessions of Cucurbita moschata. The flower colour variations are attributed to genetics (Maynard, 2007), and are important in classification of plants (Nesom, 2011). The accessions were all monoecious. McCormack (2005) reported monoecious plants in the four major domesticated species of cucurbits, with staminate flowers developing, maturing, and shedding their pollen before the female flowers. Most male flowers appeared early compared to female flowers. Maynard (2007) and. Agbagwa et al., (2007) also reported similar results. Earliness of female flowers was recorded in only nine accessions. McCormack (2005) reported earliness of female flowers in summer squash varieties planted early. It is not uncommon for Cucurbits to bear female flowers first (OECD, 2012). Flowering in cucurbits is influenced by climactic and hormones produced within the plant as well as synthetic growth regulators. Gibberellins promote male flowers, while ethylene, natural and synthetic auxins promotes pistillate flowers. High temperatures, and light intensity, and long days favour male flowers, while, low temperatures and light intensity, and short days favour female flowers (McCormack, 2005). The flower ratio in most of the

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accessions was mostly male. This ratio may be affected by the number of already developing fruits present in a plant (McCormack, 2005).

iv. Fruit characters
Fruit in most accessions were globular in shape. Ahamed et al. (2011) reported elliptical to round and pyriform shapes. Labrada et al. (1997) reported pyriform, elongate, globular and flat shapes and Xolisa (2002) cylindrical, oblate, flattened, globular or elliptical shapes. Fruit skin colours were predominantly green or dark green, with blotchy secondary pattern in most accessions. Mladenovic et al. (2014) reported predominant fruit skin colour ranges from green to orange, and secondary pattern from speckled to stripe. Ahamed et al. (2011) reported colour ranges from green, yellow to brown. The colour of fruit skin is controlled by 3 loci (Gr, Mldg and B). Dominant Gr results in green fruits, Mldg mottled immature fruit colour and mldg non-mottled rind, while B (Bicolor) gene confers a precocious yellow colour (Paris and Brown 2005; Lietzow et al., 2005; 2006). Warty, grainy, smooth, wrinkled and wavy fruits were observed in some of the accessions. Warts were either rare or numerous. Xolisa (2002) reported smooth, and Mladenovic et al. (2014) smooth to warty fruits. Fruit warts are controlled Wt gene dominant to non-warty (wt), and complementary to hard rind gene Hr. Wartiness is expressed only in the presence of the dominant Hr allele (Paris and Brown, 2005), that controls the activity of phenylalanine ammonia lyase (PAL) (Schaffer et al., 1986), to biosynthesize lignin in the fruit rinds resulting into warts (Brown, 2002). Main and internal fruit flesh colour was orange and green in most accessions, respectively. Mladenovic et al. (2014) and Xiaohua et al. (2011) reported flesh colour ranges from white to orange. Brown (2002) reported white through cream and yellow to various shades of orange, including greenish tints, and Ahamed et al. (2011) white to green, orange to deep orange fruit flesh. Genes A/B/- result in orange fruit, associated with high carotenoid levels (Brown, 2002), and A/-b/b in green fruits (Paris, 1994).

Fruit peduncle colour ranged from light-green to dark-green. Brown (2002); Paris and Nerson (1986) and Paris, (1996) reported dark-green peduncles at the stem end, gradually lightening to yellow at the fruit end in plants homozygous for D1 and light peduncles and dark stems at the base of heterozygous plants. Fruit peduncles of all accessions absised when fruits over-ripened. Abscission layer at the peduncle is attributed to ethylene (Pitrat, 2008), and is a good indicator of full ripeness (Beaulieu, 2006). The layer also plays an important role in growth and survival by discarding unnecessary organs, and protecting plants by eliminating pathogen-infected organs (Tsukahara et al., 2013). The appearance and size of fruit blossom scars ranged from obscure to conspicuous, and small to large, respectively. Xolisa (2002) reported intermediate to conspicuous appearance, and Loy (2006) reported small sized scars in fruits from pistillate flowers, than in fruits developed from perfect flowers. Blossom and stem end were rounded, depressed, flattened or pointed. Similar findings were reported by Xolisa (2002). Fruit ribbing ranged from superficial to deep, obtuse or intermediate in shape in fruits among the accessions. Xolisa, (2002) and Mladenovic et al. (2012a) reported superficial, intermediate or deep-ribbed fruits. Second fruiting cycle was observed mostly in local variegated accessions. This was attributed to genetic diversity and adaptation to agro-ecological conditions (Du et al., 2011). Cucurbits continue producing flowers and fruits for an extended period of time with appropriate conditions, (OECD, 2012). Lack of second fruiting of green leafed accessions was attributed to a recessive gene de for determinate plant habit (Paris and Brown, 2005). Most of the local variegated accessions had second fruiting cycle, unlike green leafed accessions which had no second fruit cycle. OECD (2012) reported some pumpkin species behaving as facultative annuals, dying in their first year. Paris and Brown (2005) linked a recessive gene de being responsible for determinate plant habit which results to no second fruit cycle.

v. Seed characters
The seed coats in most of the accessions seeds were predominantly cream yellow. Balkaya et al. (2010) reported cream tones seed coats in most pumpkins, and cream, tawny, dark-cream, light cream and brown in other pumpkin seeds. Aruah et al. (2010) reported brown and light-brown seeds. The separation of seed and placenta from fruit in most accessions was easy. McCormack (2005) reported seeds separating easily
from the pulp in some varieties than in others. The seed shapes were elliptic, with seed size ranging from large to very large in most of the accessions. Balkaya et al. (2010) reported widely elliptic seeds being most common, Ajuru and Okoli (2013) spherical or oval seeds. The tubercular seed coats in most of the local variegated accession seeds were attributed to deficiency of lignification in hypodermis, sclerenchyma and aerenchyma, and cellulose in epidermis. The smooth seed coat surfaces found mostly in seeds of green leafed accessions were attributed to strong lignification of epidermis, hypodermis, sclerenchyma and aerenchyma outer layers (Teppner, 2000).

b) Genetic Diversity among Accessions
The mean genetic diversity among accessions across Kakamega and Nyeri was below 1.0. Aruah et al. (2010) reported genetic diversity of 1.559 for C. moschata, 1.474 for C. maxima and 1.103 for C. pepo. Nyeri accessions had high genetic diversity, compared to Kakamega accessions. This was attributed to many exotic green leafed cultivars introduced by farmers in Nyeri. Introduction of genetically dissimilar or closely related species by farmers increase gene flow through exchange of genes. These activities whether intentional or unintentional release genotypes that later on reproduce with the local landraces (Lundqvist et al., 2008). Introduction of new species could lead in gene escape and farmers acquiring unique constructs through pollen dispersal that leads to depletion in the quality and performance of local landraces (Groot et al., 2003). Variation in biotic and abiotic resistance, or tolerance or competition due to gene exchange could generate variance in demographic parameters (Bolnick, 2011). Demographic and genetic processes act synergistically through interaction to foster the “extinction vortex” of small populations (Gugerli et al., 2008). The low genetic diversity recorded among the Kakamega accessions was attributed to the existence of many local accessions that were recycled for many generations and also to the few exotic green leafed cultivars that were introduced in the region. The highest genetic diversity was recorded in fruit shape among the accessions. Studies by Du et al. (2011); Onyishi et al. (2013); Gichimu et al. (2008) and Aruah et al. (2010) reported similar findings. Intraspecific variation among the accessions was high in predominant and secondary fruit skin colour, blossom and stem end shape, and fruit surface among other characters. Intraspecific variation represents a large proportion of total variation, which has important consequences for competition, co-existence, productivity and resistance (Siefert, 2014). The high genetic diversity observed in these characters was attributed to their high evenness. Evenness is an important component in diversity studies, as it expresses even distribution of the individuals among different species (Bibi and Ali, 2013). The value of evenness indicated high genetic diversity among the accessions more in fruit shape and surface and predominant fruit skin colour. Genetic diversity is of prime importance for the long-term preservation of biodiversity in changing environments (Gugerli et al., 2008). Characters with high diversity provide raw material for selection (Aruah et al., 2010; Bolnick, 2011). The local variegated accessions were more diverse compared to green-leafed due to their climatic and genetic adaptability over the years (Xiaohua et al., 2011).

c) Genetic Variation among Accessions
The total Cronbach’s alpha for the 13 PCs was above 0.7, which indicated an acceptable internal consistency of the collected morphological data. This meant that the variance derived from these data originated from the characters measured, and not from experimental design or method of data collection used (Sartipi et al., 2016). The characters in the first four PCs and three factors with Eigen values equal or greater than 2.0 were selected because they accounted for more than half of the total variation (Mladenovic et al., 2012b), and were mainly defined by plant, leaf, flower, fruit and seed characters. These characters were considered important and emboldened, which indicated how they were related to that PC and factor (Balkaya et al., 2010b; Mladenovic et al., 2012b). The functional relationship assigned to the first PC and factor was growth, leaf, flower, and fruit and seed factors. Fruit factors were assigned to PC and factor 2 and 3, and flower factors to PC 4, respectively. They were summed as growth, quality, yield and maturity factors. These factors could thus, be used as priority indices for selection, screening and breeding of pumpkin germplasm (Xiaohua et al., 2011). Studies by Xiaohua et al. (2011) reported PC 1 being mainly defined by leaf length and width, and leaf petiole length. PC 2 by fruit width, flesh
thickness and fruit weight and PC 3 by taste, texture and flavour of flesh. The three PCs were called leaf, fruit and flesh quality factor, respectively. Odiyi et al. (2014) reported marketable leaf yield, vine length, number of branches/plant and number of leaves/plant being important characters of genetic variability in *T. occidentalis* for both factor and principal component analysis. The functional relationships assigned to the traits were thus yield and numeric factors. The PCs and factors with Eigen values below two were considered weak and had no discriminatory power (Maji & Shaibu, 2012).

The highest weightings of similar traits using CATPCA and factor analysis ignoring the sign was revealed in second fruiting cycle, central leaf lobes, leaf pubescence type, leaf glossiness, plant growth habit, leaf and flower colour in the first PC and factor. The sign on the weighting indicated the direction of the relationship between the PCs and factors and the characters (Balkaya et al., 2010b). Odiyi et al. (2014) also reported factor and principal component analysis identifying similar characters in pumpkins, okra, rice and groundnut. The similarity of the two techniques gives a good description of variability and discrimination of the accessions (Odiyi et al., 2014) using qualitative characters. The characters with high weighting contributed maximum to the discrimination of the accessions and were under similar genetic control (Odiyi et al., 2014). The high weighting in these characters also indicated high correlation, that could be used in assessing and identifying genetic variability in pumpkins (Norman et al., 2014; Odiyi et al., 2014), without adversely affecting other characters of economic importance (Odiyi et al., 2014). Second fruit cycle and leaf glossiness were mostly observed in the local variegated accessions. Second fruiting cycle keeps cucurbits producing flowers and fruits for an extended period of time given appropriate conditions (OECD, 2012). Yogranjan et al. (2014) reported leaf glossiness lessening the impacts of climate change and optimizing overall yield potential of crops due to utmost reflectivity with least/no impact on photosynthetic yield. Nawalkar et al. (2015) reported positive correlation of leaf glossiness with yield/plant. The yield of plants increased with an increase in leaf glossiness. These traits should thus, be considered when selecting pumpkins for crop improvement.

Predominant and secondary fruit skin colour, and primary colour of immature fruit had high weighting in the second PC. Brown (2002), Paris and Nerson (1986), and Paris (1996) linked fruit colour to peduncle stem colour, with light-green and dark-green peduncles producing white and green fruits, respectively. Blossom scar appearance and size had high weighting in the second factor and the third PC, respectively. Loy (2006) reported variability in size of blossom scars, with fruits derived from pistillate flowers having smaller scars than those developed from perfect flowers. Greater fruit size was achieved in plants with smaller blossom scars and monoecious genes. The fourth PC was highly loaded with earliness of female and male flowers. Studies conducted by Organization for Economic Cooperation and Development [OECD], (2012) reported flower development in Cucurbitaceae being regulated by both genetic and environmental mechanisms such as temperature and the duration of days. Temperature and day length influences how long the plant remains in the male phase. High temperatures, high light intensity, and long days favour production of male flowers. This leads to a longer male phase and a larger number of male flowers relative to female flowers. Low temperature, low light intensity and short days favour development of female flowers relative to male flowers (OECD, 2012). Generally, male flowers usually develop and mature (McCormack, 2005) and open before any female flowers (Maynard, 2007), and shed their pollen to ensure cross-pollination occur early in the plant’s development (McCormack, 2005). However, it’s not uncommon for *C. moschata* to bear female flowers first (McCormack, 2005). Earliness of female flowers in summer squash varieties planted early was reported by McCormack (2005).

Total genetic variation captured by CATPCA was high compared to factor analysis. PCA accounted for over 78% of the total variation in the first four PCs while factor analysis accounted for 72.1% of the variation in the first three factors. Odiyi et al. (2014) reported high total variation using PCA compared to factor analysis. From the results of the factor analysis and principal component analysis, it was clear that second fruiting cycle, central leaf lobes, leaf pubescence type, leaf glossiness, plant growth habit, leaf and flower colour were important characters of genetic variability in pumpkin accessions. These
characters were considered as the most important for classifying the variation among pumpkin accessions. In addition CATPCA identified leaf senescence and predominant seed coat colour also as important characters. CATPCA captured all forty seven characters as important to discriminate the accessions unlike factor analysis which identified thirty eight characters. The variation in most characters was largely influenced by communality compared to specificity. The communality value ranges from zero to 1 where 1 indicates that the variable can be fully defined by all the factors associated with it and has no uniqueness. In contrast a value of 0 indicates that the variable cannot be predicted at all from any of the factors (Beaumont, 2012). The communality observed in most of the characters measured indicated that the observed variation in each character was as a result of total influence from all the factors associated with it. Three of the characters measured loaded more than 50% as specific factors (specificity) compared to common factors (communality). This indicated how significance each of the characters contributed to the observed genetic variation among the accessions (Beaumont, 2012). Common factors were shared in more than one of the observed variables, whereas specific factors only affected particular variables, unique to a specific variable (Yong and Pearce, 2013).

d) Configuration of Accessions

The configuration along the first two PC axes grouped accessions into two distinct (variegated and green-leafed) groups. The configuration was very significant in visualizing the genetic relationships (Mussane et al., 2010), and interrelations (Oliveira and Munita, 2011), among the accessions based on the most discriminating morphological traits. The accessions placed a distant away from the others in the configuration were considered genetically diverse. Thus, direct selection could be made on these accessions. The accessions that clustered together were considered genetically similar. Cluster analysis grouped the accessions into four clusters on the basis of their dissimilarity of morphological qualitative traits and not according to geographical origin. Accessions clustered in the same cluster were considered to belong in a heterotic group. Clustering of accessions using phylogenetic analysis agreed with PCA scatter bi-plot configuration results. Both methods grouped variegated and green leafed accessions into two distinct groups of variegated and green leafed accessions. The fact that the accessions were separated into two dissimilar groups based on qualitative character differences, it proved that use of morphological characters was an inexpensive means for distinguishing related species (Balkaya et al., 2010b).

CONCLUSION AND RECOMMENDATIONS

The present study collected 155 pumpkin accessions in Kakamega and Nyeri regions. Morphological characters were used to reveal the great variations existing in pumpkins. Most of the accessions that were assessed exhibited high variability with respect to fruit and seed characters. However, greater variation was mainly centered in fruit characters. High genetic diversity was revealed in accessions collected in Nyeri using diversity index. This was attributed to intentional or unintentional introduction of genetically dissimilar pumpkin species by farmers that later on reproduced with the local pumpkins. Fruit and seed characters also revealed high genetic diversity using the index. CATPCA was important in analyzing qualitative nominal data. Factor analysis reduced the dimensionality of characters into a limited set of descriptive categories and fewer latent characters that shared a common variance. Both CATPCA and factor analysis were useful in investigating genetic diversity of the accessions by comparing the characters capturing the most variation. This helped to give supplementary information on the usefulness of these characters in defining groups of accessions. The traits that showed the most discrimination power among the accessions using both CATPCA and factor analysis were second fruiting cycle, central leaf lobes, leaf pubescence type, leaf glossiness, plant growth habit, leaf and flower colour. Thus, these characters can be used to make direct selection of the accessions for pumpkin improvement. Configuration and cluster analysis grouped the accessions into homogeneous groups based on their morphological dissimilarity. The accessions that clustered together were considered genetically similar and shared some biological relationship. Those that were placed a distance away were considered genetically diverse. The high genetic diversity indicated that direct selection of these accessions would be effective in their utilization in breeding to improve specific traits. Therefore, estimating genetic diversity
is of paramount importance for future production, conservation and maintenance of pumpkins for use in breeding. Genetic diversity could also be achieved by crossing the accessions showing the most genetic variability to come up with new cultivars. Thus, information on the genetic diversity of pumpkins can be used to contribute to conservation and utilization of pumpkins.

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Abstract
Climate variability is currently a major concern not only to conservationist but it also cut across several disciplines such as agriculture and other production sectors. The world’s climate continues to change at rates that are projected to be unprecedented in recent human history. Climate change adds to the impact of land use change on species and ecosystems. Rising temperatures, rainfall variability, and new climatic regimes pose threats to biodiversity and human livelihoods alike. A study conducted at Meru Conservation area, Kenya established that there has been a change in climate variables which has over time affected wildlife populations, wildlife ecosystems and human livelihoods within and the protected areas. This has however exposed wildlife conservation at a higher risk due to continuous loss of preferred habitats, movement corridors, dispersal areas and population decline.

Keywords: Climate Variability, Wildlife Populations, Human Livelihoods

Introduction
Protected areas should remain a cornerstone of global conservation efforts. However, the double impacts of climate change and biodiversity loss are major threats to achieving the millennium sustainable goals (MSGs), especially those relating to environmental sustainability, poverty alleviation, and food and water scarcity. In this case, this study agrees with the finding by Lopoukhine et al. (2012) that inclusion local community in protected area planning and management comes in right time when it is of realization that national parks and reserves are changing into islands amidst the sea of changing land cover and land use activities coupled with climate change. This view is further supported by Reed, (2012) who wrote that climate change is expected to cause serious disruptions to earth’s ecological systems, resulting in an overall loss of biodiversity and a reduction in the goods and services provided to humans. Given the importance of biodiversity to wildlife and human well-being and the irreversibility of its loss, the depletion of biodiversity is one of the most important environmental threats that humanity faces.

Methods
The study was conducted at Meru Conservation Areas in Meru National Park and Mwingi National Reserve and the adjacent land. These two protected areas which forms part of the complex Meru Conservation Area adjoins Bisanadi National Reserve and Kora National Park. The study focused on establishing the changes in climate elements that has occurred over time in MNP and MNR and the impacts of these changes on wildlife ecosystems. According to Jaetzold and Schmidt, (1983) and Otuoma (2004), the entire study area which is under MCA is classified to be in a similar ecological region (AEZ VI), Arid to semi Arid receiving amount of annual rainfall ranging between 300-500mm. annually. The study based on the fact that availability of food in arid and semi arid areas is a function of spatial and temporal pattern of rainfall. Therefore, seasonal variation in rainfall amount for the entire study period (1985-2015) was used as the unit of study representing the climate elements.
This secondary data on rainfall amounts was acquired from the research department of MCA to investigate the changes in rainfall occurrence from 1985 to 2015. Since not all wildlife species could be studied under the present endeavor, the African elephant (*loxodonta africana*) was selected as the evaluation species. The elephant was used because inter alia, 1) it is highly visible and easily counted during census 2) it is water dependent 3) it is very mobile and known to cause conflicts outside the parks when resources are missing and 4) their data is readily available since they have been highly studied. The approach is supported by Esikuri (1998) who argues in his study of African elephants that capacity of savanna areas to support elephant population is influenced by rainfall patterns, availability of water and human land use activities.

Results and Discussion
The Rainfall Pattern in MNP and MNR is Bi-Modal with the long rains running from mid March to Mid May while the short rains are experienced from October to December. The protected areas both of which are in similar ecological zone receives an average of 500mm per annum being higher in the west and declining towards the east which is a livestock grazing zone.

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The rainfall data available for MNP and MNR was from 1988 to 2014. This was the secondary data that was regularly recorded by the research department from the weather stations positioned within the protected areas. To support this secondary data, questionnaires were administered to the local communities and key informant to evaluate if they were aware of the current scenarios in climate change and whether they can associate the variations in rainfall patterns in the area to changing climate. The survey also determined the implications of these changes on wildlife species and human livelihoods.

Upon investigation on whether climate change has contributed to decline in rainfall amount, 69.2% of the respondents supported while 30.8% disagreed or had no opinion if decline in rainfall amount was affected by climate change. However, upon validation from the existing data collected from the park, it was established that there has been a significant decline in the amount of rainfall received in the area from 1988 to 2014 from 1509mm to 335mm respectively. The figure below shows the trend rainfall amount received in the study area as it was recorded over the study period.

![Figure 2: Trend in rainfall amount over the study period in MNP](image)

The study findings revealed that there has been constant decline in the amount of rainfall that is received per annum. From these study findings, it is argued out that human land use activities in MNP and MNR have been affected further by climate variations where as observed, the changes in the amounts of rainfall have over the years resulted to prolonged drought and poor crop harvests. The outcome of these has influenced humans to carry out illegal activities such as grazing, charcoal burning and farming inside the protected areas as an adaptation strategy to the changing climatic regimes. These activities which are practiced both within and outside protected area boundaries provided alternative sources of livelihood to humans at the expense of
changing wildlife habitats. Consequently, the study established that reduced amounts of rainfall and seasonal variations have contributed to poor growth of preferred forage and domination of drought tolerant non palatable species of grass. In other cases, the land has been converted into bare land exposing loose soils to agents of soil erosion due to overgrazing and browsing.

Some of the rivers such as Kathithi which flows across the park to Tana River were found to be dry especially during the seasons of prolonged drought. In this case, the wildlife had to move and concentrate in areas that are closer to water, hence contributing to habitat degradation, competition, higher rate of predation and diseases.

The study results provide an important insight that charcoal burning and livestock invasion was the main threat in MNR which is managed by the Kitui County government and KWS. These disturbances have rendered the PA to be unproductive for wildlife resulting to death of wildlife species due to starvation, stress or migration nearby protected areas such as Kora National park, Meru National Park, or Bisanadi National Reserve.

Upon investigation on the impacts of climate change on wildlife ecosystems and human society, reported cases of human wildlife conflicts increased by 16% from 2000 to 2015. This report could be attributed to the changes vegetation cover compelling wildlife to move to disperal areas that have since been settled or cultivated. For instance, study findings revealed that forest cover declined by 14.1% while grasslands and bareland has increased over time by 9.9% and 6.1% respectively in the study period.

According to the image classification, the bareland represents areas of land that have been built up, degraded by livestock and also under cultivation with crops. The decline in rainfall amount has probably influenced the community to turn into activities that affect the protected areas including charcoal burning and encroachment as alternative source of livelihood.

Previous studies by KWS (2014) shows that MNR is affected by climate change where local communities have encroached into the reserve with their livestock for fodder and water as a coping mechanism to frequent and prolonged droughts that are experienced.

From the figure 13 above, it is observed with the dots that cases of sheep and goats (Shoats) encroachment was highly reported at MNR unlike in MNP. Charcoal burning was also reported to be another activity that has been adopted by the communities neighboring MNR probably as an alternative livelihood from poor farm harvest due to inadequate rainfall. The farmers reported that there has been regular crop failure as shown in the figure below prompting them to change to alternatives.

On the western part of the MCA, communities have intensified the use of water for irrigation from the rivers such as kathithi which is one othe rivers that waters MNP. The increase in water abstraction results to drying up of such rivers as shown in the photo below that was taken in the study area.
Figure 3: The distribution of shoats in Meru Conservation Area (KWS, 2014)

Figure 3B. A interviewee explaining about frequent crop failure around Mwingi National Reserve (MNR)
Figure 4A: women making ballast at Kaningo gate of MNR for construction of a rangers post as an alternative source of income. Figure 4 B: women fetching water at the dry rivers adjacent to the reserve.

Figure 5: The distribution of charcoal burning Areas in MCA (KWS, 2014)
This has contributed to human-wildlife conflicts as the animals get outside the PA in search of water. However, the changing trend in climate results to continuous drought it is anticipated these swamps and rivers may dry up due to land use pressure on the upstream catchment areas.

Further, low rainfall amount received in MCA in the recent years averaging to 350mm has resulted to prolonged drought which have had an adverse effects on wildlife. For instance, the recent drought experienced in 2009 and 2013 contributed to numerous death of wildlife and compelling others such as elephants to migrate to other ecosystems like Mt. Kenya, Samburu and Laikipia. The figure below show an example of wildlife decline as a result of changes in rainfall amount that has in turn reduced the ecosystem potential.
Upon further investigation, the study established that reported cases of human wildlife conflicts were higher 87% during the dry spells as compared to wet seasons 13%. This is because most of the species such as buffaloes, elephants, baboons were found to move out of the park boundary in search of forage.

**Conclusion**

From the above findings, the study of this objective hereby conclude that climatic variations in the study area have resulted to changes in vegetation cover and facilitated alternative land use options by local communities as coping strategies which have negative impacts to wildlife conservation. Wildlife populations on the other hand have declined in both MNP and MNR due these changes. For instance, annual census for the elephant population in MCA has been increasing over time, a factor which is associated with changes in habitat and disturbances by human beings.

Interestingly, vegetation along the rivers and wetlands outside the PA boundaries has increasingly been reclaimed for farming of Miraa and horticultural crops. The livestock keeping community in Rapsu, Kaningo and Ntoroni blocks on the other hand have been found to drive their livestock into the park during the dry spells for water and fodder. However, since climate change is an ongoing phenomenon, it is considered in the present study that the protected area managers and other conservation agents should establish mitigation measures that will reduce the effects of climate change as well as providing alternative land use options that are environmentally sustainable.

**Acknowledgement**

My foremost and sincere thanks go to the almighty God for His provisions and gift of life and enabling me to get this far. Secondly, I take this chance to thank my supervisors, Prof. Adiel Magana of Chuka University, Kenya and Dr. Cyprian Njue of University of Brighton, UK who offered me the essential academic and intellectual guidance required in the production of this thesis. I am humbled by their commitment to help me and to accept to be my supervisors.

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EFFECT OF LIVESTOCK PESTICIDES USE ON PASTORALISTS AND AGRO-PASTORALISTS’ HEALTH AND THEIR ENVIRONMENT IN NAROK COUNTY, KENYA

Gachachi, F.N.
Department of Environmental Studies and Forestry, School of Tourism and Natural Resources Management, Maasai Mara University, Narok, Kenya
*Corresponding author email: gachachif@gmail.com

ABSTRACT
This study therefore investigated the effects of livestock pesticides on pastoralists’ health and the environment in pastoral and agropastoral areas of Narok County. This was achieved through identification of the farmers' socioeconomic characteristics, types of pesticides used, the level of awareness on the negative effects of livestock pesticides on their health and that of the environment, precautionary measures employed and disposal mechanisms. The sample for this investigation was drawn from 100 pastoralists and agro-pastoralists through purposive sampling and the survey involved a combination of qualitative and quantitative techniques. A significantly (P< 0.05) higher number of farmers used acaricides compared to pastoralists. More than 70% of the respondents were not aware of the right concentration of the products. In addition, only 16.4% used at least one type of protective clothing when applying pesticides were while the rest were not. Common practices with the potential of leading to exposure of farmers and farm workers at farm level included wearing unwashed clothes from previous spraying, mixing pesticide with hand or bottle, wetting feet and hand, wetting body during spraying and soaking clothes with pesticide. The respondents enumerated a lot of health effects on themselves such as itchy skin, runny nose, dry throat and dizziness, among others. The empty chemical containers were disposed by burning, burying or both. It was noted that some farmers left the empty pesticide containers at the mixing site. Negative effect observed on the environment included contaminated soil and water. This study recommends that extension services need to be greatly improved by both public and private agencies to increase necessary awareness among pesticide users so as to encourage right practices for the safe use and handling of chemicals and pesticides. This should be done by educating them on the risks involved on the use of these poisonous materials and chemicals. There is need to establish monitoring systems by relevant authorities on handling and disposal of pesticides and pesticide containers at farm level with a view of minimizing contamination of the environment.

Key words: Acaricides, Environment, Agro-pastoralists, Pesticides

INTRODUCTION
Pesticides are substances meant for preventing, destroying or mitigating any pest (US Environmental Policy, 2007). Although there are benefits to the use of pesticides, some also have drawbacks, such as potential toxicity to humans and other animals. According to the Stockholm Convention on Persistent Organic Pollutants, nine of the twelve most dangerous and persistent organic chemicals are pesticides (Gilden et al., 2010). Pesticide use raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil (US Environmental Policy, 2007). Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them. They are one of the causes of water pollution, and some pesticides are persistent organic pollutants and contribute to soil contamination. In human and other vertebrates, exposure to pesticides can range from mild skin irritation to birth defects, tumors, genetic changes, blood and nerve disorders, endocrine disruption, and even coma or death (Lorenz Eric, 2009). They can enter the human body through inhalation of aerosols, dust and vapor that contain pesticides; through oral exposure by consuming food and water; and through dermal exposure by direct contact of pesticides with skin (Palmer et al., 2007).

Narok County is located in the arid and semiarid (ASAL) areas of Kenya with the main economic activity being livestock keeping combined with occasional nomadism. This contributes more than 60% of the...
household economy and 70% of rural employment. The pastoralists are bound to use a lot of pesticides to treat and prevent diseases in their livestock. Like in most other ASALs in the country, communal cattle dips are not functional following the withdrawal of government subsidy on ticks control under the structural adjustment program (SAPs) in the late 1980s. These were policies introduced by the International Monetary Fund (IMF) and the World Bank which required that Kenya devalue its currency, lower tariffs and end Government control of non-food commodities. Pesticide (tick) control became a private good and government subsidy was withdrawn. This led to the collapse of the National Tick Control Programme. Most of the cattle dips are nonfunctional therefore most of the pastoralists use knapsack sprayers and foot pumps to control animal pests (Narok South Development Plan 2008–2012). Most of the pastoralists spray their animals near the water sources with a likelihood of contaminating the water points. The water points also have more vegetation than most other areas thereby being a habitat of most flora and fauna in the ASALs. However, the pastoralists’ knowledge and awareness on the effects of these pesticides to the environment is very low or lacking. They do not take precautionary measures as regards to themselves and the environment. This has led to damage of fragile ecological systems with disastrous effects such as poisoning of both fauna and flora. The antidotes of these pesticides are expensive and the farmers may not afford them. This consequently leads to loss of livestock with a negative impact on the rural economy. Pesticides are also a health hazards to humans due to residues in milk, eggs and meat. Repeated use can cause land degradation making some of the areas unsuitable for any economic ventures. The disposal of the containers can also pose an environmental challenge. This study therefore finds out the various methods of application of pesticides by pastoralists on their livestock and suggests ways of sustainable utilization.

**MATERIALS AND METHODS**

**The Study Site**

Narok South Sub-county is situated in the southern part of the Rift Valley bordering Narok North Subcounty to the North, Nakuru County to the North east and Bomet County to the west. It also borders Transmara East Subcounty to the South West and Tanzania to the South Eastern corner as well as Kajiado County. It lies between Latitudes 0°54’and 1°05’ South and Longitudes 35°28’ and 36°025’ east. It covers about 10,304 square kilometers and has 34,107 households (Narok South Development Plan 2008–2012). The Subcounty is divided into five divisions namely Osupuko, Oloolunga, Loita, Mulot and Mara. It has 29 locations and 54 sub-locations. The 1999 Population and Housing Census estimated the population at 396,560 with a growth rate of 3% per annum. (Narok South Development Plan 2008–2012). The district receives a bimodal rainfall pattern average annual rainfall of between 500 to 1800mm. Low rainfall zones in Osupuko, Mara, Loita and parts of Oloolunga cover over 3/4 of the district. These are considered as arid and semiarid where there is good potential for rearing of hair sheep, goats and cattle especially beef. Livestock keeping is mainly extensive combined with occasional nomadism. Livestock rearing is the main economic activity of the community and contributes more than 60% of the household economy and 70% of rural employment. The district is an important source of livestock supply to Nairobi market. Animals are used as both fixed and current bank, providing income meat and milk. Hides and skins are important materials for clothing, bedding and roofing. Livestock numbers are the usual standard for defining social strata and status, providing for dowry and traditional festivities among other uses.

**Sampling Design and Data Collection**

Sampling was based on the nineteen (19) vector control groups within the Arid and semi-arid areas in Narok South District of Narok County (Krejcie and Morgan, 1970). The information gathered was of primary and secondary data. Primary data was collected through the use of questionnaires while secondary data was by use of literature from various sources. To enhance the validity of the questionnaire, first a pre-test pilot study was conducted on a population similar to the target population. The quantitative data collected was analyzed using conceptual descriptive analysis (mean score and standard deviation), frequencies and cross tabulation. This helped in determining the extent to which various factors have influenced use of pesticides by farmers. Questionnaires were distributed to 100 farmers who were
purposive selected. The biographic data examined variables pertaining to the respondents such as the gender, the age, education level, position in the sampled farm and enterprises going on in the sampled farm. The awareness of any negative effects of pesticides, the effect on human health and environmental components affected by pesticides were also assessed. In addition, use of protective equipment when applying pesticides, types of protective gears and preference of use were also addressed.

**Data analysis**

Data analysis was done using Statistical Package for Social Sciences (SPSS) version 20.0. The data collected which were quantitative in nature, were analyzed using conceptual descriptive analysis (mean score and standard deviation), frequencies and cross tabulation. This helped in determining the extent to which various factors have influenced use of pesticides by farmers. Data analysis was done used SPSS version 20.0. Tests done included; standard deviation in addition to the frequencies and percentages to display the characteristics of respondents, the simple correlation coefficient between some characteristics of social, educational and economic status of the respondents and their relationship with their knowledge regarding pesticides damage and their effects on the environment. Tables were used to summarize responses for further analysis and facilitate comparison.

**RESULTS**

The study aimed at interviewing 100 livestock keepers out of which 97 responses rate was achieved which translates to a response rate of 97%. The entire return rate is statistically representative, therefore, enhancing generalization of the research results. However, the statistical results have been triangulated with extensive literature to draw lessons learnt from other similar research works.

**Demographic Characteristics of respondents**

A deliberate effort was made to give consideration to gender in the sampling process. This was based on the understanding that gender roles in livestock management and the associated challenges are different. In this study 23.7% of the respondents were women while 76.3% were men. Although men played the leading role in tick control on the farms, women also play an active role in the control of ticks especially if their husbands were absence or busy with other engagements. Majority of the respondents (85.9%) were aged between 18 to 60 years while 14.1% were aged above 61 years. In terms of literacy level of awareness and practice for the pesticide use precautions, majority of the respondents (59.8%) had no formal education; 15.5% had primary education, 7.2% had secondary education while 17.5% had post-secondary (Fig. 1).

![Graph showing respondents level of education](image)

*Figure 1: Respondents level of education*

The position in the farm by the respondents may have an influence on decision making, access and ownership of protective gears used while controlling pest and livestock production. Majority of the respondents (89.7%) were owners of the sampled farms, 8.2% were employees while 2.1% were relatives of the farms owners. In terms of livelihood diversification, pure pastoralism was being practiced by 51.1% respondents in the sampled farms; about 11.3% were engaged in business while 37.1% were practicing agro-pastoralism that involved growing crops and keeping livestock on the same land (Fig. 2).
The level of awareness of any negative effects of pesticides on health
Pastoralists’ knowledge and awareness on the effects of pesticides on environment is low or lacking. Majority of them (70.7%) were not aware while 29.3% were aware. Observations made during the study shows that most farmers and farm workers do not take any precautionary measures as regards themselves and the environment when using pesticides as a result of their level of awareness. Some common practices which had potential of exposing farmers and farm workers to pesticides in the study area included; wearing unwashed clothes from previous spray, mixing pesticide with hand or bottle, wetting feet, hand and body during spraying and soaked clothes with pesticide when spraying. Both the farmers and farm workers indicated that they experienced discomforts such as headaches, tiredness, vomiting, nausea and dermal problems like itching and skin burn after spraying. A total of 29 health effects were reported. Itch skin accounted for 20.8% followed by runny nose with 13.1%, dry throat 9.3% (Table 1).

Table 1: Reported health effects due to commonly used pesticides

<table>
<thead>
<tr>
<th>Reported Health Effects</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itchy Skin</td>
<td>20.8</td>
</tr>
<tr>
<td>Runny nose</td>
<td>13.1</td>
</tr>
<tr>
<td>Dry throat</td>
<td>9.3</td>
</tr>
<tr>
<td>Dizziness</td>
<td>6.0</td>
</tr>
<tr>
<td>Headache</td>
<td>6.0</td>
</tr>
<tr>
<td>Difficulty breathing</td>
<td>4.4</td>
</tr>
<tr>
<td>Fatigue</td>
<td>4.4</td>
</tr>
<tr>
<td>Cough</td>
<td>3.6</td>
</tr>
<tr>
<td>Burning nose</td>
<td>3.3</td>
</tr>
<tr>
<td>Flushed face</td>
<td>3.3</td>
</tr>
<tr>
<td>Sore throat</td>
<td>3.0</td>
</tr>
<tr>
<td>Burning tongue</td>
<td>2.7</td>
</tr>
<tr>
<td>Itchy eyes</td>
<td>2.7</td>
</tr>
<tr>
<td>Vomiting</td>
<td>2.5</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>2.2</td>
</tr>
<tr>
<td>Burning eyes</td>
<td>2.2</td>
</tr>
<tr>
<td>Staggering</td>
<td>1.9</td>
</tr>
<tr>
<td>Stinging eyes</td>
<td>1.6</td>
</tr>
<tr>
<td>Excess sweating</td>
<td>1.1</td>
</tr>
<tr>
<td>Muscle weakness</td>
<td>1.1</td>
</tr>
<tr>
<td>Others (Nausea, Red eyes, Salivation e.t.c)</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Level of awareness on the effect of improper use and disposal of pesticides on the environment
Of the farmers and farm workers who were knowledgeable about the effect of improper use and disposal of pesticides to the environment, 42.2% cited that water was affected, 21.7% cited soil contamination, 18.1% cited air pollution while 18.1% mentioned all of them i.e. water, soil and air were affected (Fig.3).

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>42.20%</td>
</tr>
<tr>
<td>Soil</td>
<td>21.70%</td>
</tr>
<tr>
<td>Air</td>
<td>18.10%</td>
</tr>
<tr>
<td>All of the above</td>
<td>18.10%</td>
</tr>
</tbody>
</table>

Fig.3: Level of awareness on the effect of improper use and disposal of pesticides to the environment

Precautionary measures used by pastoralists
Personal Protective Equipment
The proportion of farmer respondents that wore protective materials, gloves, boots and goggles when applying or mixing pesticides were 16.7% while 83.3% did not. This is despite the enormous hazards they face if they ignore these precautions. Among farmers who used personal protection equipment; gumboots, coats / jackets and overalls were the most common types of body protection used when applying pesticides. Some respondents said they did not put on goggles and boots because they were not able to see well nor did they wear boots which would be heavy and uncomfortable. Low proportion of the farmers and of farm workers observed the instruction on the direction of wind to face when spraying chemical pesticide. Reasons given for this by some respondents were that this information was not on the label and as such it was not considered necessary. This predisposes them to contact with chemicals on their unprotected body.

Preference of using protective clothing
The farmers and farm workers who indicated that they experienced discomforts such as headaches, tiredness, vomiting, nausea and dermal problems like itching and skin burn after spraying, 75.6% expressed their need to use protective clothing. Reasons cited for wanting protective clothing included protection against open wounds, coughing, sneezing and eye irritation, among others. Those that were employed reported that their employers did not have any concern about their safety while others blamed the marketers of these pesticides.

Level of adoption of precautionary measures while applying livestock pesticides
Disposal of the unused/left over pesticide wash
Majority of the respondents who participated in this study reported that they poured on the ground any unused/left over pesticide (61.4%), 7.2% reported that they washed off into water source, 21.7% dag into the ground while 9.6% cited other means (Fig 4).
Storage of farm chemicals
From the gathered information, 55.7% of the respondents kept their pesticides in stores while 44.3% did not. Of the 55.7% who store their pesticides, majority kept it away from the main living house, few kept in their bedroom while the rest kept them in bedrooms, the sitting rooms or kitchens. There were some who stored it on tree top rapped with plastic paper bags.

Disposal of pesticide containers
A total of 124 respondents reported that they disposed empty pesticide containers by burning, burying or both burning and burying. Farmers indicated that they disposed of pesticide container by burying (32.0%), burning (15.5%) throwing into refuse heaps (29.9%) and hiding in thicket (8.2%). Those that did not practice any disposal method were only 14.4% (Fig. 5). However, some farmers washed and reused their pesticide containers for other uses such as storing cooking oil. Some empty containers were observed left at the site of mixing pesticides.

DISCUSSION
Demographic characteristics of respondents
Age is a significant factor in livestock information accessibility and utilization. Majority of the respondents (85.9%) were aged between 18 to 60 years. This implies that most of the respondents fell
within the economically active age. Young people (farmers) are more responsive to new ideas and practices while older ones are conservative and less responsive to adoption of new ideas and practices (Okwu et al., 2007). Most respondents were pastoralists. These findings agree with those of Okello et al., (2014) that most members of the Maasai community of Kenya are livestock keepers. In a related study, Ogutu et al., (2013) also observed that most residents of Kajiado County were also pastoralists. Similar observations were also made by Kioko and Okello (2010) who reported that pastoralism was still the most widespread economic activity among the Maa speaking ethnic group of Kenya. Despite livestock keeping being dominant, several studies have, however, pointed to the emerging livelihood diversification among Kenyan pastoralists. As noted by Kioko and Okello (2010), trade, formal employment, cultivation and ranching were rapidly replacing the traditional subsistence pastoralism in Narok and Kajiado Counties of Kenya. This has been mainly informed by the need to reduce environmental risks associated with pastoralism and to capitalize on the emergent social and economic opportunities. Other factors known to be influencing livelihood diversification include frequent long and severe droughts, outbreak of zoonotic diseases, shrinking available land for pasture and diminishing livestock numbers occasioned by massive livestock deaths during droughts (Seno and Shaw, 2002; Ogutu, 2002; Campbell et al., 2003). Norton-Griffiths, (2007) and Homewood (2009) further reported that meagre returns from wildlife, changing food preferences and lifestyles have also triggered livelihood diversification. The above findings corroborate with those observed under this study.

In terms of literacy level of awareness and practice for the pesticide use precautions, majority of the respondents (59.8%) had no formal education. This demonstrates that very few pastoralists and agro-pastoralist go beyond primary education, which perhaps explains the high level of unemployment. These results corroborate with those recorded in Narok County Integrated Development Plan 2013-17 that most pastoralists had no formal education. However, these results contradict those observed in the Kajiado County Integrated Development Plan 2013-17 (GoK, 2013) which recorded that a greater percentage of the population in these areas had attained secondary education.

**Levels of awareness of the adverse effects of pesticides, their disposal mechanisms and adoption of precautionary measures during their application on livestock**

Results show that pastoralists’ knowledge and awareness on the effects of these pesticides to the environment is low or lacking. Observations made during the study show that most farmers and farm workers did not take any precautionary measures as regards themselves and the environment when using pesticides as a result of their level of awareness. This low level of education reported by both farmers and farm workers must have contributed immensely to their low level of awareness and their unsafe use of pesticides. All pesticide users have the responsibility to properly dispose of pesticide wastes, such as unused chemicals and pesticide containers. Improperly disposed pesticide wastes can create serious hazards for humans, animals, and the environment through poisoning and degrading the quality of the environment. Storing or keeping pesticides in any place other than stores located on farms or far away from living areas exposes users and non-users (most especially children) to hazards associated with these pesticides. Some empty containers were observed left at the site of mixing pesticides. Such practices posed health hazards to the farmer and his family because several traces of these pesticides might still remain in the containers after washing. Similar methods were indicated by the farm worker respondents.

Pesticides are commonly used by livestock keepers for protection against pests and diseases that attack animals (Ngowi et al, 2007). Occupational exposure to pesticides occurs through poor hygiene practices and lack of proper personal protective equipment (Rusli et al., 2002). Studies have reported that only small percentage of the sprayed chemicals actually reach the targeted livestock, with most drifting to surrounding areas and eventually becoming an environmental contaminant (Panagiotis and Weili, 2008). In this study, it was observed that exposure was mainly due to poor protection of the body during pesticide application leading to contact of the chemical with the body. This may have contributed to the high percentage of reported dermal (20.8%) and eyes (9.8%) related health problems among the study participants.
group of farmers. The farmers claimed that the marketers showed little or no concern about provision of incentive or compensation after reporting unusual symptoms resulting from pesticide use. Majority of the farm workers reported that their employers (farm owners) show little or no concern about the provision of incentives or compensation to protect them from the hazards of these pesticides.

Farm workers are usually at greater risk of exposure to pesticide than non-farm workers (Calvert et al., 2008) hence there is need for personal protection equipment. In this survey only 16.4% of the farmers reported that they use personal protection equipment in spite of most being aware of its importance. One of the reasons given for not using protective equipment was that the equipments were too expensive hence unaffordable. Others said the equipments were unavailable or they were not supplied with any by the employer. These observations agree with those of Malin et al., (2004) in a study carried in Butajira, Ethiopia on conditions of pesticide management and possible health hazards. In this study, the common practices which led to exposure of human to pesticide were, wearing unwashed clothes from previous spray, mixing pesticide with hand or bottle, wetting feet and hand, wetting body during spraying and soaking of clothes with pesticide when spraying.

A total of 29 health problems were reported. Itchy skin was most common as a single health problem and contributed to 20.8% of the recorded health effects. This finding can be attributed to the common practices leading to exposure as reported in this study where 23.7 % of the respondents reported wetting their feet and hands when mixing pesticides and another 17.8% reported wetting feet and hand as well as the body and clothes during spraying. Farmers should never pour pesticides down the drain, on the ground, or in a storm sewer. They also, never bury or burn pesticides and/or pesticide containers unless directed by the pesticide label.

CONCLUSION
This study revealed that even though there were attempts at diversifying livelihoods in Narok South District, pastoralism was still the most dominant and as such, residents of these regions still valued the traditional subsistence means of livelihood. Moreover, level of education was still low as most respondents had no formal education. This exacerbated the state of ignorance to the hazards of pesticides on human health and environment leading to adverse effects such as itchy skins and other avoidable hazards.

RECOMMENDATIONS
This study recommends that National Government in conjunction with the County Government of Narok provide an enabling environment for livestock rearing. Even so, these levels of government should enhance livelihood diversification in the study area to buffer pastoralists against the adverse effects of climate change and variability which leads to massive livestock deaths and consequent loss of livelihoods. In order to minimize the environmental and health hazards associated with pesticide use, the government and other stakeholders should, in short-term, conduct a public awareness exercise on the hazardous nature of pesticides, providing protective wear for free or at subsidized prices to the pastoralists. To achieve long-term protection to health and environment, there is need for this community to be enlightened on the benefits of Integrated Pest Management as opposed to use of pesticides.

REFERENCES

GOK-2013: Kajiado County Integrated Development Plan 2013-2017


DEPLOYMENT OF QUALITY EDUCATION AND HEALTH FOR ENVIRONMENTAL CONSERVATION AND RENEWABLE ENERGY DEVELOPMENT

INDIGENOUS METHODS OF EDUCATION AS PRACTISED BY THE KIPSIGIS

Bii, Sammy Kipkorir
Department of Educational Foundations, Kenyatta University
E-mail sammykipkorirbii@gmail.com. Phone 0728516951

ABSTRACT
This paper presents an overview of indigenous methods of education used by the Kipsigis and its Relevance to modern education. The article is descriptive and relied heavily on published works. It shows that Kipsigis instructed children through formal and informal methods. Informal methods of instructions included involving children in productive work and observation. The boys were engaged in looking after livestock while girls looked after younger brothers and sisters. Children also learnt how to observe. They also learned through play. Other forms of informal methods were myths, legends folklores, riddles and songs. Myths are regarded as tales imaginatively describing or accounting for natural phenomena. The Kipsigis had songs for various occasions. Besides the numerous folksongs with which children were associated with as they grew up, there existed rich children's oral literature. Folktales among Kipsigis were based on day to day happenings. Asking of riddles was a very special form of amusement. Some riddles seemed to be simple while others were complex. Proverbs were used wisely in ordinary conversation. Formal methods of instructions were initiation and apprenticeship. The period of circumcision was the most important time in the life of the Kipsigis. It marked the passage from childhood to adulthood. Medicine was widely practiced in Kipsigis pre-colonial times. When children were sick or ill, the mother was responsible for giving advice and first aid before the father’s assistance was resorted to. Men and women learned this skill from their parents. There were individuals who were recognized as better herbalists. A person who wanted his child to learn the skills from a specialist would pay a fee and training took a period of time. The skill of iron work was transmitted from father to son. Weaving was done by women and was taught to girls. The art of pottery was learnt by the Kipsigis women from Luo and Abagusii. There were two methods of instructions used by the Kipsigis to teach their children in pre-colonial times; these were formal and informal methods.

Keywords: Informal and formal methods, Myths, Legends

INTRODUCTION
This paper presents an overview of indigenous methods of education. Informal education was a lifetime process and it involves acquisition of values, knowledge and skills relevant to the day-to day affairs of the society. The process of training was done according to age and sex. Training for social roles was accomplished through formal introduction given during initiation and apprenticeship training; initiation marked the passage from childhood to adulthood and tested a younger ability and formally concluded learning before admitting him or her to the adult community. The initiation of both sexes significant a distinct period of formal teaching and examining with specifically selected and experienced elders giving instruction and setting test. Apprenticeship training was applied in the arts of medicine, iron work weaving and pottery.

Informal method as used in this study refers to a lifetime process which involved acquisition of values, knowledge and skills. Myths are regarded as tales imaginatively and describing or accounting for natural phenomena or tales about gods or things which were beyond the understanding of men’s. Legend is regarded as a tale fabricated to account for real event that took place or was believed to have taken place in time immemorial. Proverbs were the condensed wisdom of the great ancestors. The main objective of this paper is to illuminate our understanding of indigenous methods used by the Kipsigis to instruct their children.
METHODOLOGY
This paper is largely descriptive; it has used written text to examine method of instruction used by the Kipsigis

DISCUSSION
Informal method
Rono (2000) point out that the Kipsigis instructed children through informal and formal methods. Informal education was a life time process and it involved acquisition of values, knowledge and skills relevant to the day-to-day affairs of the society. Informal method of instruction included involving children in productive work and observation.

A child was expected to learn by seeing and imitating, it could only be given formal teaching after it had made a mistake or when the outcome of its work was found unsatisfactory. The process of training was done according to age and sex. Training for social roles was accomplished through informal instructions given by person already filling those roles. These were often members of one’s own family or kin group. Other forms of informal education were myths, legends, talk cores, riddles and songs.

Sifuna and otiende (1994) content that myths are regarded as tales imaginatively describing or accounting for natural phenomena or tales about gods or things which were beyond understanding of men. There were tales about imaginary events, tales which tried to explain the beginning of things. An example of the myths is about the seven brothers which are today known as seven groups of Kalenjin.

The seven brothers
Long ago, there was a man who was very poor. He decided to leave his country in the North and look for better place. This place was called Emetab burgei because it was very hot. He travelled a long a big river until he came to a very big lake. While at the lake he prayed to the sun Asis for help from his poverty. Suddenly he was given many cattle and also a wife. Soon after marrying this wife, the man gets seven sons. Owing to his great wealth and blessings of children, the man became very arrogant and selfish. He even refused his sons to marry because of this selfishness. Eventually, he lost all his wealth. His wife left him and married someone else who had cattle. The sons also left him and decided to start their own families.

The seven brothers travelled together looking for good land for their cattle. This way they scattered and settled in different places. Each married and had their own children. Only Nandi and Kipsigis were left as each other’s companion. Nandi and Kipsigis lived together for a long time. Eventually a time came when their land was too dry and they had to look for better land for their cattle. At this time they decided to separate so that each man and his family could get enough land. Nandi moved his people and settled in Aldai. Kipsigis moved southwards. He passed a hill which he named Tulwop Kipsigis (Hill of Kipsigis). Finally, he settled in Kericho and his children and cattle increased in great numbers. Today the seven brothers are known as the ancestors of the seven group of the Kalenjin (chesaina 1991).

Ocitti (1973) observed that legends were tales fabricated to account for real events that took place or were believed to have taken place in time in memorial. Like myths, legends sounded
like fairy tales but were fragments of actual history. They were closer to real life than myth. An example of the legend is the origin of the cooking of ugali.

**The origin of cooking ugali**
Long ago the Kipsigis did not know how to cook ugali. They ground grains mixed with a little water and left it to soak. A childless woman who was desperately anxious to have a child, undertook to look after a neighbor who was about to have a baby. When she was preparing food for the mother to be, the childless woman thought to herself: “If I put this food on the fire and then give it to her, it will probably make her so ill that she will die and then I shall keep her child”. So she cooked the food after preparing it in the usual way and gave it to the woman who presently began to sweat. After looking at the sweating woman the childless one said to herself “she is ill already! I will go to the field so that when she is dead I can return and say I wonder how she died”. When she reached the field she saw that the sun was very hot and the ground was very dry, she pulled out the bracken from the other woman’s crop and use it to shed her own. When she returned home she found that her patient was still alive, so on the next day she boiled the food in same way and gave it to the expectant mother. Although boiled food was given to the patient every day she got fatter and fatter until all the neighbors remarked on it. First one tasted the boiled food and then another, until they agreed the food was good (Chesaina 1991).

Rono (2000) point that the Kipsigis had songs for various occasions. Besides the numerous folksongs with which children’s were associated as they grew up there existed rich children’s oral literature. There were many children’s songs lullabies and tongue twisters. These were learnt, recited and sung by children during free time, enabling them partly to gain mastery of their mother tongue. Apart from the fun derived from them. They also helped to promote the mental development of children.

Examples

**Don’t cry baby**
Quiet my brother
Don’t cry baby
So mother may be come back
From the farm with some grains
The grain of millet
Sleep, now our child
Our mother is on the way
Quiet my brother (Chesaina 1991)

**Fresh milk**
Cheruto, please go to the market
Cheruto, please go to the market
Go and buy salt
How much salt?
For fifty cents
How much salt?
For seventy five cents
The cow bellowed, mboo
The cow bellowed, mboo

Proceedings of the Fourth International Research Conference
The child replied thank you
For giving me fresh milk
The goat bleated, mbee
The goat bleated, mbee
The child replied thank you
For giving me fresh milk. (Chesaina, 1991)

Rono (2000) claimed that folk tales among the Kipsigs were based primarily on day to day happenings. Most of these bore very close relationships to life. Much of the ethical teaching children received come from folktales, most of which had happy endings and involved triumph over difficulties. Virtues such as communal unity, handwork, honesty, courage and conformity were reflected in many of the folk tales. Children learnt a lot about human follies, faults and weaknesses. The usual time for narrating folk tales was evening by the fireside.

Examples
The man who never attended public gatherings
Long ago, men used to go raiding for cattle. Whenever the elders gathered in order to discuss these raids, there was one man who always absented himself. He would always ask “what am I going to do at the meeting?”

One day the men met to discuss a dangerous raid. They decided to use a certain password on this particular raid. They said;’ if we come across a monster each person should tell it: “wait for the person behind to carry you across”

On the appointed day, the warriors did as they had resolved. The man who never attended public gatherings brought the rear. The monster approached him to carry it across. The man who never attended public gatherings asked the monster “there were all men who passed through this road why did you not ask them to carry you across?” The monster replied: “they told me wait for the person behind” The man who never attended public meetings said “climb on”

The monster climbed on the man who never attended public meetings, ate him up and finished him completely.

From that day every man made a point of attending all public gathering (Chesaina 1991)

Sifuna & Otiende (1994) explained that the judicious use of proverbs was usually regarded as sign wit. Proverbs were the condensed wisdom of the great ancestors. In proverbs one or two moral ideas were contained in a simple sentence. Most of them referred to different aspects of the socio political life. Old people and the parents used them in their dealings with children to convey moral lessons, warning and advice, since they made greater impacts on the mind than ordinary words. Example of proverbs are:

Proverbs on fate
You cannot take away someone else luck. This means your future or good luck is yours nobody can take it away from you.
This proverbs remind people that youthfulness is experienced only once in a person life.
Nobody can graze for another
Once fate is his alone. Nobody can assume someone else destiny
Death and laughter are brothers. This proverbs remind people about inevitability and proximity of death.
**Proverbs on initiative courage, determination and perseverance**

While waiting to eat the head on the bull,
We continue eating the head of grasshoppers
Encouragement to those who are in problems not to despair.
Struggle right and left,
One should struggle in all ways it is not advisable to give up before one has tried off many available.
Water does not stay in the sky forever
Suffering is not everlasting therefore one should not despair (Chesaina 1991)

Cautionary proverbs
If you live with a thief you also become a thief. This is a warning against exposing oneself to a bad influence.
Do not show a bone to a hyena.
Avoid courting trouble. Once you court trouble, you have to face consequences.
Do not follow a person who is running away.
Avoid being to mislead.

Proverbs on communal life.
Bees cannot get finished from a beehive.
We cannot expect everybody in a community to be perfect; it is inevitable to undesirable elements.
It is best for us to be like a tall tree.
A great deal can be achieved through units.
Many hands can uproot a mountain.
Many hands make work lighter (Chesaina 1991)

**Riddles**

That which says ‘Kurkar’ – mouse
As flexible as a wrist chain-snake
I put it upside down and it does not spill-cow’s teat
I met my father carrying arrows-porcupine
That which stand the whole night-cow’s horn
I have a child who washes herself all the time-fly
I went on a visit and slept on top of a tree-safari ant
It is coming slowly downhill-caterpillar
Pepper in the ceiling-cockroach (Chesaina, 1991)

**Formal methods of instruction**

Bogonko (1992) stated that formal instructions were given during initiation and apprenticeship training. Orchardson (1959) content that the period of initiation was the most important time in the life of the kipsigis both for the individual initiate and for the whole community. It marked the passage from childhood to adulthood and tested youngster’s ability and formally concluded learning before admitting him or her to the adult community. The initiation for both sexes signified a distinct period of formal teaching and examining with specifically selected and experienced elders giving instructions and setting tests.

A few weeks or months before start of ceremony, a site was selected for the boy’s seclusion hut ‘Menjo’ which was located away from the homestead. The building of the hut ‘Menjo’ was done
by candidates for initiation with assistance and instructions of young men from the neighborhood. These practical tasks associated with circumcision and training of boys gave them foundation of building their own houses when they were adults. Candidates were sent to invite their close paternal and maternal relatives to the beer party to be held at their home at the start of initiation. Each invited guest give instructions and advice to the candidates pertaining to the endurance.

Persistency (1939) point of that, before actual rite took place, boys underwent severe test of their endurance. On day of circumcision were stung with thistles as a test of their courage. As initiation approaches, the teasing that had been occasioned throughout the boy’s life become frequent. As he went about his activities, men would stop him and inform him that he would be circumcised by fire and generally he would be reminded that the process was very difficult one. In the last days before initiation, the candidates in the evening at each other’s homes to practice initiation songs to be sung the night before the operation. In these songs, boys were reminded to heed the advice and instructions given by their seniors.

Rono (2000) explain that on the day of ceremony, the candidates got up very early and gathered in one of the homes and many boys joined them. These large group then went off to collect sacred plants ‘Korosek’ and ‘Sinendoik’ to be used that evening. At night, songs full of advice about endurance and perseverance on the part of the initiation were sung. Later, the candidates would be taken to the central home where they were taught lessons about the importance of courage and other related social virtues. In this central place, candidates were lined up in the order in which they would go through each part of the ceremony. This was in the order of the age or age set of their fathers with son or daughters of the most senior coming first and being known as ‘Kiboretiet’. The initiation of the second most man was placed last and was called ‘Koyumgoi’ (the one herds the other’s home). The other candidates were placed in line in descending order according their father’s age set. Initiates were trained to attach great respect to seniority, particularly to their fathers.

Fish & G. Fish (1995) claim that, the next morning as soon as the sun got warm or about 7:00 am, the actual operation begun for the girl initiates but for the boys it took place a bit earlier, as early as five o’clock in the morning. Boys were circumcised in their individual ‘Menjo’ huts. Girls were circumcised in the central place; usually outside the house of a well-off person. The actual circumcision was cutting off the boy’s foreskin and cutting off clitoris for the girls. After the operation, caretakers took their charge in hand. The girls were led away to the various homesteads where they would be put in the seclusion. The movement also took a form of an emotional and dramatic event, culminating in the reunions by clans and close relatives on the way. This marked test of the initiate bravery. Any girl who failed the test was finally expected to be married by an old or sick ling man of the community. Sometimes, some clans excommunicate such members. After this, elders teach candidates rules of behaviors. They were taught to be obedient throughout the period, listen to instructions carefully and make no complaints even when mistreated.

Orchadson (1959) point at that the second ceremony was Labe tap eun (the dipping of the hands) which took place after a prolonged period of seclusion. Education for the two sexes differed in methodology and curriculum because they were trained to play different roles in society, for example boys were given instructions on military techniques and skills.
This was an important task of boy’s courage. Candidates were taken to stream by their instructors, dipped their hands in the water, washing off their uncleanliness, including their childhood activities. They were allowed to handle and given tools and weapons such as Machetes, knives, axes and arrows and spears. They were taught how use them both for domestic and external purpose. In the evening, the candidates were shown various constellations of stars and planets called ‘Taboita’ which they were taught to recognize. This was a metaphor for blessings during procreation. For the boys, kinship knowledge was imparted by their father’s. Sometimes; sponsors assumed their role. Boys’ in initiates had to know their genealogy and their exact position in the clan. They were farther secluded in a state of limited mobility in which they practiced physical skills of manhood such as making bows and arrow, walking sticks and similar articles for shooting birds. Rono (2000) observe that the ceremony of labet ap eun for girls had some similarities to that of boys. The initiates were taught some basic songs to sing led by some old women. Above all the importance of cattle to the community was emphasized at every stage in this process. Here, every morning and evening when cattle went in and out, the girls were instructed to sing praise to them. Usually girls were instructed by their mother for whom they had great respect. Following labet ap eun ceremony, the initiates were taught virtues of love, generosity, courage and responsibility. Formal teaching through songs (tienninet) commenced at this stage. The initiates sang every early morning before and after each meal and every evening. The songs were archaic in language. They had lessons in proper behavior in relation to elders, parents, peers, opposite sex and children. The men usually took turns testing boy initiates with the latter having to answer questions carefully, systematically and correctly.

Peristaiany (1939) states that boys were taught what they could and should do what they should not do in terms of controlling natural calamities such as rain. They were advised to love and defend their communities from external attacks. Boy initiates were also taught sense of oneness, character formation, loyalty to clan and age set and importance of individual place in the community. In addition, they were taught good behaviors and kindness and were forbidden to use bad language or quarrel as this would bring curse to him and to the society and would find difficult to obtain a wife. The girls during ‘Tienjiniet’ were expected to kneel down and put a basket on her head while holding a stool in each hand with a stool placed on her back. She was instructed by her sponsors and elderly women to move four times round central wall of manure with touching the ceiling with her basket. She was prohibited to touch the floor with her stool. The stool was not allowed to fall off. This was a test on psychomotor skills of the girls, particularly on how to carry of many loads of possible in anticipation of domestic chores which could involve carrying heavy items from one place to another. It was also learning the skills of balancing. girls receive socialized knowledge on milking techniques, sing, praise to their men-be husbands, clan and other community members also they were taught how to keep their houses tidy and clean gourd as well art of cloth making.

`Kayaet ceremony was the fourth stage and it took place at night for both sexes. The initiates were led by their instructors (motirenik) down to a stream. In both cases emphasis at this stage was a ritual purification.

The initiates were made to swear that whatever they saw during seclusion and whatever they had been taught at any other stage of initiation would not be revealed to the young children or other an initiatively within community or outside. If they did, they taught that they would not prosper in future. At this stage, girls were allowed to do all domestic chores, particularly
cleaning their houses and grinding grain, however, they were not allowed to cook. Their chief occupation was to sew their new dresses (sirek) which were hemmed with beads in readiness for their coming out (ngetunet).

The fifth and last stages were more ritualistic than the previous ones. It was called yatet ap oret (opening of the way). The emphasis placed was ritual protection against death for example those initiates who had lost at least three brothers older than them would squirrel or blue monkey skin. During this stage, the boy initiates mother formally recognized and anointed him as was the case during beginning stage of initiation. This implied that the young man was respected by the mother and had accepted him as any adult. The newly initiated man now took the title `arap` before his name.

Rono (2000 & peristiany 1939) observe that ng’eetunet (coming out) ceremony, girl initiates were taught how they should behave towards their husbands and how to interact with other members of the community as pertains to their social and moral conduct. Also girl initiates were given instructions and advise on ways and means of looking after husband’s property, especially cattle. The initiates were trained to protect themselves against evils they would meet in the life ahead. Social conduct in the family and in other circles was emphasized. Girls were equipped with ritual powers to handle misfortunes. This stage constituted final break with childhood where clothes worn in the previous stage was removed and new ones put on. In addition, old hair was shaved off to mark the entry into new a new life.

By taking the child out of the home environment, the initiation rites emphasized that an individual must be responsible to the whole society and that the community and family had an interest in him

Apprenticeship training
Rono (2000) explained that medicine was widely practice in Kipsigs in pre-colonial times. When children were sick or ill, the mother was responsible for giving advice and first aid before the father’s assistance was resorted to. She fetched different types of curative leaves, roots and juices of particular trees. Men and women learnt their skills from their parents. Girls were taught to collect medicinal herbs from forests by mothers; in initial stages, they were accompanied by mothers to the forest and learn right types of medicinal plants. There were individuals who were recognized as better herbalists. They came from special clan Kapkerichek. A person who wanted his/her child to learn their skills from the specialist would pay a fee and the training took a period of time. The apprentice learnt through observation and participation.

Persons practicing witchcraft did this in secret and even trained their children in the art. When discovered, a suspected witch was driven out of his/her own home to live with maternal uncles; others could be subjected tom death through strangling. There were some specialists in exercising witchcraft; they passed skills to their offspring’s.

Rono (2000) content that iron working was a major economic activity. The skills of iron work were transmitted from father to son. Blacksmith, ‘Kitongik’ made hoes, knives and weapons. Weaving was practiced by women and was taught to girls. The skill a girl obtained depended on personal interest in skills practiced by her older sister, mother or grandmother. She learnt through observation and participation. The art of pottery was learnt by the Kipsigis women from the Luo
and Abagusii. In pottery, all the work from the start to finishing was done by women; the digging of the clay, beating and softening it, the molding and drying and the burning of the pots. They made pots of different sizes and shapes for various purposes.

CONCLUSION AND SUMMARY
There were two methods of instruction used by the Kipsigis in pre-colonial time. These were formal and informal methods. A child was expected to learn by seeing and imitation. It could only be given formal teaching over it had made a mistake or when the outcome of its work was found insanitation. Other forms of informal education were myths, talk, riddles, and songs. There were also other forms of teaching which were essentially formed. Learning through apprenticeship was formed, and direct parents who wanted their children to acquire some exceptional training normally sent their children to work with graft men such as potters, blacksmiths, and basket makers who could then teach them formally. Formal education also took the form of initiation.

REFERENCES
HIV TRANSMISSION TO INFANTS IN RELATION TO MODE OF FEEDING AND MOTHER’S IMMUNOLOGICAL STATUS IN KIRINYAGA COUNTY

Njagi, Catherine
Department Zoology, Kenyatta University P.O. Box 43844 – 00100 Nairobi.
E-mail: njagicatherine69@yahoo.com Cell phone: 0722892521

ABSTRACT
The assertion that most children die of HIV/AIDS before celebrating their eighth birthday is the motivation for studies unveiling the correlation between HIV transmission and the mode of feeding among infants. By 2014, it was estimated that worldwide, 2.6 million children below 15 years were living with HIV while more than 90% were infected through mother to child transmission (MTCT) during pregnancy, delivery and breast feeding. In Kenya, there were about 12940 children while 1480 of these were from Kirinyaga County. The Kenya government has put intervention measures to reduce these infections through access to highly active anti-retroviral therapy (HAART) and elective caesarean section. These are intended to decrease the MTCT rate to below 2% and reduce new pediatric HIV infections by 90% by 2017. The study conducted laboratory research in order to establish the main outcome among women and infants accessing a local programme for PMTCT of HIV. The research followed, for 18 months, records of 303 HIV positive mothers who had given birth to live infants along variables of anti-retroviral drugs and mode of infant feeding in the first six months. CD4-count and viral load tests were performed on all women after delivery to evaluate the indication to ART treatment and monitor the mother’s immunity. HIV testing on the infant was performed 6 weeks after birth through PCR. Antibody tests were done at the 9th and 18th months using rapid test with either Unigold or Determine strips. In cases where positive the first PCR negative, confirmatory PCR tests were performed. Data was analyzed using logistic regression models involving student t-test chi-square tests with 95% confidence interval as the set confidence limit in univariant analyses. The result indicates that replacement feeding is ten times safer than breastfeeding and should therefore be embraced.

Keywords: Immunological status, infants, mode of feeding, CD4-count.

INTRODUCTION
Most children in many developing countries die before their eighth birthday due to ailments that include malaria, measles, pneumonia, common cold and HIV. Of the diseases, HIV is of great importance. Over two thirds of these deaths are in sub-Saharan Africa. It is estimated that worldwide, 2.6 million children younger than 15 years were living with HIV in 2014 with Kenya having about 12940, while 1480 were from Kirinyaga County. More than 90% had been infected via mother to child transmission during pregnancy, delivery and breast feeding (NACC-UNAIDS 2014). Developed countries have achieved remarkable progress in reducing HIV infections to below 2% by scaling up access to highly active anti-retroviral therapy (HAART), elective caesarean section and formula feeding as replacement to breastfeeding. However, in developing countries, more than 90% of new pediatric HIV infections occurs each year. Most of these countries have expanded access to comprehensive and more efficacious PMTCT interventions by use of ARV. For example, by December 2009, 22 countries, Kenya included had reported antiretroviral coverage rates of more than 50%.

The benefits of breastfeeding relating to nutrition, prevention of common childhood illness, child spacing, reduction in infant and child morbidity and mortality are well described in various studies (WHO, 2000; Coutsoudis et al., 2005; Kekuta et al., 2005). However in recent years, there has been conclusive evidence that breastfeeding confers a significant risk of HIV transmission from an infected mother to child (De Cock et al., 2000; Coutsoudis et al., 2005). Globally it’s estimated that 20,000-35,000 infants contract HIV via prolonged breastfeeding up to 2 years (De cock et al., 2000). Option B of WHO recommends that all HIV positive pregnant women receive HAART starting at different stages of their pregnancy. Mothers who do not meet the WHO criteria for affordable feasible accessible safe and sustainable
formula feeding continue ARVs throughout the entire breast feeding period (NASCOP KENYA, 2011). This study investigated the effect of exclusive replacement feeding option on the HIV status of the newborn babies especially for mothers whose immunity was low and had very high viral load.

**Objective**
The objective of the study was to investigate whether exclusive replacement feeding could be a better option especially for mothers whose immunity is low and have very high viral load.

**METHODS**
The study was carried out at the PMTCT clinic in Kerugoya county referral hospital in Kirinyaga County, which acts as the referral hospital for patients from Kianyaga and Kimbimbi sub-district hospitals as well as the 12 health centres and 63 dispensaries supported by the Ministry of health. There are a total of 259 health facilities in the county whose population is about 572889. Kerugoya is at 0° 30’ 0” N and 0° 36’ 01” S latitude and a longitude of between 37° 19’ 6” to 37° 17’ 17” E. It is located about 100km from Nairobi city and has a temperature of between 12°C to 30°C (appendix iii). Majority of the residents are farmers with business people concentrated in the towns and shopping centres. Kerugoya town is the administrative headquarter with a population of about 150000 people which is about 25% of the general county population. HIV prevalence is about 4.4% with women having twice the rate compared to men, with 3% men and 6% women. The general infant mortality rate is 39.2 per 10000 births. Children under five years of age have the highest mortality rate taking 59.2 per 1000 deaths. Maternal mortality rate is about 530 deaths per 100,000 live births (NACCK, 2008).

The study involved all the HIV-infected pregnant women who accessed the perinatal and HIV-PMTCT services at Kerugoya district hospital between August 2011 and September 2014 and delivered live newborns. About 303 HIV positive mothers were followed from the time they visited the PMTCT clinic, at delivery until their infants got to 18 months of age. Information regarding the method of infant feeding, which was either; EBF, ERF or mixed feeding in some case was got from the mothers. Research permit was obtained from the ministry of education science and technology, the ethical committee of Kerugoya district hospital, the district medical officer of health (MOH) and clearance from Kenyatta University ethical review committee.

HIV status in children was carried out using the polymerase chain reaction test (PCR) for all the children at the age of six weeks after birth, then rapid HIV whole blood test was done at an interval of three months until the infant was eighteen months of age, whereby if the test was found to be positive a final PCR test was carried out for confirmation.

**Data Analysis**
Data was analysed using logistic regression models and was compared by student’s t-distribution and the chi-square test. Significant levels were set at 0.05 and a 95% CI for HIV transmission or death.

**RESULTS**

**Mode of feeding**
The table below presents the feeding practices of the enrolled mothers. The proportions of the mothers who had practiced exclusive breastfeeding and exclusive replacement feeding were, respectively, 77.9% and 22.1%. Additionally, 29 mothers (9.6%) reported switching from breastfeeding to replacement feeding during the study period, most of whom did it within a period of six months from birth or less (58.6%). Seven mothers (2.3%) practiced mixed feeding.
Table 1. Description of the feeding approaches used by the enrolled mothers

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No.</th>
<th>%</th>
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<tbody>
<tr>
<td>Initial feeding (n=303)</td>
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<td></td>
</tr>
<tr>
<td>Exclusive breastfeeding</td>
<td>236</td>
<td>77.9</td>
</tr>
<tr>
<td>Exclusive Replacement Feeding</td>
<td>67</td>
<td>22.1</td>
</tr>
<tr>
<td>Switched from breastfeeding (RF) to Replacement Feeding (RF) (n=303)</td>
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<td></td>
</tr>
<tr>
<td>Yes</td>
<td>29</td>
<td>9.6</td>
</tr>
<tr>
<td>Number</td>
<td>274</td>
<td>90.4</td>
</tr>
<tr>
<td>Age of switching from BF to RF (n=29)</td>
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<td></td>
</tr>
<tr>
<td>≥6 months</td>
<td>17</td>
<td>58.6</td>
</tr>
<tr>
<td>&lt; 6 months</td>
<td>12</td>
<td>41.4</td>
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<tr>
<td>Mixed feeding (n=303)</td>
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<td></td>
</tr>
<tr>
<td>Yes</td>
<td>7</td>
<td>2.3</td>
</tr>
<tr>
<td>No</td>
<td>296</td>
<td>97.7</td>
</tr>
</tbody>
</table>

HIV/Serological status of the study children

Results from the HIV DNA polymerase chain reaction tests at 6 weeks after birth indicated a mother to child transmission rate of 3.3% (95% Confidence interval (CI) 1.8%- 6.0%). At the completion of the study, fourteen children tested positive for HIV by PCR method, thus, a transmission rate of 4.6% (95% CI 2.8% - 7.6%). A total of 34 children tested positive on conducting the first antibody-based tests with only 14 children testing positive in the second antibody-based tests. This was also confirmed by the second PCR test.

Table 2. Results from HIV tests undertaken during the study period

<table>
<thead>
<tr>
<th>HIV test Results</th>
<th>Total</th>
<th>No. positive</th>
<th>%</th>
<th>95% Confidence interval (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCR test at 6 weeks</td>
<td>303</td>
<td>10</td>
<td>3.3</td>
<td>1.8- 6.0</td>
</tr>
<tr>
<td>1st Antibody test</td>
<td>303</td>
<td>34</td>
<td>11.2</td>
<td>8.1 - 15.3</td>
</tr>
<tr>
<td>2nd Antibody test</td>
<td>303</td>
<td>14</td>
<td>4.6</td>
<td>2.8- 7.6</td>
</tr>
<tr>
<td>PCR test at 18 months</td>
<td>303</td>
<td>14</td>
<td>4.6</td>
<td>2.8 - 7.6</td>
</tr>
</tbody>
</table>

The initial mode of feeding the child was found to be a significant determinant of mother-to-child transmission of HIV ($\chi^2=4.167$, df=1, p= 0.045). Indeed, exclusive breastfeeding reduced the risk of HIV transmission by about 10% when compared to exclusive replacement feeding (odds ratio (OR) 0.941(95% CI 0.911-0.971). Switching from breastfeeding to replacement feeding was not significantly associated with mother-to-child transmission of HIV ($\chi^2=0.100$, df=1, p= 0.998). However, transmission rate was higher, though not significant, in those who switched from breastfeeding to replacement feeding when the child was younger than six months (8.3% in children who were switched to replacement feeding before 6 months of age versus zero incidence of transmission in the opposing group, $\chi^2=1.294$, df=1, p=0.414).

Mixed mode of feeding was shown to increase the likelihood of mother-to-child transmission (OR 19.432 (95%CI 3.870-97.560), $\chi^2=23.772$, df=1, p = 0.002). The sex of the child was not associated with the risk of transmission of HIV from mother to child (chi square statistic($\chi^2$)=0.036,degrees of freedom(df)=1, p=0.849). Similarly, age of the mother was not a significant predictor of the risk of mother to child transmission of HIV($\chi^2=0.048$, df=11, p=0.763).
Table 3. Assessment of factors associated with mother-to-child transmission

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Total</th>
<th>PCR Test Results</th>
<th>OR (95% CI)</th>
<th>X², df, P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Positive (n=14)</td>
<td>Negative (n=289)</td>
<td></td>
</tr>
<tr>
<td>Sex of Children</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>159</td>
<td>7(4.4)</td>
<td>152(95.6)</td>
<td>0.901 (0.308-2.635) X²=0.036,df=1, p=0.849</td>
</tr>
<tr>
<td>Female</td>
<td>144</td>
<td>7(4.9)</td>
<td>137(95.1)</td>
<td></td>
</tr>
<tr>
<td>Initial mode of feeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exclusive breastfeeding</td>
<td>236</td>
<td>14(5.9)</td>
<td>222(94.1)</td>
<td>0.941(0.911-0.971) X²=4.167,df=1, p=0.045</td>
</tr>
<tr>
<td>Exclusive Replacement Feeding</td>
<td>67</td>
<td>0(0.0)</td>
<td>67(100.0)</td>
<td></td>
</tr>
<tr>
<td>Switched from BF to RF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>29</td>
<td>1(3.4)</td>
<td>28(96.6)</td>
<td>0.717(0.090-5.688) X²=0.100,df=1, p=0.998</td>
</tr>
<tr>
<td>No</td>
<td>274</td>
<td>13(4.7)</td>
<td>261(95.3)</td>
<td></td>
</tr>
<tr>
<td>Age of switching from BF to RF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 6 months</td>
<td>17</td>
<td>0(0.0)</td>
<td>17(100.0)</td>
<td>1.091(0.920-1.294) X²=1.294, df=1, p=0.414</td>
</tr>
<tr>
<td>&lt; 6 months</td>
<td>12</td>
<td>10(8.3)</td>
<td>11(91.7)</td>
<td></td>
</tr>
<tr>
<td>Mixed mode of feeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>7</td>
<td>3(42.9)</td>
<td>4(57.1)</td>
<td>19.432(3.870-97.560) X²=23.772,df=1, p=0.002</td>
</tr>
<tr>
<td>No</td>
<td>296</td>
<td>11(3.7)</td>
<td>285(96.3)</td>
<td></td>
</tr>
</tbody>
</table>

**DISCUSSION**

Exclusive breast feeding was found to increase the risk of HIV transmission by 10% when compared to exclusive replacement feeding this is comparable to findings by Coutsoudis et al., (2009) most children born to HIV positive mothers and raised on formula do not get infected but die of undernourishment, diarrhea and pneumonia since formula milk isn't always a sterile product and is easily contaminated and hence the study recommended breast feeding due to a higher nutritional value and provides innate immunity. Mixed mode of feeding was shown to increase mother to child transmission. It had a four-fold increment in children who were less than 6 months old, this is in-line with findings by WHO(2003), UNICEF(2011), where the studies found that the gastrointestinal walls of infants below six months of age were not fully developed hence they get inflamed easily, allowing passage of the virus. The study recommended breast feeding with ARV drugs if replacement feeding is not AFASS (affordable, feasible, available, safe and sustainable).

**CONCLUSION**

Mother to child transmission was prevalent in situations where women practiced E.B.F (59%), and mixed feeding (4.2%). Mother to child transmission did not occur in infants who were exclusively replacement-fed. This study recommends as follows; Expectant women should be monitored closely for ARV adherence and adverse drug reactions during antenatal care and breast feeding period. Exclusive replacement feeding should be encouraged and made AFASS (Affordable, Feasible, Available, Safe and Sustainable) to HIV positive mothers thus, ensuring sterility of the product and maintaining nutritional...
value. Although WHO has a two year exclusive breast feeding recommendation, this study has found that exclusive breast feeding had higher transmission prevalence than exclusive replacement feeding, hence more studies need to be carried out concerning the mode of feeding and mother to child transmission.

ACKNOWLEDGEMENT
I wish to express my sincere gratitude to all the people that supported me in whichever way during the research period. These include my lecturers at Kenyatta University, the supervisors; Prof. Gicheru M.M., Dr Mwatha J.K., the Ministry of Health workers at Kerugoya County Referral Hospital and the National HIV Reference Laboratory (NHRL).

REFERENCES
INFLUENCE OF FAMILY RELATIONSHIP ON ACADEMIC PERFORMANCE OF PUPILS IN PUBLIC PRIMARY SCHOOLS IN KIANJIRU ZONE, EMBU COUNTY, KENYA

Njiru, M. M.
Department of Education, Kenya Methodist University, P. O. Box 899983-80100, Mombasa
Email: wamuriithi@yahoo.com, Tel.: 0723453189

ABSTRACT
Home factors have been pinpointed as of great importance in moulding the performance of pupils in schools worldwide. This research, therefore, investigates the influence of family relationship on the academic performance of pupils in Kianjiru zone, Mbeere South Sub-county. The interest to pursue this research arose after the researcher was provoked by the outcry of the examination cheating countrywide. The study adopted a descriptive survey design method to collect information. The target population of the study was 458 standard seven and eight pupils in the zone from where a sample size of 88 pupils was drawn which was 19% of the whole population. The data was collected using questionnaires for pupils that were analyzed using descriptive statistics and presented using frequencies, percentages. Statistical Package for Social Sciences version 21 was used to aid in generating a summary of results. The study established that families play a vital role in pupils’ learning and that parents’ efforts are important in improving the grades of the pupils. The study further established that pupils’ academic performance is affected by parental factors that include; providing them with learning materials, providing them with the necessary stationery, helping them to do their homework, doing follow-up of their schoolwork and attending their PTA meetings. The results also led to the conclusion that differences in educational background of parents did not contribute to a significant difference in the academic achievement of pupils. In view of the above findings the following recommendations are made: the parents should be sensitized on the need of their involvement in the children’s learning. The school administration should also organize seminars and educate the parents on the importance of creating a good home reading environment. Learning environments at home should be made conducive by parents to promote the learning while at home.

Keywords: Learning environments, Home factors, Academic performance, Family relationships, Parental factors, Family structures

INTRODUCTION
Good academic performance in education guarantees skilled and dynamic citizens. In addition, one of the aspects of social pillar of Kenya vision 2030 is education. Kenya vision 2030 points out that education and trainings fundamental in ensuring Kenya becomes a middle-income economy. Noting the importance of education to the Kenyan economy it would be useful to identify those factors that affect pupils and their academic performance. Identifying such factors would be essential in ensuring that the ministry of education and other relevant government bodies are able to develop systems for addressing the negative and maximizing on the positive factors. Existing literature identifies home attributes as essential factors affecting pupil’s achievements and thus the long term outcomes of the pupils (Glanz 2002, Graetz 2005, Jeynes 2002). Home factors are of great importance in shaping the performance of pupils in schools worldwide. The reason is that academic performance is usually a result of support and motivation that pupils get from the parents/guardians and people interact with in their initial stages of life.

Many researchers conducted detailed studies about the factors contributing to a pupil’s performance at different study levels. Glanz (2002) suggested “Pupils educational success contingent heavily on home status of his/her parents/guardians in the society”. Considine and Zappala (2002) noticed the same that parent’s income status positively affects the pupil test score in examination. Parent’s economic condition, which includes parents’ academic and professional qualification, revenue and occupational affiliation, is also associated with academic gain of pupils. The results of many studies confirmed that academic achievement of pupils is contingent upon parent’s economic condition. So the pupils belonging to higher economical backgrounds will perform better than other pupils associated with low economic...
Success, in an educational institution is measured by academic performance. Over the years, the importance of pupils doing well in school has become the common concern of parent, legislators, teachers, counselors and psychologists. According to Adeyemo (2006), parents devote a lot of resources to their pupil’s education because they believed that good academic performance would provide a stable future for them. Also, Jeynes (2002) opines that many educational authorities have sought to find out reasons for the downward trend in the academic performance of pupils in public primary schools.

In Kianjiru, it is noted that academic achievement of pupils may not only depend on the quality of schools and the teachers, rather the extent of home- based factors have vital role to play in academic achievement of their pupils. This, therefore, creates a gap on other ways that home factors influence the academic performance of pupils in public primary schools in Kianjiru zone. There are 4,784 pupils and 20 public primary schools whereby learning environment may be more complex and academic achievement expectations increases. Pupils are more likely to have higher academic achievement levels and improved behavior when the home factors are favourable (Bryan, 2005).

**Objective of the Study**
The objective of this study was to examine the influence of family relationships on academic performance of pupils in public primary schools in Kianjiru Zone.

**Methodology**
The study employed the descriptive survey research design. The descriptive survey design was relevant to this study because it enabled the researcher to describe the state of affairs in schools by collecting data without manipulating variables. The target population for this study was all the 4258 pupils in public primary schools in Kianjiru zone, Mbeere South Sub-county. A sample size of 19% is sufficient for the study considering the degree of variability, in which the population did not have a high level of variability. The sample constituted 4 standard seven pupils and 4 standard eight pupils from each school in 11 schools. The stratified random sampling method of simple random sampling was used in selecting the 11 schools, with 8 pupils participating per school. A questionnaire was suitable for collecting data for research because it was appropriate for collecting a lot of information over a short period of time. Expert opinions of University supervisors were engaged to ascertain the validity of the research instruments. Reliability of the instruments was estimated by use of Spearman’s rank correlation coefficient and a correlation coefficient of 0.816 was obtained. The data were analyzed using descriptive statistics including percentages and frequency counts with the aid of SPSS version 21. The analyzed data were presented on frequency tables.

**RESULTS AND DISCUSSION**
The following are the results of the study and the discussions of the results

**Socio-Demographic Characteristics of the Respondents**
This section presents a brief description of the demographic characteristics of the study participants. The study established that the majority (55%) of the respondents were aged between 10 and 13 years, while 30% of the respondents were age between 14 and 16 years. The study further established that 15% were aged 17 years and above. The study established that the majority (58%) of the respondents were female while 42% of the respondents were male. The study established that the majority (50%) of the respondents were in class seven while another 50% were in class eight. The majority (31.8%) of the pupils’ respondents who sat for the end of first term exam scored D grade, 26.1% scored E grade, 20.5% scored grade C. The data further shows that 12.5% scored B grade while only 9.1% pupils scored A grade in the end of term exams. Glanz (2002) attributes the cause of poor academic performance of pupils to a
combination of personal and institutional factors. The Personal factors include the level of individual's intelligence, knowledge and ability, while Institutional factors are family or parental influence. The study further sought to find out the causes of the pupils to repeat classes, and the respondents indicated that one of the major causes of repetition was irregular attendance of school. This led to poor performance of the pupils, hence repetition.

**Influence of Family Relationships on Academic Performance of Pupils in Public Primary Schools**

The study further sought to establish whether the pupils came from families with single or complete families. The responses are presented on the table below.

**Table 1: Status of the Family**

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>66</td>
<td>75</td>
</tr>
<tr>
<td>No</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>88</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

The study established that the majority (75%) of the respondents indicated that they came from complete nuclear families with both parents, while 25% were not from such families. The study further established that 30% of the pupils that did not come from complete nuclear families lived with single parents, while 70% of them were living with relatives and their grandparents. The study further sought to establish how the family relationship affected the performance of the pupils in the primary schools. The responses are presented on the Likert scale below where: Strongly Agree (SA) Agree (A) Disagree (D) Neutral (N) Strongly Disagree (SD).

**Table 2: Effects of Family Relationship on Performance of the Pupils**

<table>
<thead>
<tr>
<th>Statement</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Having good family relationship encourages me to have</td>
<td>0</td>
<td>2.5</td>
<td>12.5</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>high goals in education.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My parents show concern over my academic performance.</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>I receive help from other family members when doing homework at home.</td>
<td>0</td>
<td>12.5</td>
<td>12.5</td>
<td>55</td>
<td>20</td>
</tr>
<tr>
<td>Families are the conductive environment for the development of the</td>
<td>5.6</td>
<td>1.7</td>
<td>8.7</td>
<td>49.8</td>
<td>18.6</td>
</tr>
<tr>
<td>virtues which humanize the pupil's life hence academic performance.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The emerging family structures may have an influence on academic</td>
<td>11.2</td>
<td>1.1</td>
<td>4.3</td>
<td>63.5</td>
<td>16.1</td>
</tr>
<tr>
<td>performance as pupils depend on the family emotional and material</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>support.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family provides the environment where the pupil learns to use</td>
<td>10.6</td>
<td>3.6</td>
<td>6.8</td>
<td>62.9</td>
<td>13.0</td>
</tr>
<tr>
<td>their faculties and understand and cope with the physical world.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The structure of a family has been changing from the traditional family</td>
<td>11.2</td>
<td>1.7</td>
<td>4.9</td>
<td>64.8</td>
<td>10.6</td>
</tr>
<tr>
<td>structure comprising of parents and pupils to other forms of family</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>structures that provides alternative dependence system.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The family relationship probably has the greatest influence on the pupil's</td>
<td>13.0</td>
<td>7.3</td>
<td>2.4</td>
<td>67.3</td>
<td>6.8</td>
</tr>
<tr>
<td>future life than any other agent.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficacy of a family influence for academic performance is determined to</td>
<td>4.3</td>
<td>9.3</td>
<td>1.2</td>
<td>62.9</td>
<td>17.4</td>
</tr>
<tr>
<td>a large degree by family relationship.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic performance is achieved only if family relationship resources</td>
<td>9.3</td>
<td>5.5</td>
<td>6.8</td>
<td>54.2</td>
<td>19.3</td>
</tr>
<tr>
<td>can be accessed to maximize the association between family influences and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>outcomes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The study established that the majority (75%) of the respondents indicated that they came from complete nuclear families with both parents, while 25% were not from such families. Existing literature identifies home attributes as essential factors affecting pupil’s achievements and thus the long term outcomes of the pupils (Glanz 2002, Graetz 2005, Jeynes 2002). The study further established that 30% of the pupils that did not come from complete nuclear families lived with single parents, while 70% of them were living with relatives and their grandparents.

Many researchers conducted detailed studies about the factors contributing to a pupil’s performance at different study levels. Glanz (2002) suggested “Pupils educational success contingent heavily on home status of his/her parents/guardians in the society”. The findings showed that majority of the respondents at strongly agreed (40%) or agreed (45%) that having a good relationship with their family helped in their academic performance. The reason is that academic performance is usually a result of support and motivation that pupils get from the parents/guardians and people interact with in their initial stages of life.

Home is the first level of socialization where important interactions happen with parents, care-givers, friends, siblings, and others in the community (Glanz, 2002). The study further established that another 25% strongly agreed that their parents showed concern over their academic performance, and 50% agreed. Those that disagreed or remained neutral over the role of good family relationship were 15% combined, and 25% over those disagreeing (15%) or neutral (10%) regarding parental concern over their academic performance. Thus the home continues to exercise a strong influence over the pupil’s life and academic performance in school. It has to be noted that homes differ in terms of their significances in the social orders. For instance, some have more prestige and money while some have wider experience and knowledge of how to operate within the society or school environment (Constatine, 2005).

The study further established that 55% of the respondents indicated that they received help from their family members when doing homework at home, and thus this had an impact on their performance. Interactions between children and adults are seen as “the primary medium by which literacy is acquired” (Collins, 2007). Interactions with others around (Bryan, 2005), as well as general talk about events not present (engagement in decontextualized language) (Bandura, 2007) have been shown to play key roles in pupil’s literacy development.

The study further established that families are the conductive environment for the development of the virtues which humanize the pupil’s life hence academic performance, as was revealed by (49.8%) of the respondents. The training provided in the home is practical rather than theoretical. It provides the most conductive environment for the development of the virtues which humanize the pupil's life hence academic performance (Bryan, 2005). The study further established that the emerging family structures may have an influence on academic performance’ as pupils depend on the family emotional and material support, as was revealed by (63.5%) of the respondents. The study further established that the family provided the environment where the pupil learns to use their faculties and understand and cope with the physical world, as was revealed by (62.9%) of the respondents.

According to Balli et al (2008), noted that better-educated families are more likely to consider the quality of the local schools when selecting a neighborhood in which to live. Once the pupil enters a school, educated families are also more likely to pay attention to the quality of the pupil’s teachers and may attempt to ensure that the pupils are adequately served. The study further established that Healthy family relationships, love of the dearest people, understanding and care of everybody are needed in this pupils’ life, as was indicated by (64.2%) of the respondents. High parental expectations, more parental attention to and effort towards pupil education help raise pupil academic performance. (Bradley et al., 2001).

The majority (64.8%) of the respondents indicated that the structure of a family has been changing from the traditional family structure comprising of parents and pupils to other forms of family structures that
provides alternative dependence system. The study further established that the family relationship has the greatest influence on the pupil’s future life than any other agent, as was agreed by 67.3% of the respondents. In a family socialization perspective, it is proposed that the absence of a parent is probably associated with a decrease in total parental involvement, which in turn is related to poorer school outcomes (Balli et al. 2008).

Good family relationship provides conducive home environment that entails parent encouragement that proves to be catalyst in boosting, maintaining achievement and motivation among the pupils that in turn influence their academic performance. The study further established that the efficacy of a family influence for academic performance is determined to a large degree by a pupil's family relationship, as was revealed by (62.9%) of the respondents. Pupils need a pleasing and interesting environment, characterized by human care particularly by the mother, and at the same time, providing various experiences and stimulations (Caldwell, 2002).

The study further established that Academic performance is achieved only if family relationship resources can be accessed to maximize the association between family influences and outcomes, as was revealed by 54.2% of the respondents. A Pearson correlation between effects of family relationship and performance of the pupils was computed and the results are shown below:

| Table 3. Pearson Correlation between Family Relationship on Academic Performance of the Pupils |
|----------------------------------|------------------|------------------|
| Family Relationship variables  | Pearson Correlation | Sig. (2-tailed) |
|                                  | 1                | .737**           |
|                                  | N                | 88               |

**. Correlation is significant at the 0.05 level (2-tailed).

The study established that the strength of relationship between Family Relationship variables and Performance of the Pupils was high (r= .737) and the correlation coefficient was significantly high as indicated by P<0.05. This implies that 54.32% (r²= 0.737²) of the variations in the Family Relationship variables negatively affected Performance of the Pupils. According to (Balli et al., 2008) analyses on the relations between families and academic performance also need to consider pupil's family structures; a mother does homework with her children. It is generally acknowledged that family relationship is the most powerful influence in determining a pupil's academic motivation and achievement.

The study established that the family relationship variables had an influence on the academic performance of the pupils in primary schools in Kianjiru zone. The extent of the relationship has been revealed by the Pearson’s correlation coefficient of 0.737, which implies that for every positive change in the family relationships variables, there was a significant improvement in the academic performance of the pupils.

CONCLUSIONS
It can be concluded that families play a vital role in the pupil’s learning and that the efforts of the parents are important in improving the grades of the pupils. Based on the findings of the study, it can be concluded that pupils’ academic performance in is affected parental factors that include; providing them with learning materials, providing them with the necessary stationery, helping them to do their homework, doing follow-up of their schoolwork and attending their PTA meetings.

RECOMMENDATIONS
It was recommended that the Headteachers should hold meetings with the parents to sensitize them on the need of their involvement in the pupils learning. The school administration should also organize seminars and educate the parents on the importance of creating a good home reading environment. Learning environments at home should be made conducive by the parents to promote the learning of pupils while at
REFERENCES


INFLUENCE OF PARENTS LEVEL OF EDUCATION ON STUDENTS’ ACADEMIC PERFORMANCE IN PUBLIC SECONDARY SCHOOLS IN MAKUENI SUB-COUNTY

*Theresia Yula David, Paul Mwenda and Eric Mathuva
Department of Education, School of Arts And Social Studies, Kenya Methodist University, Kenya
Lecturer, School of Business, Kenya Methodist University, Kenya
Senior Lecturer, School of Business, Kenya Methodist University, Kenya
* Theresia Yula David, P. O. Box 157-90300, Makueni. Email:davidtheresia4@gmail.com, Tel.: +254711351509

ABSTRACT
The study aimed at finding out parents’ level of education as a contributor to students’ performance. This study was based on Potter Lawler theory on expectancy theory, Socio constructivism theory by Vygotsky, Beans theory on psychological theory. The researcher provided information that will be useful to the principals, teachers, parents, and policy makers. The population of the study was 460 respondents distributed in 20 public secondary schools across the entire geographical area. The researcher assumed a descriptive survey design based on a target sample of 135 respondents from Makueni sub-county, Makueni County. The sample size included, teachers, principals, parents and students from the sub-county. The researcher used questionnaires and interview guide for data collection. Reliability of the instrument which was used in the study was done by piloting the instruments in two secondary schools. Data was collected from 9 schools covering 6 teachers, 4 parents and 5 students per school totaling to135 respondents. The data collected was analyzed qualitatively using pie charts, bar charts and graphs. The research findings were that students with educated parents performed better academically was at 55%, educated parents are serious with their children education was at 50%, educated parents provide learning resources to their students was at 72%, students not doing assignments was at 64% and withdrawal from class was at 85%. The study concluded that parents’ educational level has direct impact on their students' educational aspirations.

Keywords: Contributor, Academic performance, Level of education

INTRODUCTION
Schools as learning institutions have no worth without students. Students are most essential assets for any educational institute. The students’ performance that is the academic achievement plays an important role in producing the best quality graduates who will become great leaders and man power for the country thus responsible for the country’s economic and social development Ali et al, (2009). Educated parents can provide such an environment that suits best for academic success of their children. The academic performance of students heavily depends upon the parental involvement in their academic activities to attain the higher level of quality in academic success Bernard, (2004).

Muola, (2010) while doing a study at Machakos district observed that students’ motivation to do well in academic works depend on the nature of their parents’ income and their level of education. According to the study conducted by Kunje (2009) there is a significant relationship between parental level of education and the student’s education aspirations. Ogoye (2007) showed that illiterate parents were unable to assist their students in doing homework. It has been assumed that academic achievement of students in Makueni county may not only depend on the quality of schools and the teachers, rather the extent of environmental factors has vital role to play in academic achievement of their students. Students are more likely to have higher academic achievement levels when the environmental factors are favorable Bryan, (2005). The aim of the study was to establish the influence of parents’ level of education on students’ academic performance in public secondary school in Makueni sub-county.

METHODOLOGY
The researcher used descriptive survey design to collect information. The design was effective in securing evidence concerning all existing situations; identify standards with which to compare present conditions Mugenda and Mugenda (2003). The information was obtained through the use of questionnaires. The study was carried out in Makueni SubCounty which is situated in Eastern Kenya. It is located between
37.3° and 38.20° East of the Greenwich meridian and 1.7° and 26° South of the Equator. The population of the study was 23 respondents from the 20 public secondary schools which was totaling to 460 respondents. Stratified sampling was used to sample the schools. The sample size comprised of secondary school teachers, parents and students purposively selected from a total of 9 schools. This formed more than 30% of the entire target population and is considered enough representation of the whole. This is in agreement with Turkmen’s assertion (1988) that a sample of 25% or a quarter and above of the study population is enough representation and adequate for collecting reliable information or data for study, provided that consideration is made on the distinct characteristics of the population. Three sampling methods were used in this study; first stratified sampling method was used to categorize schools into boarding or days schools. Secondly, purposive sampling was used to select teachers. Sample random sampling was used to select the students.

The study sample included 3 mixed day secondary schools, 3 girls boarding and 3 boys boarding secondary schools with 15 respondents from each school making a total of 135 respondents. The researcher used questionnaires to the teachers and students because of their convenience. Pre-testing through piloting was done in two schools in Makueni SubCounty so as to establish the reliability of the questionnaire. The schools used in piloting were not included in the study. Feedback obtained from the pilot study assisted the researcher in revising the questionnaire to ensure that it covers the objective of the study. Raw data obtained from the questionnaires was analyzed qualitatively by using detailed information from the questionnaires. The data was interpreted and conclusion drawn by use of tables, pie charts and graphs. High confidentiality was assured to the respondents. The researcher analyzed the data in a manner that avoided misstatement, misinterpretation or fraud rent.

**Data Analysis, Presentation and Interpretation**

In order to analyze the structured section of the questionnaires, content analysis technique was used.

**Demographic information**

The distribution of the respondent according to the above demographic characteristics is shown below. Majority of the respondents were females as shown by 36 which is (67%) of teachers and 30 which is (83.3%) parents while 18 which is (33%) teachers and 6 which is (16.6%) parents were male.

**Table 4.1 Gender of respondents**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parents</td>
<td>Female</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
</tr>
<tr>
<td>Teachers</td>
<td>Female</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>54</strong></td>
</tr>
</tbody>
</table>

**Table 4.2 Age of the respondents**

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Age</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parents</td>
<td>Below 30 years</td>
<td>6</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>30-40 years</td>
<td>10</td>
<td>27.8</td>
</tr>
<tr>
<td></td>
<td>Over 40 years</td>
<td>20</td>
<td>55.6</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
<td><strong>100</strong></td>
</tr>
<tr>
<td>Teachers</td>
<td>Below 30 years</td>
<td>5</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
<td>30-40 years</td>
<td>26</td>
<td>48.1</td>
</tr>
<tr>
<td></td>
<td>Over 40 years</td>
<td>23</td>
<td>42.6</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>54</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
9.3% of the teachers were below 30 years of age while 48.1% of the total respondents had ages between 30-40 years. 42.6% of the respondents had ages over 40 years. This shows that the teachers’ respondents were mature enough to respond to questions. Most of the parents were also mature enough as indicated by 55.6% of the parents being over 40 years and 27.8% of the respondents ranging between 30-40 years. A few of the parents were below 30 years which is 16.7%).

<table>
<thead>
<tr>
<th>Years worked</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3 years</td>
<td>14</td>
<td>25.9</td>
</tr>
<tr>
<td>4-5 years</td>
<td>20</td>
<td>37.1</td>
</tr>
<tr>
<td>5-10 years</td>
<td>10</td>
<td>18.5</td>
</tr>
<tr>
<td>Above 10 years</td>
<td>10</td>
<td>18.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>54</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

The findings indicated that majority of teachers had a frequency of 20 which is (37.1%) worked for between 4-5 years. This shows that the teacher respondents have enough experience to offer reliable information.

Figure 4.1 Education level of the respondents

The figure 4.1 shows that majority which is 65% of the teachers had a degree as their highest level of education while 23% had a diploma. This findings show that the respondents had the required qualification to teach at secondary level and would understand environmental determinants influencing academic performance of secondary schools. Majority of the parents above 20% had a diploma, degree and masters so they were suitable in the responding of the questionnaires.

4.2 Parents’ level of education
The objective of this study was to establish the influence of parents’ level of education on students’ academic performance in Makueni County. To achieve this objective the following question was answered. Are there indicators that show that the parents’ level of education is high? To answer this question, descriptive statistics inform of frequencies, percentages were used and results presented in Table 4.4 below
Table 4.4 Indicators to show that parents’ level of education is high.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Respondents</th>
<th>SA</th>
<th>A</th>
<th>D</th>
<th>Strong D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students with educated parents perform better in KCSE</td>
<td>Parents</td>
<td>20</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55.6%</td>
<td>44.4%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>25</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55.6%</td>
<td>22.2%</td>
<td>22.2%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Teachers</td>
<td>30</td>
<td>14</td>
<td>5</td>
<td>5</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55.6%</td>
<td>25.9%</td>
<td>9.3%</td>
<td>9.3%</td>
<td>100%</td>
</tr>
<tr>
<td>Educated parents are serious with their children education</td>
<td>Parents</td>
<td>16</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44.4%</td>
<td>27.8%</td>
<td>27.8%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>5</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44.4%</td>
<td>33.3%</td>
<td>11.1%</td>
<td>11.1%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Teachers</td>
<td>34</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>63%</td>
<td>18.5%</td>
<td>18.5%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Educated parent provide learning resources to their students</td>
<td>Parents</td>
<td>30</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83.3%</td>
<td>16.7%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>77.7%</td>
<td>22.2%</td>
<td>11.1%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Teachers</td>
<td>30</td>
<td>19</td>
<td>5</td>
<td>0</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55.6%</td>
<td>35.2%</td>
<td>9.3%</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

From the table above 55.6% (30) teachers strongly agreed that students with educated parents perform better in K.C.S.E. 25.9% (14) agreed to the same while 9.3% disagreed to the opinion as 9.3% strongly disagreed. 55.6% (25) of the students strongly agreed that students from educated parents perform better in K.C.S.E backed by 55.6% agreeing to the same. 22.2% disagreed while 0% strongly disagreed. After the parents were interviewed, 100% of the parents agreed with the opinion. No parent disagreed with the given opinion.

![Figure 4.2 Extend of parental level of education influence on students’ KCSE performance](image)

Teachers who strongly agreed that educated parents are serious with their children education were 34 which is 63% echoed by 10 which is 18.5% who also agree with the opinion compared to only 10 which is 18.5% disagreeing that educated parents are serious with their children education. Above 35 equivalents to 77.9% of students agreed with the question compared to only 10 same as 22.2% disagreeing with the question. After the interview was carried out over 50% of the parents disagreed with that educated parents are serious with their children education while below 50% disagreed with the
opinion. 90% which is 49 of the teachers strongly agreed that educated parents provide learning resources to their students compared to only 9.5% disagreeing with the opinion. 99% of the students also agreed to the opinion that educated parents provided their children with the required learning resources. Less than 20% disagreed with the opinion. All the parents who were interviewed agreed strongly. None of the parents disagreed. This is a clear indication that students with educated parents performed better academically compared to those with uneducated parents.

The researcher found out that majority of the respondents that is 53% agreed that parents’ level of education influenced students’ KCSE performance to a large extent. These were followed by 30% who agreed to a very large extent. This finding was also heighted by the parents’ who indicated that parents’ level of education influenced students’ academic performance. It can therefore be concluded that parents’ education influences greatly students’ academic performance and therefore should be enhanced. Parents’ educational value has direct impact on their students’ educational aspirations. The researcher then investigated the level of agreement that students with educated parents perform better in KCSE.

Table 4.5 Indicators to show that parents’ level of education is low

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Respondents</th>
<th>Agree</th>
<th>Disagree</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students not doing given assignment</td>
<td>Parents</td>
<td>20</td>
<td>16</td>
<td>36 (100%)</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>30</td>
<td>15</td>
<td>45 (100%)</td>
</tr>
<tr>
<td></td>
<td>Teachers</td>
<td>32</td>
<td>22</td>
<td>54 (100%)</td>
</tr>
<tr>
<td>Students lacking learning resources</td>
<td>Parents</td>
<td>26</td>
<td>10</td>
<td>36 (100%)</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>35</td>
<td>10</td>
<td>45 (100%)</td>
</tr>
<tr>
<td></td>
<td>Teachers</td>
<td>34</td>
<td>20</td>
<td>54 (100%)</td>
</tr>
<tr>
<td>Withdrawal from class</td>
<td>Parents</td>
<td>30</td>
<td>6</td>
<td>36 (100%)</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>30</td>
<td>15</td>
<td>45 (100%)</td>
</tr>
<tr>
<td></td>
<td>Teachers</td>
<td>49</td>
<td>5</td>
<td>54 (100%)</td>
</tr>
</tbody>
</table>

From the table 4.5 above indicated that above 50% of the teachers agreed that most of the students were not doing given assignments compared to less than 50% respondents who disagreed that students were not doing given assignment. 77.7% of students agreed while only 33.3% disagreed. After the parents were interviewed on the same, 55.6% of the parents agreed while 44.4% disagreed. Over 60% of the teachers, students and parents agreed that students were lacking learning resources as an indicator that their parents’ education was low compared to less than 40% of the same respondents disagreeing. The respondents highly agreed that students were being withdrawn from classes to go for levies which affected their learning, this is indicated by above 80% agreeing to the opinion compared to less than 20% respondents disagreeing. As cited by Considine and Zappala (2009), in their study that families where parents are educated foster a higher level of achievement in their performance because of providing psychological support to their children.

RESULTS
Data analysis and interpretation of interview and questionnaire responses from teachers, students and parents revealed that students with educated parents performed better academically compared to students with uneducated parents. The results of the findings showed that slightly over half of the teachers agreed. 55.6% students as well as the parents also agreed to the opinion. 63% teachers and above 50% of the students and parents agreed that educated parents were serious with their children education. Above 80% of the respondents agreed that educated parents provided their learners with learning resources.

From the teachers’ results 59.3% teachers, 77.7% students and 55.6% parents were in agreement that students’ not doing given assignment was an indicator that parents’ level of education was low. Over 60% of the respondents agreed that students’ lacking learning resources was an indicator of parents’ education being low. 90.7% of teachers agreed that students were being withdrawn from the class to go for unpaid school levies which was a clear indicator of parents’ level of education being low. 87.3% of the parents agree to the same.

CONCLUSION
The study established that parents’ level of education influenced students’ performance because of the following indicators: Students with educated parents performed better in KCSE, educated parents were serious with their children’s education and students were provided with learning resources.

RECOMMENDATIONS
The study found out that education levels of parents influenced the students’ academic performance. Therefore, school administrators and policy makers should make an effort to investigate ways to increase parents’ involvement on the students’ education and demonstrate to parents that their involvement is related to their students’ academic performance.

Future policy should focus on developing and promoting school programs that enable parents to increase attention on their students’ academic performance. For instance, school administrators may set aside time in the curriculum for mentorship programs involving motivational speakers to share to the students, teachers and parents as a team in focus of improving the academic standards. This study identified mechanisms by which parental level of education is related to student performance and it is the hope that these findings lead to further research and new policies to increase students’ academic performance.

REFERENCES


ABSTRACT

Financial literacy is quite significant in personal financial management and creation of wealth in line with the attainment of the Kenya’s vision 2030. In particular, language plays a critical role in financial education and wealth creation. The words, phrases and common sayings people use to talk about money issues either inhibit or promote their personal financial growth. The words or phrases constitute the myths or stereotypes often used to describe money. The myths about money have been handed down from one generation to another over the ages. Therefore, many people have been financially programmed to think and act in a particular way. To change people’s financial blueprint that is deeply ingrained on their mindset, there is an imperative need for mental reprogramming in order to produce remarkable results on the path to attaining financial freedom. It is against the above backdrop that this study aims at debunking and/or deconstructing the disempowering financial myths upheld by many people. First, the paper seeks to identify and describe common myths associated with money and wealth creation. Two, it aims at explaining the financial implications of the identified myths. The paper uses the framework of Critical Discourse Analysis to analyse 20 purposively sampled age-old financial sayings. The paper underscores the compulsive need for financial education in deconstructing unsubstantiated beliefs about money and the significance of reprogramming people’s mindset. It advocates for the incorporation of financial literacy skills in the 8 – 4 syllabus or in the revised curriculum. Therefore, the choice of language is critical in environmental conservation and renewable energy development. Language encodes beliefs, attitudes and values which are significant to the socio-economic development of a country.

Keywords: Language Use, Deconstructing Myths, Wealth Creation.

INTRODUCTION

Financial education is quite significant in personal financial management and creation of wealth in line with the attainment of the Kenya’s vision 2030. In particular, language plays a critical role in financial education and wealth creation. Hill (1938:9) asserts, “thoughts are things and powerful things at that…” In reference to Eker’s (2005) argument that the inner world creating the outer world, thoughts can be considered as direct manifestation of what goes on the mind. Similarly, Omanga (2012) reiterates for one to become wealthy he or she has to change his/her language and be ready to ditch the poverty support group that uses negative expressions about money. Kiyosaki (2011) equally states that one can tell one’s cash flow quadrant based on the language or the words s/he uses to describe money and/or financial wealth. The poor and middle class often complain of the scarcity of money as they blame the rich for being greedy, selfish and corrupt. They inadvertently play the game of money not to lose while the rich play it to win. To win the money game, there should be a paradigm language shift. This paper, therefore, aims at deconstructing age-old sayings or myths about money and wealth creation.

Hill (1928: 64) states, “The word “education” is derived from Latin word “educo” which means to educe, to draw out, to develop from within.” In view of this definition, the author avers that an educated man is one who has developed the faculties of his mind that one may acquire anything he wants without infringing on the rights of others. An abundance of general or specialized knowledge is the hallmark of the traditional formal education system that is an indicator of academic and/or professional intelligence.
Similarly, Akinyemi (2014) says an educated person is one who can organize into definite actions and use the knowledge s/he has acquired to discern future opportunities. In this context, the application of knowledge is one of the determinants of Opportunity Discerning Quotient (ODQ). Academically intelligent people are very good at mastering abstract concepts and are reservoirs of knowledge rather than being processors of the same. However, this paper examines the role language plays in encoding financial beliefs which both the educated and uneducated uphold. By highlighting them, the beliefs will be denaturalized and deconstructed.

‘Financial education’ refers to the ability to comprehend the words and number systems of capitalism (Kiyosaki, 2011). Financial intelligence is the knowledge and skills people use to solve their money problems. Kiyosaki (2013: 20) further states that financial intelligence quotient (FIQ) is the measurement of a person’s financial intelligence. For instance, a person who earns more money through passive and portfolio income and pays less in taxes can be regarded as having a higher financial IQ than one who does not. There are five financial IQs, according to Kiyosaki (ibid): making more money, protecting your money, budgeting your money, leveraging one’s money and improving one’s financial education.

On this note, lack of financial education is the major cause of the financial problems that the poor and middle class face. Therefore, people use language that is typical to their respective socio-economic class or what Kiyosaki (2011:13) terms as ‘the four types of cash flow quadrants’: ‘E’ for Employee, ‘S’ for Specialist, Self-employed or Small business owner, ‘B’ for Big business owner, and ‘I’ for Investor. In response to the consumerist mindset and lavish lifestyle championed by the media, Stanley and Danko (1996: 29) contend that young people are brainwashed with the belief that “those that have money spend lavishly and if you don’t show it, you don’t have it.” Ideally, sound financial education advocates for a plan that forgoes high consumption today in order to attain financial independence tomorrow. The two authors conducted research on the affluent Americans and discovered the following seven characteristics among those who successfully build wealth – the millionaires next door.

1. They live well below their means.
2. They allocate their time, energy, and money efficiently, in ways conducive to building wealth.
3. They believe that financial independence is more important than displaying high social status.
4. Their parents did not provide economic outpatient care.
5. Their adult children are economically self-sufficient.
6. They are proficient in targeting market opportunities.
7. They chose the right occupation.

Stanley and Danko (1996: 3 – 4)

Eker (2005) argues that every person has a personal money and success blueprint deeply ingrained in the subconscious mind which shapes one’s financial destiny. As a result of financial conditioning is caused by thoughts which originate from the “files of information” stored in the mind due to past programming. Hence, thoughts lead to feelings which precipitate actions that eventually culminate into certain subconsciously predetermined results.

So how are we conditioned? We are conditioned in three primary ways in every arena of life, including money:

1. **Verbal programming:** What did you hear when you were young?
2. **Modelling:** What did you see when you were young?
3. **Specific incidents:** What did you experience when you were young?

(Eker, 2005:20)

In agreement with Eker’s (ibid) postulation that every person has a financial blueprint, Gitau (2015: 6) contends that “we all have a set ceiling for how much money our subconscious can allow us to have and live with.” The financial life coach further adds that parents, teachers, siblings and the environment are
early programmers of people’s financial trajectory. This argument reinforces the need to debunk false beliefs about money and wealth creation by undergoing gradual transformation on the path towards acquiring financial literacy and stability.

Kithinji (2015) points out that people should learn to change their language in order to reflect their future success. As such, negative self-talk can harm one’s performance. More poignantly, words have a creative power for they create our reality because words are vehicles that people use to transmit ideas. In concurrence, Nganga (2014: 4) observes that there is a direct correlation between between one’s language and one’s actions and that one’s choice of lexical items is basically attitudinal and ultimately optional. The two motivational authors emphasize the need to develop a positive mental attitude that cultivates success consciousness instead of failure.

This paper theorises that to change people’s financial blueprint that is deeply ingrained on their mindset, there is an imperative need for mental and verbal reprogramming in order to produce remarkable results on the path to attaining financial freedom. In light of the quest for financial education, this paper aims at debunking and deconstructing the limiting financial myths upheld by many people as guiding principles. First, it seeks to identify and describe common myths associated with money and wealth creation. Two, it aims at explaining the financial implications of the identified myths.

The paper uses the framework of Critical Discourse Analysis to analyse 20 purposively sampled age-old financial sayings. It is divided into three sections. The first one is about the introduction that presents the background to the problem, the second deals with the framework for analysis, the third focuses on the analysis of financial myths and the last one draws a conclusion that stresses the need to deconstruct the age-old financial beliefs that create financial dependency and job enslavement.

Framework for Analysis
This study is modelled on the approach of Critical Discourse Analysis (CDA). Fairclough (1995) posits that CDA is the critical study of discourse that views language as a form of social practice. It focuses on the ways social and political domination are reproduced by text and talk. The author also stipulates that any analysis of discourse is three-dimensional: the analysis of text (written or spoken), the discursive practices entailing production, consumption and interpretation of texts, and the social practice in which the text is embedded. CDA approaches discourse as a circular process in which social practices influences texts, via shaping the context and mode in which they are produced. In turn, texts (utterances) help to influence society through shaping the viewpoints of those who read or otherwise consume them.

CDA is an interdisciplinary approach of analysing texts as objects of study. It primarily studies how social power, abuse, dominance and inequality are enacted, reproduced and resisted by text and talk (van Dijk, 1997). This paper examines how certain statements about money perpetuate a mindset of scarcity and justify the narrative of abject poverty among the masses.

CDA is preferable to other methods like Content Analysis (CA) because it is interpretative, explanatory, self-reflective and constructivist (Fairclough, 1995). CDA examines texts (such as spoken statements passed on as myths) which have a great influence on the people in the context of financial freedom and wealth creation. It is both a theory and method of analysis. CDA’s notion of context embodies psychological, political, ideological and historical components. As a result, CDA offers an interdisciplinary procedure to the study explicated by this paper.

In this paper, CDA is conceptualised as unveiling socio-economic problems brought about by divergent ideologies between the poor, middle class and rich regarding money and wealth creation. This constitutes unequal power relations. As such, discourse constructs society and culture which in turn construct
This dialectical relationship points to the reflexivity of language and society as mediated by intentions, ideologies and discursive practices that determine production and interpretation of texts.

**Sampling of Texts for Analysis**

This paper analyses 20 purposively sampled common financial sayings regarded myths or stereotypes and coded as follows.

- T1: *Go to school, work hard, get a good grade and get a good job.*
- T2: *I will save money when I earn more*
- T3: *It takes money to make money*
- T4: *The rich are lazy, corrupt, greedy and ignorant*
- T5: *Money is a source of all evil*
- T6: *Live below your means or spend less than you earn*
- T7: *Don’t put all your eggs in one basket*
- T8: *Invest in the long-term, buy, and hold*
- T9: *You can’t have your cake and eat it*
- T10: *Don’t sweat on small charges*
- T11: *A penny saved is a penny earned*
- T12: *Money can’t buy happiness*
- T13: *Another day another dollar*
- T14: *Money doesn’t grow on trees*
- T15: *I just want to be comfortable*
- T16: *I am looking for a safe, secure job*
- T17: *Image is everything, substance is nothing*
- T18: *I don’t like my job but I can’t afford to quit*
- T19: *Play it safe, avoid risk; investing is risky*
- T20: *You can’t serve two masters at a go*

**Analysis of Linguistic Strategies**

Within the Fairclough’s (1995) CDA framework, the study examines the linguistic features used to construct financial myths. Of particular significance are the linguistic strategies of transitivity and modality in encoding beliefs, values and attitudes about money and wealth creation.

**Transitivity**

Fowler (1999: 71) postulate that transitivity is the way in which “the clause is used to analyse situations as being of certain types – the way the clause is used to analyse the same event in different ways.” Similarly, Simpson and Mayr (2010: 65) contend that transitivity focuses on the semantic structure of clauses by generally implying “who does what to whom and how.” It is characterized by participant roles and processes describing states or actions. Therefore, the paper analyses how transitivity encodes and constructs financial beliefs, values, and attitudes in financial sayings or myths.

Generally, at the surface and relational level, some of texts are: imperatives: T1, T6, T7, T8, T10 and T19 and/or declaratives: T2, T3, T4, T5, T9, T 11, T12, T13, T14, T15, T16, T 17, T18 and T20. Some of the imperatives and declaratives are positive affirmations while others are negative. The participant processes manifest in the corpus under study are material, mental, verbal, relational, behavioural and existential as explicated below.

**Material process**

This is the process of doing, happening, and creating encoded by verbs and marked by their progressive forms. There is doing effected by human beings (intentions), action caused by non-humans or occur on their own (supervention). It has three participant roles: agent, goal or medium and circumstances.
Examples:
T1: Go to school, work hard, get a good grade and get a good job
Material process Phenomenon
T2: I will save money when I earn more
Agent material process Phenomenon
T7: Don’t put all your eggs in one basket
Material process Phenomenon
T8: Invest in the long-term, buy, and hold
Material process Phenomenon Material process
T10: Don’t sweat on small charges
Material Process Phenomenon
T12: Money can’t buy happiness
Supervention Material process Phenomenon
T19: Play it safe, avoid risk; investing is risky
Material process Phenomenon Carrier Relational Attribute

Some of the above texts are constructed in the imperative form (giving firm instructions on what to be done or not to be done) with the omission of the agent such as T1, T7, T8, T10 and T19; some as future intentions (T2). Superventional acts denoted by non-human entities consist of T12 whose non-human agent is “Money”. T1, T8 and T19 contain a series of sequential actions encoded by active verbs in imperative form such as “go”, “work”, and “get” in T1, “invest”, “buy”, and “hold” in T8, “play” and “avoid” in T19. The material processes comprise 7 texts accounting for 35% of the corpus and the highest in frequency. They are used as a marker of objectivity or facticity and play a key role in encoding financial beliefs that are passed on as uncontestable facts.

Mental process
This is a process of perceiving, sensing or feeling encoded in a verb. It deals with feelings not facts and the cognition process of realizing. It has two semantic roles: the senser (the one who senses or feels), and the phenomenon (what is sensed or felt). It is encoded in verbs like believe, find, look, concern, think, realize, and consider. Sensing is based on the opinion of the individual. Examples include the following:
T16: I am looking for a safe, secure job
SenserMental process Phenomenon
T18: I don’t like my job but I can’t afford to quit
SenserMental process Phenomenon
In T16 and T18 above, the sensor is “I” while “am looking”, “don’t like” and “can’t afford” are the verbs denoting mental processes associated with phenomena such as “a safe, secure job” and “my job”. The mental processes are used to construct a mindset of financial dependency on job security, create a sense of entitlement and job enslavement. The negating verb elements like “don’t” and “can’t” are powerful lexical elements that disempower and deprive the sensors or persons of the power to make prudent financial choices. The process comprises two texts which constitutes 05% of the corpus and the second lowest in frequency.

Behavioural process
The process constitutes the “beholder” who is involved in certain physical or psychological actions embodied in words like taste, smell, stare, want, think, listen, begin, read, laugh et cetera. Semantically, it falls between the material and mental process.
T15: I just want to be comfortable
BehaverBehavioural process Phenomenon
T15 denotes a desire or sentimental longing to financially stable and able to avoid the good things of life without any struggle. This semantic process encodes the boulomaic modality expressing the desire to be
rich and comfortable. The commitment level expressed by the modal verb “want” is very low. It consists of one text (03%) and hence the lowest in frequency.

**Relational process**
The process encodes meanings about states of being where things are stated to exist in relation to others. It includes the intensive or attributive, possessive and circumstantial elements. Examples include:

T4. *The rich are lazy, corrupt, greedy and ignorant*
Carrier relational process attribute
T5. *Money is a source of all evil*
Carrier relational process attribute
T17. *Image is everything, substance is nothing*
Carrier relational process attribute

T4 is a common illocution is often repeated especially when people are talking about the rich in the society. They are usually indicted for most of the economic problems affecting the country and/or the poor. T5 above The famous saying is repeatedly uttered in churches, schools, homes and myriad social gatherings. It is akin to quotations such as “Man made money and money made man mad” as well as “Money cannot buy happiness” (Text 12). Therefore, many people when asked whether they would like to be wealthy they respond that they would rather be comfortable working in high-paying jobs than spend sleepless nights in search of the elusive and trouble-ridden financial riches. Besides, lack of money can be considered to be the root of all evil (Kiyosaki, 2012). Acquisition of money in a fair and just way guarantees one the freedom to afford the good things in life like going for holidays, buying or building palatial homes, posh cars and so on. Lack of money makes people to kill, steal, or even bribe to get jobs among other evils. Ultimately, money is not the source of all evils in the society.

T17 above underscores the consumerist attitude implanted on the subconscious minds of both the young and old. This trend has propagated the hackneyed notion that image is everything, creating a spendthrift mindset aimed at pleasing and winning admirers by positioning fashion stars, beauty pageants or models, media celebrities, and sports personalities as ‘persons of class’. ‘Substance’ herein refers to what one has in terms of knowledge, socio-economic class and the assets one owns which are often underrated.

Contrary to the above skewed assertion crafted from a consumerist perspective, the rich buy assets while the poor and middle class buy flossets or doodads that depreciate in value. In response to the consumerist mindset and lavish lifestyle championed by the media, Stanley and Danko (1996: 29) contend that young people are brainwashed with the belief that “those that have money spend lavishly and if you don’t show it, you don’t have it.” Ideally, sound financial education advocates for a plan that forgoes high consumption today in order to attain financial independence tomorrow. The two financial researchers aver that wealthy persons do not display a high consumption lifestyle as the rich do but derive pleasure in owning substantial amounts of appreciable assets like stocks, bonds, private businesses, real estate and so on. Therefore, substance is everything while image is nothing. The process comprises three texts constituting 15% of the corpus.

**Existential process**
This involves the use of words that encode and represent something that exists or happens. Examples are as follows:

T3: *It takes money to make money*
T11: *A penny saved is a penny earned*
T13: *Another day another dollar*

The existential process accounts for the existence of a big gap between the rich and poor. “It” in T3 is an existential subject that takes the object (“money”). This assertion is upheld by people who live in a comfort zone or who subscribe to the belief that without much money one cannot be financially stable.
Hill (1928) observes that money is just an idea and it takes an idea to make money. That is why Bill Gates came up with idea of buying Microsoft and modelled it into one of the richest global companies listed in the Wall Street bourse.

T11 is a common saying constructed in the passive voice to encourage people to save a little of their earnings to help them during a rainy day. However, when one thinks in terms of pennies, rainy days or small amounts then one has a programmed mindset of scarcity which in turn demeans one’s ideas. Thinking big is a fundamental way of soaring to greater heights. Clason (1926:11) says, “A part of all I earn is mine to keep. It should not be less than a tenth no matter how little you earn. Pay yourself first.”

T13 extols financial life of the poor who live one day after another and are categorized as people who barely earn a dollar a day. Conversely, the rich exchange dollars for time because time is more valuable. Eker (2005) postulates that the rich choose to get paid based on results while the poor choose to get paid on time. The process constitutes three texts (15% of the corpus).

**Modality**

Modality refers to the tone of the statements in regard to their degree of certitude and authority. In other words, it has to do with the speaker or writer’s authority. Fairclough (2001) asserts that there are two dimensions of modality. The first one is the relational modality which entails a matter of one’s authority in relation to others whilst the second is expressive. Expressive modality deals with a matter of the speaker’s or writer’s authority with respect to the truth or probability of a representation of reality. Modality is carried mainly by words and phrases like *may, might, could, must, will, it seems to me without doubt, it is possible that*, et cetera. Modal verbs encode knowledge, predication and evaluation.

**Deontic modality**

It expresses a sense of duty or obligation as illustrated by the imperatives statements such as:

T1. Go to school, work hard, get a good grade and get a good job.
T9. You can’t have your cake and eat it
T20. You can’t serve two masters at a go

**Boulamaic modality**

This kind of modality expresses a system of desire or wants

e.g. T2. I will save money when I earn more
T15. I just want to be comfortable

**Epistemic modality**

This type of modality conveys categorial assertions of certainty or uncertainty.

e.g. T3. It takes money to make money
T5. Money is a source of all evil

**Perception modality**

This modality conveys personal or collective feelings shared by many people. Example is shown below.

T18: I don’t like my job but I can’t afford to quit

In light of the above forms of modality, it can be observed that the financial sayings are constructed with a high degree of certitude and are passed on categorical or absolute truths. Therefore, they are hardly challenged. They form the basis of the money problems that many people experience like spending without a budget, buying luxuries with credit among others.

**Description of the financial myths**

*Text 1: Go to school, work hard, get a good grade and get a good job.*
The performative verbs (‘go’, ‘work’ and ‘get’) encode the material process of saying. They have myriad perlocutionary effects on interactants (between parents and children, instructors and learners) of this discourse. This imperative statement is very authoritative, seems credible, alluring and passes on as a basic rule that programmes people’s lifestyle and worldview. Learners who perform poorly at school are labelled very weak and/or failures not only at school but also in real life. This is because a poor learner will not get a well-paying job on account of poor academic grades that hinder him/her from pursuing highly coveted professional courses such as medicine, engineering, law, actuarial science et cetera. This statement anchors a strong belief in the subconscious minds of salaried/employed people that their pension will sort out their retirement.

The above statement is a widely held common belief that is emphasized by the education system, parents, churches and the mass media. It gained currency at the onset of the industrial age (1492 – 1990) when job security, academic and professional skills were crucial in getting a white-collar job as an engineer, doctor, lawyer, accountant and so on. Text 1 has similar implications in tandem with Text 18 (I am looking for a safe, secure job). In today’s fast-track information age, what matters is not the job nor the abundant professional knowledge one has but how one uses the information acquired in the process of learning. That is why there are a new crop of young millionaires like Mark Zuckerberg, the founding CEO of Facebook and WhatsApp owner.

Notably, nowadays people live in a self-learning society, and not a society that learns from its parents (as manifested in the Agrarian Age) or from its schools (as per the Industrial Age). What matters is how one utilizes the information s/he has in order to creatively and innovatively use the leverage to serve thousands and thousands of people with more pay but with little effort.

Text 2: I will save money when I earn more
The pronoun “I” is topicalised to foreground the agentive assertion of a speaker when asked about plans to save and invest. The assertion has a conditional rider “when I earn more” which is inhibitive and a pointer of non-commitment to the culture of saving. This declarative illocutionary proposition underscores one’s belief that ‘it takes money to make money’ (as stated by Text 3). That is, for one to save, one needs a surplus or earn more form his/her job. However, such a belief is a myth because the more one earns, the more s/he spends. This act of procrastination is controlled by one’s subconscious mind informed by the fear to control and manage one’s income. Essentially, one who does not save at least 10% of his/her salary and invest in income-generating projects will die poor (as envisaged by Clason, 1926). To become financially-independent, there is a compulsive need to get out of one’s comfort zone, change the negative financial expressions to empowering positive ones that open unlimited opportunities for success.

Text 3: It takes money to make money
“It” is an existential subject that takes the object (“money”). This assertion is upheld by people who live in a comfort zone or who subscribe to the belief that without much money one cannot be financially stable. However, as one climbs the ladder of his/her job the stark reality dawns on such a person. The expenses immediately rise to match up with the increased remuneration making it difficult for one to save and invest more. This financial problem is exacerbated by the fear to take risks as procrastination takes centre stage. Knowing the difference between what is a risk and what is risky is important. A ‘risk’ is venture or an event that has a possible loss or positive outcome. The term ‘risky’, on the other hand, implies involving risks that have potential danger or likely to lead to losses. Lack of financial knowledge, for instance, is risky while taking the initiative to educate oneself about personal financial management is a risk that has significant gains.

Hill (1928) observes that money is just an idea and it takes an idea to make money. That is why Bill Gates came up with idea of buying Microsoft and modelled it into one of the richest global companies listed in...
the Wall Street bourse. The same applies to the founders of Apple, Berkshire Hathaway, and Dell Computers. In Kenya, there are self-made billionaires like Chris Kirubi, Manu Chandaria, young multimillionaires like Gideon Ndambuki – the founding CEO of Laugh Industry that airs Churchill Show on NTV, Simon Gicharu – the founding chairman of Mount Kenya University, among others.

Text 4: The rich are lazy, corrupt, greedy and ignorant
This common illocution is often repeated especially when people are talking about the rich in the society. They are usually indicted for most of the economic problems affecting the country and/or the poor. Hill (1928) posits that Henry Ford was regarded by intellectuals as a very ignorant person who did not attain sound and advanced academic qualifications. When he faced a panel of scholars to answer some scholarly questions, he replied that there is no need of memorizing everything. He summoned his skillful team of advisors to give answers to the questions. Ford argued that that he assigns various duties to certain experts so that he can handle the greatest task that people are afraid of – finding ample time to think.

The rich are considered “idle and lazy” on account of the enormous financial resources and abundant time they spend with their loved ones relaxing, holidaying at luxurious coastal beaches and travelling round the world for business conferences or deals. They are deemed “greedy and corrupt” because they continue getting richer no matter the hard economic times. They are said to evade paying tax or accused of paying very little tax as the common man bears the tax burden.

Of significance are the financial knowledge and the high affinity to wealth creation that the rich have which the poor and middle class do not (Eker, 2005). They work smart instead of working hard for money as the salaried people do. They know how money works and are smarter than money. In other words, they hardly work for money as money works hard for them while relaxing. Nevertheless, this common financial stereotype underpins the lack of financial intelligence among majority of people. Such inbuilt negative attitude against the rich makes people rest on their laurels and avoid learning the secrets of being financially stable. Some resort to shortcuts in order to acquire instant riches which are contrary to the ethical principles of creating wealth.

Text 5: Money is a source of all evil
The famous saying is repeatedly uttered in churches, schools, homes and myriad social gatherings. It is akin to quotations such as “Man made money and money made man mad” as well as “Money cannot buy happiness” (Text 12). Therefore, many people when asked whether they would like to be wealthy they respond that they would rather be comfortable working in high-paying jobs than spend sleepless nights in search of the illusive and trouble-ridden financial riches.

The preponderance of numerous incidents of the rich indulging in immoral and corrupt practices cannot be gainsaid. That in essence does not imply it is wrong to have lots of money. Besides, lack of money can be considered to be the root of all evil (Kiyosaki, 2012). Acquisition of money in a fair and just way guarantees one the freedom to afford the good things in life like going for holidays, buying or building palatial homes, posh cars and so on. Lack of money makes people to kill, steal, or even bribe to get jobs among other evils. Ultimately, money is not the source of all evils in the society.

Text 6: Live below your means or spend less than you earn
The illocution has certain perlocutionary effects on the recipients. The statement is a popular piece of advice highly championed by financial experts. The advice is not bad per se but it lacks the ultimate aim of leading a frugal lifestyle. Living beyond one’s means is admittedly one of the causes of poor personal financial management. However, living below one’s means is not a panacea to transforming one’s life. To save, one has to pay oneself before s/he spends money by setting aside at least 10% of his/her income. Similar to this imperative is the belief in the saying, “Save money, get out of debt, invest in the long-term
and diversify” (Kiyosaki, 2012: ). Expanding one’s means of earning a living should accompany and/or surpass the need to live below one’s means.

**Text 7: Don’t put all your eggs in one basket**
This age-old saying implies that people should not bank on one asset, income stream or source for a better life. In business, it means spreading one’s risks by investing in diversified portfolios with varied risks and high returns. One can invest in multiple businesses to guard against potential loss. Kiyosaki (2013) says such kind of thinking is anchored in the old rules of making money that nowadays are likely to make people poorer because the value of the money is wiped out by taxes, interests and inflation. One of the ingredients of successful smart investors is not diversifying but integrating or combining two or more businesses in different asset classes and accelerating as Bill Gates did with Microsoft company.

**Text 8: Invest in the long-term, buy, and hold**
This text is similar to text 7 above. In today’s fast-paced information age, the velocity of money is important in creating wealth. If one’s money is held somewhere for long, the currency will lose value due to taxes, interests and inflation. Most financial experts who are employees of insurance companies, stock exchange market and mutual funds providers give this classical advice. Their aim is to sell products irrespective of whether clients gain or not.

**Text 9: You can’t have your cake and eat it**
This simply means that you can’t serve two masters at a go. The above text is a common saying that is deeply ingrained in people’s mindsets. The metaphorical saying, in this context, implies one cannot have money or wealth and happiness at the same time. However, that may not be the case because one can have wealth and enjoy the freedom that comes with it. Eker (2005) observes that the rich “think both” while the poor people “think either/or”. The poor and majority of the middle class hail from the world of scarcity and limitation while the rich from a world of abundance. The saying anchors a belief that is fear-based and self-defeating.

**Text 10: Don’t sweat on small charges**
The imperative illocution alludes to the act of not minding about little deductions like bank fees, withdrawal charges, loan fees, policy fees, M-Pesa transaction deductions, shopping price disparities etcetera. If one does not consider the small fees that eventually amount to much then one is wasteful and financially illiterate. The English saying, “Little by little fills the measure” and the common saying cited by Mandi (2017). “If you take care for the cents, the shillings will take care of themselves” are fundamental in deconstructing the import of T10. Monitoring the small charges will make one devise strategies of minimizing losses.

**Text 11: A penny saved is a penny earned**
A penny refers to the little amount of money set aside is equally gained as one can use to invest or meet basic expenses. The saying is constructed deliberately to encourage people to save a little of their earnings to help them during a rainy day. However, when one thinks in terms of pennies, rainy days or small amounts then one has a programmed mindset of scarcity which in turn demeans one’s ideas. Thinking big is a fundamental way of soaring to greater heights. Clason (1926:11) says, “A part of all I earn is mine to keep. It should not be less than a tenth no matter how little you earn. Pay yourself first.” Learning about the culture of saving, for example 10% of one’s net earnings, prepares one for the future. It demystifies wealth and deconstructs the get-rich-quick money laundering schemes aimed at extorting money from gullible people.

**Text 12: Money can’t buy happiness**
The saying is true to some extent but can be interpreted wrongly in one’s quest to be rich. Not all rich people who have lots of money are happy because they are always looking for more and have a litany of
court cases to mind about. Hart (Sunday Nation Dec 6th, 2015) critically notes that the world is full of many unhappy billionaires whom people should not copy. However, money grants one the freedom to spend it without worry which is everybody’s dream and plan. Clason (1926) observes that wealth is power and with wealth many things are possible. Money cannot buy priceless things like love, peace and happiness but is important where it matters in life. Eg, money enables one to afford the good things of life such as holidaying in palatial coastal beaches, travelling round the world, establishing a foundation for the needy, buying posh cars, expensive residential apartments among other passionate desires.

Text 13: Another day another dollar
The poor live one day after another and are categorized as people who barely earn a dollar a day. Conversely, the rich exchange dollars for time because time is more valuable. Eker (2005) postulates that the rich choose to get paid based on results while the poor choose to get paid on time. The middle class too live on a steady monthly salary since they highly value security anchored on the illusion of permanent and pensionable jobs. The fear of losing their jobs is deeply implanted on their mindsets. With every dollar, one decides to be rich, poor, or middle class (Kiyosaki, 2011). Living a life of being broke and that of not enough money is suicidal.

Text 14: Money doesn’t grow on trees
This is a popular statement that is invoked by parents, benefactors and many other people in admonishing children or those who need help. This is part of verbal modeling that programmes children that money is always scarce and should be used carefully for it not to get finished. This old ideology makes people fear using money on things that matter like saving with particular goals in mind, starting a business and starting another business again after failing a number of times. Money should be treated as one’s friend not an enemy. Kiyosaki (1997: 228) states, “If your financial intelligence is low, money will run all over you. It will be smarter than you. If money is smarter than you, you will work for it all your life.”

Text 15: I just want to be comfortable
This is a declarative statement of intention is similar to Text 19 (Play it safe, avoid risk; investing is risky) which people utter when challenged on whether they would like to be rich or wealthy. As a matter of self-defense and on account of the inherent fear to tackle difficult problems, they resort to take refuge in their comfort zones. Eker (2005) points out that one’s comfort zone is equal to one’s wealth zone. People should learn to do what is hard so that life will be easy. Jeffers (1986) notes in her book, “Feel the Fear and Do It Anyway.” Notably, the rich act despite the fear that engulfs them whereas the poor are inhibited by fear.

Text 16: I am looking for a safe, secure job
This is the clarion call for many a job-seeker notwithstanding the young university or college graduates. Beneath this declarative lies a warped ideology of not exploring new areas like entrepreneurship because of the misconception that one must have money first before starting a business. The quest for white-collar jobs is a classical industrial age thinking whose present application is obsolete and irrelevant. Young people should be trained to be entrepreneurs and job-creators rather than being held captive by age-old enslaving ideas. Just like text 15, text 16 is aimed at making one reside in a comfort zone where one works for money instead of letting money work for him or her.

Text 17: Image is everything, substance is nothing
This illocution has adverse perlocutionary effects. It is the basis of media advertisements (especially the fashion industry) of products. The fashion industry has grown in reaps and bounds in the turn of the 20th century due to aggressive mass media marketing and globalization. The emergence of celebrities ranging from sport stars like David Beckham, Lionel Messi, Usain Bolt, Tiger Woods, media host personalities like Oprah Winfrey, reknown musicians like Whitney Houston among others have greatly influenced many young people worldwide. The celebs have become fashion stars due to their global image brand that
is used to sell and advertise goods. This trend has propagated the hackneyed notion that image is everything thereby creating a spendthrift mindset aimed at pleasing and winning admirers by positioning them as ‘persons of class’. ‘Substance’ herein refers to what one has in terms of knowledge and the assets one owns which are often underrated.

Contrary to the skewed assertion crafted from a consumerist perspective, the rich buy assets while the poor and middle class buy flossets or doodads that depreciate in value. In response to the consumerist mindset and lavish lifestyle championed by the media, Stanley and Danko (1996: 29) contend that young people are brainwashed with the belief that “those that have money spend lavishly and if you don’t show it, you don’t have it.” Ideally, sound financial education advocates for a plan that forgoes high consumption today in order to attain financial independence tomorrow. The two financial researchers aver that wealthy persons do not display a high consumption lifestyle as the rich do but derive pleasure in owning substantial amounts of appreciable assets like stocks, bonds, private businesses, real estate and so on. Therefore, substance is everything while image is nothing.

Text 18: I don’t like my job but I can’t afford to quit
The statement captures the dilemma that faces many employees who are stuck in their ‘safe and secure job’ that are not inspiring and are a recipe for financial instability. If they were to build and work for their business part-time, they would have found it more fulfilling than their enslaving jobs. The rider, “I can’t afford to quit”, blocks the thinking capacity and disempowers such a person. One gets trapped in a perpetual rat race which is passed on to the children and to their children’s children. Nganga (2016: 5) asserts, “You were never meant to be in a permanent job situation. The motivational author advises employees to discover and unleash their inherent gifts. This implies that one should be ensnared in a job he or she is uncomfortable with.

Text 19: Play it safe, avoid risk; investing is risky
This is a popular advice given to the indiscernible and gullible people either by theory friends or by their amateur advisors. Clason (1926:12) asserts, “Advice is one thing that is freely given away .... He who takes advice about his savings from one who is inexperienced in such matters, shall pay with his savings for proving the falsity of their opinions.” Investing is not risky, what is risky is the lack of financial knowledge. One should know the difference between risk and risky.

Text 20: You can’t serve two masters at a go
That is to say you cannot be rich and generous, have money and be happy. To the contrary, one can have his cake and eat it too. Eker (2005) declares that the rich think both while the poor think either/or because they come from a background of scarcity. Money is important as it brings freedom to afford the good things one desires. The more money one has, the more it amplifies one’s character – if one is mean, the meaner s/he gets.

Summary of financial implications of the financial myths
1. Financial dependency and job enslavement. The financial stereotypes inculcate a culture of financial dependency on job security leading to lack of financial freedom. This can be illustrated by the following texts.
   T1: Go to school, work hard, get a good grade and get a good job
   T2: I will save money when I earn more
   T16: I am looking for a safe, secure job
   T18: I don’t like my job but I can’t afford to quit
2. Stagnation in one’s economic or financial growth. For one to grow financially, one has to get out of one’s comfort zone and scale to higher levels of financial freedom and wealth creation by creating more than one stream of income. One should mind his business despite doing one’s routine job. This is exemplified by the following texts.
T2: I will save money when I earn more  
T3: It takes money to make money

3. Job dependency and enslavement. Money is said to be a drug; the more one sticks to one’s job, the more addicted one becomes and this limits thinking. It is imperative to think outside the box, do the extraordinary and work on becoming a self-reliant entrepreneur, educator and investor.

4. Propagation of scarcity mindset. Many people’s minds are wired upon the belief that money is evil, rich people are greedy and unless one gets a better paying job one cannot be comfortable or live a fulfilling life. Such myths are impoverishing and they cultivate a scarcity mindset whereby the remedy to the financial problems is blamed on external factors. The following texts demonstrate this aspect.
   T4: The rich are lazy, corrupt, greedy and ignorant
   T5: Money is a source of all evil

5. Entrenchment of vicious cycle of poverty. The age-old beliefs are passed on from one generation to the next culminating into a rat race that makes people perpetually poor or unstable financially.

6. Stagnation of a nation’s economy. A country’s whose citizens are financially illiterate lag behind socio-economically. Most third world countries have a stagnating economy whereby the gap between the rich and poor is ever growing. The leaders too practice corruption and blatantly mismanage the economy for their selfish gain.

7. Joblessness. The young people move to towns in search of all sorts of jobs. Worse still, graduates from colleges and universities believe that unless they get well-paying jobs for which they have been trained their future is doomed. They are not creative and innovative in applying learned skills by starting small businesses that can grow with time and solve the problem of unemployment.


9. Engaging in get-rich-quick schemes such as betting, engaging in lottery or money laundering programmes. This is brought about by the skewed socialization, modeling and verbal programming.

CONCLUSION
In a nutshell, the paper explores the role of language in encoding belief and stereotypes about money and wealth creation. It emphasizes the need for people to be financially literate. By analysing the age-old financial myths using CDA, various socio-economic implications are unveiled. Therefore, many people have been financially programmed to think and act in a particular way. To change people’s financial blueprint, there is an imperative need for mental reprogramming in order to produce remarkable results on the path to attaining financial freedom. In light of this financial problem, this paper aims at debunking and/or deconstructing the disempowering financial myths upheld by many people. The paper underscores the compulsive need for financial education in deconstructing unsubstantiated beliefs about money and the significance of reprogramming people’s mindset. It advocates for the incorporation of financial literacy skills in the 8 – 4 – 4 syllabus.

REFERENCES
A DISCURSIVE ANALYSIS OF POLITICAL DISCOURSE DURING THE 2010-2014 MAU FOREST RESTORATION DEBATE IN KENYA

Albert Mogambi Moinani, Margaret Nasambu Barasa, Eucabeth Ong’au
Kisii University, P. O. Box 408-40200, Kisii, Kenya
Email: albert.mogambi@yahoo.com, barasamargaret@yahoo.com, eucamore@yahoo.com

ABSTRACT
Climate change and global warming are challenges facing the world today. This problem is aggravated by the fast disappearance of forest cover in the world. The Mau Complex is not only Kenya’s largest water tower but also the largest closed canopy ecosystem. The forest is therefore of great importance nationally and globally. In spite of its national and global importance, there has been a proliferation of political utterances against the efforts to rehabilitate this water tower. This paper seeks to describe the linguistic features manifest in political discourse and their social implications for forest conservation in the country. This study was guided by a combination of Corpus Linguistics and Norman Fairclough and Ruth Wodak’s Critical Discourse Analysis (CDA) framework. Down sampling procedure was used to select 10 speeches by political leaders on Mau Forest saga. These speeches were obtained from the national archives for transcription and analysis. The CDA analysis was carried out on a sample of texts from the corpus and the data analyzed using qualitative and quantitative techniques. The T-Test and Mutual Information (MI) score were employed as measures of significance. The t-score rankings were used to measure the certainty of the collocation while the MI-score was used to test the strength of the collocation in the corpus. The CDA analysis on linguistic features indicated that political leaders’ utterances influence the way people think about the Mau Forest conservation. The T-test results were 4.27 and the MI scores were 2.95. Utterances laden with negative attitude undermined the Mau Forest conservation efforts. The dominant use of the pronominal “we”, “me” and “my” were for identity and inclusion with regard to the Mau Forest conservation. Conservationists should interpret the potent messages of language and its ability to influence people and society. Linguists should use their expertise to complement the efforts of natural scientists in conservation. Thus language can help achieve shift in attitudes and behavior on conservation issues and interrelationship between language and forest conservation.

Keywords: Persuasive strategies, ideology, attitude, conservation

INTRODUCTION
The voices of political leaders in regard to the conservation of the Mau forest in Kenya in the last decade form the focus of this study. A voice is a powerful source for spreading beliefs and forming attitudes. Research has proved that the power of the voice is incomparable to anything else in the world. Different voices in history which have stood out include that of Martin Luther King Junior against racism in America, Adolf Hitler’s voice of racial hatred and discrimination in Germany, and Jesus Christ’s voice of love and forgiveness. The social impact of these voices has been phenomenal and is felt in the world to date. Kristen and Barbra (2000) also argue that there are a number of voices which have revolutionized the world in terms of environmental awareness. These include the voices of John Muir (American writer), Marjory Douglas (American journalist), and Wangari Maathai (Kenyan Biologist and politician). These individuals’ speeches and writings on conserving the environment for future generations raised awareness among governments and influenced policies on conserving the environment in different parts of the world. There is need therefore to investigate the role played by the voices surrounding the Mau forest discourse during the 2010-2014 Mau Forest restoration debate.

Goshgarian (1998) asserts that the social impact of language is just powerful. This is because language can be used to lead and mislead and can also be used to distort reality, to hurt others and to shape our perception of the world. Politicians use language to make their hearers zealots on behalf of the programmes they espouse, consequently making them form opinions favourable to their predetermined ends. This study seeks to determine the connections between political discourse and forest conservation because public debate go a long way in shaping people’s opinions on many different issues manifest in
political speeches. This is because the language political leaders’ use plays a big role in attitude formation towards various issues in society. Politicians use language to convey information, persuade their hearers, and convey attitudes, feelings and emotions. There is need therefore to find out the relationship between language use and forest conservation in Kenya.

Other studies such as Malvern (2000), van Dijk (2000) and Potter (2009) have also shown that politicians use language in such a way that ensures they win support from the public masses. They use language to bond the minds of the public masses in favour of the politicians’ viewpoints. Discourse analyses of political utterances have equally shown that political utterances exhibit language techniques which make hearers form opinions favourable to speakers’ predetermined ends. Therefore, political leaders have been known to use language to lead and mislead, distort reality and to shape society’s perception of the world (Goshgarian, 1998).

The Mau complex is Kenya’s largest water tower. It spreads over four hundred thousand hectares making it Kenya’s largest closed canopy ecosystem (Ministry of Environment report, 2010). It is the single most important water catchment in Rift Valley and Western Kenya. This is because it is the source of all major rivers which form tributaries from as far as Lake Turkana in the North to Lake Natron in the south and also to Kenya’s most populous Lake Victoria basin. Further, the Mau Forest complex regulates water flow, mitigates flooding, regulates ground water recharge and most importantly mitigates climate change by storing carbon. The forest is therefore globally important for mitigating climate change. In spite of its national and global importance, many areas of the forest have been deforested and degraded in the past few decades (Ministry of Environment report, 2010).

The Government and development partners embarked on a programme to rehabilitate the forest. This project cost two hundred and thirty one billion shillings in the last ten years (NCCRS 2013). Despite such efforts, political leaders from Rift Valley have come out strongly and campaigned in public rallies against the Mau Forest restoration programme (NCCRS 2013). The forest restoration programme has been turned into a political issue. For instance, between 2005 and 2013, the forest conservation featured prominently in political campaigns in the Rift Valley, especially during electioneering periods. In the meantime, large tracts of forest have been cleared and turned into farmland (NCCRS 2013). The consequences of such practices have already been observed in Kenya: shrinking arable land, persistent dry spells, flooding and an unpredictable weather pattern (Ministry of Environment report, 2010). Ironically, many areas of the Mau Forest Complex have been deforested or degraded in the past few decades, in spite of its national and global importance. Degazettement of forest reserves and continuous widespread encroachment has led to the destruction of over one hundred thousand hectares since 2000 (Ministry of Environment Report, 2010). This scenario has impacted negatively on rivers originating from the western and eastern slopes of the Mau Forest. These include Ewaso Nyiro, Mara, Sondu, Molo and Njoro. The forest loss has therefore resulted to ecological and hydrological changes which threaten the sustainable future of areas downstream (NCCRS, 2013).

The Government, development partners and other stakeholders have campaigned so hard for environmental conservation. Such efforts are aimed at restoring Kenya’s forest cover which UNEP 2010 reports indicate stands at two percent instead of the globally recommended minimum of 10 percent. UNEP and other environment agencies have warned that unless this minimum forest cover is attained, the country risks catastrophic ecological disasters. UNEP and other stakeholders have committed millions of dollars in forest conservation projects in the country. Over two thousand people had returned to the forest in spite of the forceful evictions carried out by the government in 2015 (The East African Standard, March 4, 2015).

The Government initiated a move in 2010 to evict forest dwellers from the Mau forest so as to allow for rehabilitation of the depleted sections of the forest. The Government and other development partners have
so far spent a total of two hundred and thirty one billion shillings in the last ten years for the forest conservation programme (National Climate Change Response Strategy, 2013). In spite of this ecological zone being under the threat of depletion and millions of livelihoods threatened, a section of the political class came out and campaigned strongly against this move. The politicians held public rallies in various parts of the country to make their viewpoints known to the public.

Therefore the many studies carried on political discourse such as Goshgarian (1998), Malvern (2000), and Potter (2009) have shed considerable light on the power of language in influencing public opinion and attitude formation towards political viewpoints. However, research has shown that conservation has become an integral part of modern politics. Consequently, there is need to shift focus to the politics of climate change and global warming as emerging issues in society. This implies that there is more that linguists need to do to reveal the underlying interrelationship between language and environmental conservation. This is because language has the ability to influence people and society in terms of attitude and behaviour (Schultz, 1992). This study therefore sets out to investigate the Mau forest discourse and examine its implications for forest conservation in the country. Thus the specific research question was to establish in what ways forest conservation is linguistically defined and constructed in the 201-2014 Mau Forest Conservation Programme?

**LITERATURE REVIEW AND THEORETICAL PERSPECTIVES**

Political discourse is the formal exchange of reasonable views as to which of several alternative courses of action should be taken to solve societal problems (Johnson and Johnson, 2000). It is a method of decision-making. That is, political discourse is about which viewpoints politicians would like their hearers to adopt so as to solve societal issues. Kristen and Barbra et al (2000) on ‘Approaches to environmental issues’ pose a very important question: can one individual change the way people think about environmental issues? They argue that dealing with environmental issues at personal, national or global levels involves making choices. That is, the viewpoint an individual chooses has a great influence on how others view environmental issues. They cite examples of leaders in various parts of the world whose speeches and writings on environmental issues have been known to influence the way many people think about environmental conservation.

These include John Muir (American writer), Theodore Roosevelt (US President), Rachel Carson (British Writer), Marjory Douglas (American Journalist) and Wangari Maathai (Kenyan Biologist, politician). These are few examples of individuals whose speeches and writings on environmental conservation are known to have had a positive influence on people’s attitude towards wildlife and environmental conservation. These individuals spoke and wrote persuasively about conserving the environment for future generations. They won hearts for their course, raised awareness among governments and influenced policies that favoured environmental conservation in various parts of the world. In the contemporary times, US President, Barack Obama and the leader of the Roman Catholic Church, Pope Francis are among key leaders who have expressed concern over environmental degradation. In his State of the Union address (Daily Nation, August 3, 2015), President Obama observed that climate change was no longer an issue for future generations but a reality for the current generation. He said that taking a stand against climate change is a moral obligation and promised to rally all world leaders to champion this course so as to save the world from a looming climatic catastrophe.

Pope Francis on his part told the 70th United Nations Assembly that there is need for urgent action to halt the earth’s destruction through environmental degradation (Daily Nation, September 29, 2015). The Pope said that he had launched a teaching document to champion the rights of the environment. He said that the environment has rights and mankind has no authority to abuse them. He urged world leaders and governments to take action against those who were responsible for environmental degradation because of selfish and boundless thirst for money. These sentiments also featured prominently during the World Summit on Climate Change in France (COEPIC 2015). The summit agreed to set timelines in the fight
against climate change with the hope that the deliberations would help in influencing world leaders to set commitments in tackling climate change. This paper endeavours to answer the question posed by Kristen and Barbra (2000) as to whether the political leaders’ utterances influence the way people think about the Mau Forest conservation. This study also considered the viewpoints of Kenya’s political leaders and determined the connection between language use and forest conservation during the 2010-2014 Mau Forest restoration debate. This is because the utterances made by politicians influence the viewpoints of the masses (Melvern, 2000). Politicians are also known to vigorously drum up public support for their viewpoints on critical issues in society. Politicians will go to any length to rally the ignorant public behind their viewpoints which are usually meant to serve the selfish interests of the politicians and their political parties.

What is written or said exerts a lot of influence on people’s political attitude (Mutz, 1996). Mutz further posits that the field of politics requires successful mastery of the art of persuasion. Mutz defines persuasion as an activity or process in which a communicator attempts to induce a change in belief, attitude or behaviour of another person or group through transmission of a message in a given context. Mutz however argues that there is need for studies to show the influence of elite discourse and mass political attitude formation and change. This study is informed by Mutz’s persuasion strategies in the analysis of political discourse on the Mau forest issue. This study looks at the language features manifest in political discourse and try to establish their social implications for forest conservation. This study will also provide insight into the interplay between political discourse and environmental conservation.

Language is a powerful force that shapes people’s mind and society’s attitudes and ultimately, behavior (Schultz, 1992). She further argues that most conservationists appear to be deaf to the potent messages of language and blind to its ability to influence people and society. She therefore urges linguists to use their expertise with language to complement the efforts of natural scientists in the field of conservation. The current study will address Schultz’s concerns by trying to unearth the interrelationship between political discourse and forest conservation in Kenya.

Politics is concerned with power to make decisions, control resources, other people’s behaviour and often to their values or beliefs (Jones & Peccei, 2004). Politicians throughout history have achieved success through their skillful use of rhetoric by which they aim to persuade their hearers of the validity of their views. This study will analyze politicians’ language use to ascertain the influence of language in informing public opinion and attitude formation towards forest conservation. The study will try to show how political leaders’ language use is embedded with feelings and beliefs about forest conservation.

Ethnic communities that live close to nature will use their languages to create solidarity between themselves and the environment and for exploitative discourse. One can use CDA framework to analyze or criticize such speakers’ discourse by looking at the words, syntax and pragmatics of spoken and written texts. (Muhlhhauser, P & Harre, B., 1999). They argue that such analysis focusing on such texts as political speeches, green ads, and articles on the environment will enrich Ecolinguistics as a thriving field of study. This study strives to respond to Muhlhhauser and Harre’s concerns. The study also uses the CDA framework to analyze political speeches on the Mau forest restoration to reveal how speakers use words and phrases to achieve legitimation and delegitimation and also to share their ideologies with their audience. The findings will enrich the field of Ecolinguistics as an emerging area of study.

Language plays an important role in tackling ecological issues and the environmental problems which affect more and more groupings and individuals (Fili, 2001). As far as conservation is concerned, it is a mistake to believe that technical experts and natural scientists are the appropriate or only experts in this field. The problems of the environment are problems of the consciousness of our self and its role rather than problems of nature itself (Finke, 1998). Linguists should be admitted as experts on some of the issues involved, more especially in reforming man and his inner landscapes (attitudes). This study will try
to answer Fill’s question. The study will critically analyze political discourse on the Mau forest so as to reveal the hidden ideologies and interrelationship between language and conservation.

Wood (1983) asserts that a range of language features exert a lot of influence on how people think and see the world (Wood, 1993). Speakers use specific words, phrases or metaphors to suit their hearers’ circumstances. These words, phrases or metaphors make the hearers feel good or cared for. Wood further says that the features of political language vary, as do its purposes. Where politicians interact with society, their purposes may be to persuade hearers to a party loyalty or to make hearers adopt general or social attitude, so they support a given policy. According to Wood, language plays a big role in attitude formation. This is because attitudes are social phenomena which emerge and are embedded in social interaction. The current study will be informed by Wood’s assertion that political speeches are embedded with certain attitudes which they try to communicate to their hearers. The study will endeavour to identify the language features manifest in political discourse on the Mau forest conservation and determine their social implications for forest conservation.

The social impact of language is just powerful. This is because language can be used to lead and mislead and can also be used to distort reality, to hurt others and to shape our perception of the world (Goshgarian, 1998). Goshgarian asserts that politicians use certain language techniques to win support from the public masses. These techniques are used by politicians to bond the minds of the public masses in favour of the politicians’ viewpoints. Goshgarian further observes that politicians use certain language devises to work up their hearers’ emotions. They can make their audiences glow with pride or burn with hatred. They use language to make their hearers zealots in behalf of the programme they espouse. They make hearers form opinions favourable to speakers’ predetermined ends. Therefore political language is power. It is the language that gets things done, influence government policy and action.

Political discourse entails political speeches interviews, programmes, campaigns during elections or propaganda that typically focuses on the preferred topics of in-group and out group representation (van Dijk, 2000). Van Dijk further argues that implication is one of the most powerful notions in a critical analysis of political discourse. Words, clauses and other textual expressions may imply concepts or propositions that may be inferred on the basis of background knowledge. This feature has significant ideological dimension since the analysis of the ‘unsaid’ is sometimes more revealing than what is expressed in the text. The current study will look at the persuasive devices manifest in the political utterances made during the Mau Forest conservation debate and describe their social implications for forest conservation in Kenya.

Political speeches perform a number of rhetorical functions. They inform, persuade, manipulate, influence and control, while also serving to place the speaker in the best possible light (Durant & Lambrou, 2009). Where the speaker is a political leader, the content of a political speech can make a major difference to public opinion. In such circumstances, the choice of language is fundamental not only to encouraging the public to vote but also in persuading them to vote in a particular way. That is, the language used seeks to persuade hearers towards some particular viewpoints, beliefs or course of action. Hearers are persuaded because they believe the speaker to be fair and honest thus this largely depends on the personal character of the speaker (ethos), the emotion aroused by what the speaker says (pathos) and by the proof provided by the words (logos). Durant describes a number of persuasive devices manifest in politicians utterances. The devices include metaphor, metonymy, sound patterning, (repetition, alliteration), list of three, rhetorical questions, catch phrases and lexical choice. This study will borrow from Durant’s system of describing the language features manifest in political speeches. This study will analyze the persuasive devices such as repetition, metaphor, and pronominal choice manifest in politicians’ utterances on the Mau Forest conservation debate to determine their implications for environmental conservation.
Political discourse intends to enhance people’s understanding of a particular issue and inform about possible solutions to the problem (Chilton (2004). However, the communicative effect of a political message does not only depend on advancing the level of understanding of the interlocutors, but it can also depend on bringing about changes in their opinion about a particular issue. This can be achieved with the help of discourse strategies, which include a variety of linguistic devices used by interlocutors to serve the intended communicative function. This study will entail the analysis of persuasive devices in the political discourse on the Mau forest debate and the communicative function they serve.

Other studies such as Kimenyi (2008) and King’ei (2001) argue that the tribal clashes which have characterized the electioneering period in Kenya are attributed to the political leaders’ utterances. Citing the 1992, 1997 and 2007 election periods, they aver that the political leaders used language that was embedded with messages of negative ethnicity. These messages fanned the post election violence. These studies observed that the politicians used language with the purpose of shaping, directing, controlling and manipulating the audiences in politically desired ways.

Language can play a powerful role in resolving political related conflicts (Barasa, 2014). Using a sample of four political speeches, analyzed from a CDA perspective, the findings indicated that politicians can manipulate language to advance individual and political party ideologies which can compromise peace in the country. However, it was also observed that the mitigated language used by the national leaders in their negotiation helped to resolve the crisis on Portfolio Balance during the aftermath of the post-election violence in Kenya in 2007-2008. This study will be informed by Barasa’s (2014) work in data analysis.

In view of the above studies, it can be observed that many of them address the role political discourse plays in influencing people’s attitudes towards political viewpoints. The studies have indicated that language is a powerful force that shapes people’s minds and society’s attitudes and behavior. However, there is need to pay a more critical attention to the interrelationship between language use and conservation. Consequently, a shift in focus to the domain of conservation which trails behind the necessary dimension the world over is necessary.

Theoretical Framework
Different theories have been advanced in the study of political discourse. This study will be guided by the tenets of Corpus Linguistics (CL) and Critical Discourse Analysis (CDA) by Fairclough and Ruth Wodak. It could be argued that the CL methodology offers the researcher a reasonably high degree of objectivity; that is, it enables the researcher to approach the texts (relatively) free from any pre-conceived or existing notions regarding their linguistic or semantic/pragmatic content. The examination of the strongest key words and clusters in the corpora, (archived discourses) combined with concordance analysis, will provide helpful indications of the respective stance towards forest conservation of the Mau Forest. However, it may also be beneficial to examine the keyness not only of word-forms, but also of lemmas, word families, and, more pertinently for this study, semantically/functionally related words.

By grouping together key words relating to specific topics, metaphors or topoi, it will be possible to create a general impression of the presentation of forest conservation in the 2010-2014 Mau Forest Conservation Programme. At this point, we need to introduce the concepts of semantic preference, and semantic/discourse prosody (terms which are sometimes used inconsistently or interchangeably), as they can be seen as the semantic extension of collocation. Semantic preference refers to semantic, rather than evaluative, aspects; it is the relation ‘between a lemma or word form and a set of semantically related words’ (Stubbs, 2002: 65). For example, the two-word cluster ‘glass of’ shows a semantic preference for the set of words to do with drinks (water, milk, lemonade etc.) Semantic prosody is evaluative, in that it often reveals the speaker’s/writer’s stance; it is the ‘consistent aura of meaning with which a form is imbued by its collocates (Louw, 1993: 157).
Discourse prosody, also evaluative, ‘extends over more than one unit in a linear string’ (Stubbs, 2002: 65); Stubbs provides the eg of the lemma CAUSE, which ‘occurs overwhelmingly often with words for unpleasant events’ (ibid.). The notion of discourse prosody makes it explicit that collocates need not be adjacent to the node for their meaning to influence that of the node. The analysis of emerging significant lexis and lexical patterns will be supplemented throughout with the examination of their concordances. A concordance presents the analyst with instances of a word or cluster in its immediate co-text.

The number of words on either side of the word/cluster in focus can be usually set to fit the researcher’s needs, and concordance lines can be expanded up to the whole text. Also, concordance lines can be sorted in various ways to help the analyst examine different patterns of the same word/cluster. Concordance analysis affords the examination of language features in co-text, while taking into account the context that the analyst is aware of and can infer from the co-text. In turn, this indicates that CL is no stranger to ‘qualitative’ analysis. Furthermore, as concordance analysis looks at a known number of concordance lines, the findings can be grouped (e.g. topoi related to a specific word or cluster) and quantified in absolute and relative terms for possible patterns to be identified (e.g. the tendency of words/clusters to be employed in the utilisation of particular topoi).

Critical Discourse Analysis (CDA) is a practically-oriented form of discourse analysis aimed at addressing social problems. It seeks not merely to describe language but also to offer critical linguistic resources to those wishing to resist various forms of power. Therefore, the goal of CDA may be seen as to uncover the ideological assumptions that are hidden within texts. One of the most influential practitioners of CDA is Norman Fairclough, and it is his model of language as discourse and Ruth Wodak’s Discourse Historical Approach (DHA) upon which this study is approached. CDA is a form of discourse analysis which uses SFL to study how formal linguistic features of text, such as vocabulary and grammar, are related to social power. The relationship between text and power is mediated by ideology. People are often unaware of this ideological mediation of power in language. Therefore, the goal of CDA may be seen as to uncover the ideological assumptions that are hidden within texts.

Because of SFL’s social constructivist conception of language, and CDA’s practical-orientation to addressing social problems, together they have been used in many spheres of social struggle. Although there has not, as yet, been much CDA work published in this area (Halliday 1992), many environmental issues involve power struggles between opposing groups, and these struggles frequently take place in, and over, language. SFL and CDA can help us become more systematically and critically aware of the language in which environmental matters are discussed. Such awareness can help us understand the ideological presuppositions of environmental texts.

Critical Discourse Analysis provides a general framework to problem-oriented social research. Every ‘text’ (e.g. an interview, focus group discussion, TV debate, press report, or visual symbol) is conceived as a semiotic entity, embedded in an immediate, text-internal co-text as well as intertextual and socio-political context. CDA thus takes into account the intertextual and interdiscursive relationships between utterances, texts, genres and discourses, as well as extra-linguistic social/sociological variables, the history and ‘archaeology’ of an organization, institutional frames of a specific context of situation and processes of text production, text-reception and text consumption.

Furthermore, CDA is socially and politically committed, being heavily informed by social theory and viewing discursive and linguistic data as a social practice, both reflecting and producing ideologies in society. In this way, all CDA approaches have to be regarded not only as ‘tools’ but as discourse theories (Wodak & Chilton 2005; van Dijk forthcoming).CDA thus sees ‘language as social practice’ (Fairclough & Wodak 1997), and considers the context of language use to be crucial (Weiss & Wodak 2003).
CDA researchers are fundamentally interested in analyzing opaque as well as transparent structural relationships of dominance, discrimination, power and control, as they are manifested in language. For CDA, language is not powerful on its own – it gains power by the use people make of it. This explains why CDA often chooses the perspective of those who suffer, and critically analyzes the language use of those in power, who are responsible for the existence of inequalities and who also have the means and the opportunity to improve conditions. In agreement with its Critical Theory predecessors, CDA emphasizes the need for interdisciplinary work in order to gain a proper understanding of how language functions in constituting and transmitting knowledge, in organizing social institutions or in exercising power.

Language provides a vehicle for differences in power in hierarchical social structures. Very few linguistic forms have not at some stage been pressed into the service of the expression of power by a process of syntactic or textual metaphor. CDA thus takes an interest in the ways in which linguistic forms are used in various expressions and manipulations of power. Power is signalled not only by grammatical forms within a text, but also by a person’s control of a social occasion by means of the genre of a text, or by access to certain public spheres. It is often exactly within the genres associated with given social occasions that power is exercised or challenged. Those groups who are in control of most influential public discourses, that is symbolic elites such as politicians, journalists, scholars, teachers and writers, thus play a special role in the reproduction of dominant knowledge and ideologies in society (Van Dijk 2005). Since prejudices are not innate, but socially acquired, and since such acquisition is predominantly discursive, the public discourses of the symbolic elites are the primary source of shared ethnic prejudices and ideologies (Van Dijk, 1993). CDA theories argue that the theorization of context is constitutive for the text analysis (see Fairclough & Wodak 2007). In this way, ‘context’ cannot be reduced to exploring the seemingly ‘objective’ dimensions of the broader locution of utterances (time, space, speakers, etc.); context has to be perceived and interpreted so that speakers produce utterances they regard as adequate and hearers interpret them due to their perceptions of context and their knowledge (van Dijk, 2005). Hence, van Dijk claims that we need to assume ‘context models’ which allow understanding what is said and meant.

On the other hand, a ‘critical’ analysis would not only be interested in accounting for what linguistic elements and processes exist in a text or set of texts but would also need to explain why and under what circumstances and consequences the producers of the text have made specific linguistic choices among several other options that a given language may provide. That is, a critical analysis takes into account absences as well as presences in the data. This justifies the use of CDA rather than purely descriptive, data driven approaches which are epistemologically inadequate in accounting for the complex linguistic choices made during the processes of production of a text. The CDA approach adopted for this study focuses on macro-structural categories (such as the specific genre) and on text-inherent categories developed in the DH approach of CDA for the analysis of positive self-presentation and negative other-presentation (Reisigl and Wodak 2001). These dimensions include inter alia strategies employed for predication, labelling, argumentation, perspectivation, and intensification/mitigation. Each of these strategies are manifested textually through a number of linguistic indicators, eg specific lexical items to construct in-groups and out-groups, along with adjectives, attributes, metaphors, and selection of verbs.

This study will analyze the political utterances to reveal the persuasive devices and their social implications for forest conservation. CDA will make it possible to analyze the utterances in terms of the lexical choices the speakers make and the ideologies underlying these choices. CDA will also enable the researcher to reveal how power and social relations are negotiated, performed, and produced through discourse. The researcher will give the interpretation of the pronominal choices the speakers make and how they perform the function of expressing the speakers’ power to dominate and direct public debate on Mau forest conservation. This study will analyze political discourse to reveal how social views, power, identity, legitimation, and delegitimation are represented in discourse through lexical choices made by the speakers. These choices will reveal the speakers feelings, thus, attitudes towards forest conservation.
CDA therefore seeks to unveil the obscure relationships between power and discourse. CDA approaches discourse as a circular process in which social practices influence texts (written and spoken) via shaping the context and mode in which they are produced. In turn, the texts help to influence society through shaping the viewpoint of those who consume the texts (spoken or written). The current study will therefore strive to bring to light the power relations manifest in political utterances on the Mau Forest conservation. The approach will help reveal how speakers use language to display their authority to direct and inform public viewpoint on environmental issues. That is, CDA will help the researcher explain what political leaders say and do in their use of discourse in relation to their views of the conservation debate, themselves and relationships with each other. CDA will also help the researcher in tracing the underlying attitudes from the persuasive devices manifest in political discourse on forest conservation and relating this to the people’s experiences and beliefs. In sum, CDA was chosen because of its interpretive and explanatory nature. CDA goes beyond the level of description to a deeper understanding of texts and provides as far as might be possible, some kind of explanation of why a text is as it is and what it is aiming to do.

CDA examines texts such as political discourse which have great influence on the people. CDA is therefore both a theory and method of analysis. CDA’s notion of context embodies psychological, political, ideological, and historical components. Consequently, CDA offers an interdisciplinary procedure to this study.

Fairclough also borrows from Halliday’s Systematic Functional Grammar (SFG). This theory is concerned with how language choice enables one to convey meanings of different kinds. According to Halliday (1985, 1994), a language is a “system of making meanings”. People use language to express meaning and therefore it is in understanding the theory behind the assembling of words to form a grammar that meaning can be interpreted correctly. Thus, Halliday sees language as made up of semantic units and that a functional grammar is needed to bring out the meanings of wordings. Halliday avers that this kind of analysis is functional because it is about analyzing language in use according to context.

Halliday identifies three functions that language performs, namely; ideational, interpersonal and textual. This study will be guided by SFG in the analysis of lexical choices made by political leaders in the Mau forest restoration debate. The context will help in the interpretation of the speakers’ lexical choices and the embedded attitudes and perceptions. This analysis will also reveal what speakers feel based on their experiences of the real world including the inner world of their consciousness. What the speakers feel will be reflected by the lexical choices they make, consequently revealing their attitudes towards forest conservation. This is what Halliday refers to as the Ideational function.

In serving this function, language gives structure to experience and helps to determine our way of looking at things; it requires some intellectual effort to see them in any way that that which our language suggests to us. Language also serves the Interpersonal function. This function is concerned with how language reflects the attitude and opinion of speakers. The words speakers choose to use in particular contexts will be embedded with their feelings and attitudes. This study will focus on this function in the analysis of the lexical choices and persuasive devices political leaders during the Mau forest debate. Language further serves the textual function, which is concerned with how words and sentences are organized to make the text and to steer the reader’s/hearers interpretations of events and people (Eggins, 1994).

SFG just like CDA will inform this study in the analysis of the politicians’ language use during the Mau forest conservation debate. It will reveal how politicians view conservation debate through their choice of words and the structure of their texts. The analysis of language use will therefore reveal the values and ideological constructs found in the politicians’ discourse on Mau forest conservation. It is these values and ideological constructs that the speakers intend to share with the people through discourse.
METHODOLOGY
This study will use a Qualitative research design. The design presents a qualitative analysis, comparison and interpretation of the study’s findings to find a solution to significant problems in society (Glesne, 2012). Researchers have argued that the greatest strength of qualitative research is to add understanding and insight into behaviour and attitudes. Speeches by political leaders on the 2010-2014 Mau Forest debate will be selected for analysis. Downsampling procedure will be used to select the samples of political utterances during the 2010-2014 Mau forest restoration. Texts will be selected from the articles within 2010-2014 period of the Mau forest conservation programme. The CDA analysis will be carried out on a sample of texts from the corpus and the data analyzed using qualitative techniques. The use of particular words and phrases within the context of Mau forest restoration debate will imbue these items with hidden meanings which will in turn provide cultural and ideological information.

RESULTS AND DISCUSSION
Linguistic definition and construction of forest conservation
This section discusses how political leaders perceived and defined forest conservation. The lexical items, metaphors and expressions the political leaders used during the Mau Forest conservation debate indicate how the speakers perceived and defined the forest conservation issue. The government and other stakeholders embarked on a programme to rehabilitate the Mau Forest Complex. This programme involved the eviction of people who had encroached on the forest land for farming, charcoal making and logging. Political leaders from the Rift Valley region came out and campaigned against this programme. The forest conservation programme was turned into a political issue and it featured prominently during the electioneering periods since 2005 to date. A critical analysis of these lexical items and expressions offered insight into how the political leaders perceived and defined the forest conservation. The lexical items and expressions they used also indicate the speakers’ beliefs and attitudes towards the Mau Forest conservation issue. The following are some of the ways in which the speakers defined and described the forest conservation issue.

Oppression
Different speakers referred to the Mau Forest Conservation issue as a form of oppression. The speakers used expressions which implied that the entire conservation issue was inhuman. This is illustrated by the following examples (ref Appendix C)

Sample 1
You oppress the people- imagining Mau- does all the water
Come from Mau! (Excerpt 13 line 7)
You push people in the name of water catchment areas... (Excerpt 14, line 6)
You push people. Are people rats and cats...? (Excerpt 14 line 8)
We should bear in mind that we are dealing with human beings, not chicken! (Excerpt 19 line 4).

The examples in Sample 1 indicate how the speakers perceived the forest conservation issue. The speakers’ lexical choices imply that the forest conservation programme was a form of brutality and unfairness. The phrases ‘push people’ and ‘not chicken’ indicate that the conservation programme was equated to inhuman treatment of the people. This implies that the people should resist the conservation programme because of its being oppressive.

Distortion
A closer look at the political discourse on the Mau Forest reveals that the politicians viewed the conservation issue as a distortion of the reality on the ground. The speakers argued that the politicians from other ethnic communities (outsiders), who never understood the nature of the Mau Forest Complex were misleading the government in this issue. The speakers portray those advocating for the conservation programme as ignorant. Therefore the conservation programme is a product of ignorance and lack of knowledge.
Sample 2

I do not know whether these days Mau Forest stretches all the way to Nairobi... (Excerpt 1 line 1)
Do you want to tell me that Mau Forest is the source of Water in Ndakaini Dam? ... (Excerpt 1 line 3)
There was proper excision of forest land, proper survey, Proper documentation-complete with issuance of title deeds... (Excerpt 5 line 2)
Is Mau there? Why is it that there is no water in Mount Kenya area? Let us get the scientific knowledge about it... (Excerpt 25 line 13-18).

The examples in Sample 2 imply that the Mau Forest is not related to the drought situation in different parts of the country. The speakers argued that other regions that are not within the Mau catchment were experiencing drought and yet the people in the Mau Forest Complex were being told to move out. The speakers therefore implied that the conservation exercise was based on falsehoods. That is, the people in the forest should be free to carry on with their activities because the Mau Forest is not responsible for the drought. However, it is important to note that although the speakers’ assertions are not true, they could influence the way the people view the conservation issue.

Ethnic provocation

Speakers viewed the conservation programme as a form of ethnic – based provocation and a recipe for violence. The lexical choices in the politicians’ utterances show that the eviction of people from the Mau Forest was regarded as deliberate attempt by political leaders from other ethnic communities to stir the people of Rift Valley to violence.

Sample 3

Those who do not understand the importance of peace are the ones running up and down... thinking that Rift Valley is just like any other province... (Excerpt 9 line 3).
Leaders from outside to come and dictate what the people of Rift Valley should do... are there no men and leaders in Rift Valley?... (Excerpt 14 line 2-4).
Rift Valley has its own people and the people have their own leaders... (Excerpt 9 line 4).
To tell us that a deadline has been set for people to be evicted by force- we will never let it happen! (Excerpt 13 line 14).

The examples in Sample 3 indicate that the political leaders viewed the conservation issue as a recipe for tribal clashes in the Rift Valley region. The speakers highlighted the fact that those calling for the eviction of people from the Mau Forest hailed from different ethnic communities, hence did not deserve to be listened to. The speakers urged the people to repulse them and rely on their own political leaders for guidance in as far as the Mau Forest issue was concerned. The use of expressions such as ‘are there no men’, leaders from outside’, and ‘we will never let it happen’ could be interpreted to mean that the speakers were inciting their people to physically resist the conservation exercise. These assertions could reinforce, inform or even influence the people’s beliefs about forest conservation.

Blackmail

Some speakers perceived the conservation issue as an excuse to settle political scores and ultimately gain political mileage. A closer look at the utterances indicates that the speakers felt that those advocating for the eviction of people from the Mau Forest were insincere. The forest issue had been turned into blackmail. That is, the Mau Forest was being used as an excuse to harass the people of Rift Valley and their political leaders.

Sample 4
Ndakaini Dam is drying up...do you want to tell me that the Mau Forest is the source of the water in Ndakaini Dam? (Excerpt 1 line2).
There was proper excision of forest land, proper survey, proper documentation...
(Excerpt5line1-2)
Lake Naivasha- is it not dry? Have they queried about it... (Excerpt 13 line 5).
Forests are burning all over...trees are being felled, they keep on shouting Mau Mau Mau...
(Excerpt14 line 9-11).
It has been said that Sondu Miriu is drying up because of Mau....I want us to be very sincere... Let us be honest... is Mau there? (Excerpt 25 line 12-13).

The examples in Sample 4 indicate that the speakers perceive the Mau Forest issue as an excuse to push for the eviction of people from the forest. That is, the political leaders’ belief that the destruction of the Mau Forest is not related to the drought in other parts of the country is emphasized. They cite Lake Naivasha, Sondu Miriu and Ndakaini Dams which had been reported to have recorded receding water levels as prove of their claims. This means that those advocating for the removal of people from the Mau Forest had other motives other than conserving the Mau Forest. The political leaders are therefore urging their people not to accept the view that the destruction of the Mau Forest is related to drought.

CONCLUSION
Insights from the linguistic data analysis have revealed that political leaders perceived the Mau Forest Conservation programme in bad light. The speakers used words, phrases, metaphors, and expressions with negative connotation to either refer to or describe the forest conservation issue. The speakers defined the forest conservation issue as oppression, distortion, blackmail and ethnic provocation/animoity. These definitions and perceptions repeated over time could easily become the community’s shared perception and definition of the forest conservation issue and thus derailing the efforts to conserve the Mau Forest.

REFERENCES
PERCEIVED INFLUENCE OF KNOWLEDGE, ATTITUDE AND VALUES ON CLIMATE CHANGE MITIGATION BEHAVIOUR AMONG TOURISM BUSINESS MANAGERS IN KENYA: A LITERATURE REVIEW.

Kinyanjui, D. N.
Chuka University, P. O. Box 109-60400, Chuka
Correspondence: danielngochi@gmail.com, 0720 939 412

ABSTRACT
Climate change is now widely recognized as a major, anthropogenically induced environmental threat, with potentially severe and far reaching consequences on among others; health for human and natural systems. The tourism sector has specifically been recognized as having a significant range of impacts on the natural and social environment. The sector is estimated to contribute 21% of tourism’s global greenhouse gas (GHG) emissions. In addition, the sector is not only a major user of energy, land and water resources but is a contributor to water, food and other waste. The negative effects of climate change in the sector need therefore to be contained as a matter of urgency and hence players in the tourism sector have a central role to play in addressing climate change risk. Corporations can respond to climate change through adaptation to potential and unavoidable climate impacts or mitigation efforts that are focused on reducing GHG emissions to prevent or delay further damages. With climate change being primarily rooted in excessive energy consumption, engagement in mitigation activities by corporations is recognized as critical to achieving a sustainable future. Undoubtedly, this will involve shifting towards a new, low-carbon paradigm behavioral practices. In this paper, the author reviews the existing literature on Kenya’s policy recommendations for climate change adaptation and mitigation within the tourism industry. The author also presents conflicting findings on how knowledge, attitude and value orientation in human beings have been established to influence climate change mitigation practices in several globally. Although climate change mitigation behavior is influenced by the above factors, no studies have been done in Kenya to establish whether knowledge, attitude and values have a similar effect the implementation of climate change related policies in the tourism businesses. Therefore, this review identifies a gap for future research to find out if the same applies in the Kenyan context so as to be an important input in the climate change policy formulation process in future.

Keywords: Climate change mitigation, Knowledge, Attitude, Value orientation

INTRODUCTION
This is explained by the fact that tourism relies on the climate, which defines the length and quality of tourism seasons and thus extreme events, such as heat waves, tropical cyclones, heavy precipitations, or droughts, are likely to become more frequent and intense, and can play an important role in destination choice (Field & Intergovernmental Panel on Climate Change, 2012). There are concerns that the tourism industry in many African regions may not be in a position to cope with challenges posed by climate change (Gössling, Peeters, et al., 2012). This threatens the livelihoods of people who depend on the tourism industry. There have been calls for assistance in building capacity for the management of issues relating to undesirable climate change impacts in the tourism industry (Simpson, Gössling, Scott, Hall, & Gladin, 2008). For instance, stakeholders have been urged to prioritize on ‘green actions’ in the tourism industry (UNEP, 2005). Addressing such calls will require data on where action is most needed.

Climate change directly impacts on many economic activities. The tourism industry is especially sensitive to climate variability and change (Gössling, Scott, Hall, Ceron, & Dubois, 2012). This is explained by the fact that tourism relies on the climate, which defines the length and quality of tourism seasons and thus extreme events, such as heat waves, tropical cyclones, heavy precipitations, or droughts, are likely to become more frequent and intense, and can play an important role in destination choice (Field & Intergovernmental Panel on Climate Change, 2012). There are concerns that the tourism industry in many African regions may not be in a position to cope with challenges posed by climate change (Gössling, Peeters, et al., 2012). This threatens the livelihoods of people who depend on the tourism industry. There
have been calls for assistance in building capacity for the management of issues relating to undesirable climate change impacts in the tourism industry (Simpson et al., 2008). For instance, stakeholders have been urged to prioritize on ‘green actions’ in the tourism industry (UNEP, 2005). Addressing such calls will require data on where action is most needed.

**Climate Change Policy in Kenya**

Kenya is one of the leading tourist destinations in Sub-Saharan Africa with significant potential for tourism growth. However, extreme climatic events have long posed a significant risk to regions in Kenya, and they have contributed to making it one of the most disaster-prone countries in the world where in recent years had its share of climate-related impacts such as prolonged droughts; frost; hailstorms; extreme flooding; receding lake levels; drying of rivers and other wetlands; among others leading to large economic losses and adversely impacting many sectors including tourism (GoK, 2013).

The tourism industry has a key role to play in confronting the challenges of climate change. The spectacular growth of tourism provides both a challenge and an opportunity. The tourist community itself has responded to this challenge over the past few years and visibly stepped up its response to climate change (McClanahan & Cinner, 2011). There is now a clear understanding that the industry can be part of the solution to climate change, by reducing its green house gas emissions as well as by helping the communities where tourism represents a major economic resource to prepare for and adapt to the changing climate (Scott & Becken, 2010, (Hall, Gössling, & Scott, 2012). The pervasive nature of climate change in the tourism industry is one of the reasons for increasingly steering polices towards plans and strategies aimed at reducing it.

The government of Kenya has designed a medium term strategy aimed at curbing the climate change contained in the National Climate Change Action Plan 2013 - 2017 (Koh, Kelman, Kibugi, Eisma-Osorio, & Kelman, 2016). This is an important document because policy-making in the short to medium term will be geared towards implementing this strategy and realizing its goal (Muchuru & Nhamo, 2017). Two important objectives of this strategy is adaptation analysis and prioritization and mitigation action. The tourism sector has been proposed as an important sector for taming the adverse effects of climate change (Ford et al., 2015). The important question, however, is how the government is going to achieve that goal. This question cannot be adequately answered unless there is information on characteristics of stakeholders in the tourism sector and how their characteristics determine issues in climate change. This policy aspect is the major justification for this study.

Although in general the study is interested in establishing the influence of knowledge, attitude and values on the climate change mitigation practices, at a specific level this study is concerned about how government policies can be linked to these determinants, so as to arrive at evidence based policy measures. The effectiveness of the strategy then can be evaluated in using the available knowledge on climate change, attitude and values of the stakeholders. The results of this review will provide a basis for evaluating the government’s climate change reduction strategies and policies and may possibly suggest alternative policies.

**Climate Change Mitigation Behaviour**

The term behaviour appears as though it is a common vocabulary yet it is technical and difficult to define. Basically behaviour refers to the way in which an individual behaves or acts. It is the way an individual conducts herself/himself (Fox, 2006). It can be seen in reference to society norms, or the way in which one treats others or handles objects. Behaviour, therefore, is the way an individual acts towards people, society or objects (Kollmuss & Agyeman, 2002).

Climate change mitigation consists of actions to limit the magnitude or rate of long-term climate change. Climate change mitigation generally involves reductions in human (anthropogenic) emissions of
greenhouse gases (Nyong, Adesina, & Osman Elasha, 2007). Mitigation may also be achieved by increasing the capacity of carbon sinks, e.g., through reforestation. Other examples of mitigation include phasing out fossil fuels by switching to low-carbon energy sources, such as renewable and nuclear energy, and expanding forests and other “sinks” to remove greater amounts of carbon dioxide from the atmosphere (Melnick & UN Millennium Project, 2005). Energy efficiency may also play a role, for example, through improving the insulation of buildings. Another approach to climate change mitigation is climate engineering (ürge-Vorsatz, Danny Harvey, Mirasgedis, & Levine, 2007). The sector has a responsibility to minimize harmful emissions by encouraging sustainable, carbon-neutral transport solutions, improve the efficiency of the use of natural resources (water, energy), and contribute to the conservation of natural areas. Carbon neutrality can be achieved by improving the way the organization operates (e.g. through modified procurement considerations), by improving efficiency of operations (e.g. communications and meetings) and equipment (e.g. vehicle fleets and building) (Gössling et al., 2007).

Climate change mitigation behaviour in the tourism industry
There is widespread agreement in the literature regarding the two basic measures to be undertaken in order to combat climate change in the tourism sector: adaptation and mitigation (Füssel, 2007). On one hand, adaptation involves responses on the part of corporations, institutions and governments by taking advantages of the benefits of climate change for tourism and looking for solutions to minimize the problems it causes (Termeer, Biesbroek, & van den Brink, 2012). On the other hand, mitigation refers to undertaking actions in order to minimize the contribution of tourism activities to global warming (Hall et al., 2012; Scott & Becken, 2010). The former measures attempt to change the company to meet the conditions of climate change while the latter buffers a company against the effects of climate change (Scott & Becken, 2010). While their first set of adaptation measures deliberately change the company, measures of the second set do not transform the company. According to the UNWTO (2008) both policy-makers and business managers in the tourism industry must become involved in decision-making on adaptation and mitigation strategies for tourism (Belle, 2005; Scott & McBoyle, 2007).

Determinants of climate change mitigation behaviour
Climate change mitigation behaviour can substantially reduce the risks associated with human-induced global warming. Mitigation responses to climate change as a pro-environmental behaviour, can be operationalized at multiple levels of analysis, such as individual, group, organizational, or regional/national levels (Ortega-Egea, García-de-Frutos, & Antolín-López, 2014).

The focus here is on organizational-level, mitigation behaviour that, according to previous literature, can be broadly described as comprising voluntary and future-oriented behavioural responses to climate change (e.g., reduction in energy consumption with mid- to long-term positive impacts on climate change) (Berkhout, et al 2011). Given the multi-faceted nature of mitigation behaviour, it potentially encompasses a broad range of actions in private and public spheres of life, one-off and regular decisions, simple and more difficult steps, as well as low and high impact actions as regards their effectiveness in mitigating climate change (Ortega-Egea et al., 2014). This diversity of climate change mitigation behavioural actions is complex and influenced by numerous factors.

The influence of attitude and climate change mitigation behaviour
The topic of attitude as a driver of behaviour is popular in literature (Icek Ajzen & Fishbein, 1977, 1980; Fishbein & Ajzen, 2015). The concept of attitude is difficult to define. Attitude can largely be described as the like or dislike of any psychological object such as climate change. According to Icek Ajzen, 2011 attitude is the tendency to think, feel, or act positively or negatively towards objects in our environment.

The topic of attitude as a driver of behaviour is very popular in literature(Ajzen & Fishbein, 1977, 1980; Fishbein & Ajzen, 2015). The concept of attitude is however difficult to define. Attitude can largely be described as the like or dislike of any psychological object such as climate change. According to Icek
Ajzen (2011), attitude is the tendency to think, feel, or act positively or negatively towards objects in our environment. Research has additionally made significant progress in characterizing the cognitive processes that are important to success in understanding various psychological objects. In the literature attitude is widely viewed as a multidimensional aspect.

Enormous effort has also been expended in identifying the link between attitude and various aspects of performance (Montabon, Sroufe & Narasimhan, 2007). The results of these efforts have been surprisingly disappointing with most studies reporting very low and often non-significant correlations. Indeed meta - analyses reveal low correlations between attitude and various measures of performance (Halpenny, 2010). The disappointing findings in this tradition can be explained by lack of compatibility between attitude (a very broad concept) and the more specific performance criteria(Ajzen, 2007). Regrettably the concept of attitude and its role in climate change mitigation behaviours is conspicuously neglected in the literature.

**Values and climate change mitigation behaviour**

Values are responsible for determining much of our inherent motivation. The question of what shapes our values is however a complex one(Mobley, Vagias, & DeWard, 2010). A person’s values are most influenced by the micro system which is comprised of the immediate social net; family, neighbours, peer-groups, etc. Values are influenced to a lesser extent by the exosystem such as the media and political organizations. Least strong, but nevertheless important, is the influence of the macro system which is the cultural context in which the individual lives (Ungar, Ghazinour, & Richter, 2013).

People may be concerned about environmental issues for several reasons. Thus, previous research has explored the different types of value orientations underlying motivations for environmentally significant behaviour. Based on Schwartz’s norm-activation model, most studies have differentiated between self-transcendent (altruistic) and self-enhancement (egoistic) values (Ortega-Egea et al., 2014). Altruistic values can further be divided into social-altruistic and biospheric value orientations (Gustavsson, 2008). Similarly, a distinction is made between ecocentric and anthropocentric motives and values. Ecocentric individuals attach importance to the environment for itself and will engage in pro-environmental behaviour, even if it involves some sort of sacrifice on their part; this behaviour pattern is largely rooted in biospheric values. Anthropocentrics’ actions are more deeply grounded in social-altruistic and egoistic values; that is, these individuals will engage in pro-environmental behaviour, such as climate change mitigation behaviour, only if it has positive consequences for mankind and does not diminish their quality of life or wealth (Ortega-Egea et al., 2014)

**Knowledge and climate change mitigation behaviour**

Literature distinguishes between declarative knowledge and procedural knowledge (Chi, 1981). Declarative knowledge refers to an understanding of the principles behind phenomena such as the causes, characteristics or consequences of climate change. On the other hand, procedural knowledge refers to knowing the procedures for how to do things and arises from experience with similar situations.

Procedural knowledge can be equated with the concept of recipe knowledge (Holsapple, 2005). This knowledge is like a recipe book containing formulae for solving routine problems. The recipe knowledge for curbing climate change effects is a scheme for remedial action, implying a culturally learned and well-established repertoire of actions which provides guidance about what to do and when to do it. Recipe knowledge has practical value and is largely unrelated with concepts and beliefs (Bereiter, 2014). The effect of procedural knowledge on climate change is largely neglected in behavioural studies.

Procedural knowledge is considered to be valuable since it is highly immobile and has general applicability. It permits individuals to predict more accurately the nature and potential of changes in the environment and the appropriateness of strategic and tactical actions (van der Heijden, 2002). Without such knowledge, individuals are less capable of taking advantage of emerging opportunities.
Consequently, individuals with higher levels of procedural knowledge will be expected to have superior performance. In climate change, we should expect that hoteliers with superior knowledge will utilize effective remedial options.

**CONCLUSION**

Existing studies show varying prevalence rates of climate change behaviours among tourism businesses globally (Jarvis & Ortega, 2010; Mensah, 2014; Miao & Wei, 2016). These results suggest that prevalence rates differ among country contexts and within various sectors of the tourism industry. Such detailed information is not readily available in Kenya. It is imperative to document the prevalence of climate change mitigation behaviours in Kenya in order to offer context-specific information.

Additionally, literature identifying the determinants of mitigation measures of climate change behaviours among tourism businesses is unfortunately limited. Further, the available scanty literature has disappointingly shown that there are mixed correlations between demographic characteristics and psychological factors on one hand and climate change mitigation behaviours on the other (van der Linden, 2015). This limits the design of effective policies and practical guidance for mitigations against adverse effects of climate change.

**RECOMMENDATION**

Literature reviewed in this paper chronicles the interplay between knowledge, attitude, values and climate change mitigation behaviours. It conveys two important ideas. First, due to its anchorage to psychological and sociological factors, it highlights the set of factors that have been proposed variously in literature as relevant to climate change mitigation behaviours. However the individual and joint effects of the identified factors are neglected in most studies.

Climate change mitigation behaviours have been associated with other demographics, perceptions and traits of an individual to climate change mitigation responses only identify a few of these factors singly, implying that the interactive effects of multiple psychological and social based determinants of effective climate change mitigation and adaptive responses are not known. This implies that the studies fail to help in the development of an accumulated and related body of literature. This therefore creates an immediate need to undertake further research that seeks to establish the individual and joint effects of the numerous factors that influence climate change mitigation behaviour among tourism business managers to facilitate in formulation of a comprehensive climate change policy that is appropriate for Kenya.

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MATUMIZI YA UDHAHANIA KATIKA WALENISI NA MAFUTA

¹Matthew Kwambai and ²Dave Bowen
¹Idara ya Fasihi, Lugha na Isimu, Chuo Kikuu cha Egerton
²Idara ya Elimu, Chuo Kikuu cha Kabarak
Email: kwambai09@yahoo.com ²ntbowenza@yahoo.com
*Corresponding author

IKISIRI

1.1 Nadharia ya Usasaleo

Nadharia hii ina mihimili mingi kama vile: uandishi ndani ya uandishi, ufungumanishi wa isa, uchanganishi wa matini, utamaduni teknolojia, vurugo la wakati na masihara, ucheshi bwegwe na kinaya. Nadharia hii ya Usasaleo ina kipengee cha ufungumanisha mazingaombie ambacho kinaambatana na mhimili wa ufungumanishi wa isa. Katika kipengee hiki, kuna bunilizi za kisayansi zilizogonishwa na bunilizi za kisiosiolisti, hadithi za kipelelezi za ngano za kimazingaombie. Kutokana na nadharia ya Usasaleo, llibainiki kuwa udhahania uhalisia kwa njia mbalimbali: Lugha ya kudhihirisha udhahania; Utu na mapenzi yaliyokithiri mipaka;
Mandhari ya kipekee yaliyopita uhalisia; Wahusika wa kiajabu wenye ukakamavu; Maendeleo ya kisayansi na kiteknolojia na Matumizi ya jazanda.

1.2 Uwakilishi wa Udahania
Lengo kuu la karatasi hii ni kubainishi jinsi udahania ulivyowakilishwa katika riwaya za Katama Mkangi: Walenisi na Mafuta. Ilibainika kuwa udahania uliwakilishwa kwa njia mbalimbali: Lugha ya kudhihirisha udahania; Utu na mapenzi yaliyokithiri mipaka; Mandhari ya kipekee yaliyopita uhalisia; Wahusika wa kiajabu wenye ukakamavu; Maendeleo ya kisayansi na kiteknolojia na Matumizi ya jazanda.

2.0 Lugha inavyotumia maneno kama maajabu na miujiza kuleta udahania

3.0 Utu na Mapenzi yaliokithiri mipaka

4.0 Mandhari ya kidhahania na ya kipekee
Tatu, kuna matumizi ya mandhari ya kipekee kama vile Wawalenisi ane Mafuta, mandhari haya si mahsusi, pia wakati katika Wawalenisi na Mafuta si mahsusi, kwa hivyo, mandhari na wakati katika vitabu hivi te ne ni ya kidhahania. Katika Wawalenisi Mandhari ya Mbinguni, Jehanamu na nchi ya Wawalenisi ni ya kidhahania.

Utafiti huu ulibainisha kuwa, usambamba katika uwalishaji wa mandhari ni dhahiri katika Wawalenisi, usambamba unaleta pamoja mandhari yanayojulikana kama namna ya kukejeli moja kwa kudhihirisha ubaya wake na kupendekeza mengine kwa kuwaweka na uhalisia mazuri yanayoambatana na mandhari hayo. Mandhari ya kibepari na uhalibusi yanaoambatana na yanaojulikana huku upande mmoja mandhari ya kibepari yanaojulikana huku vuli ya kijamaa na kisosiolisti, usawa usawa angefaele na ukuwa na uhalisia na kujitenganya uhalisia sawa na anavyosema More.

Anahitimisha kuwa, usambamba katika ukufanya kivuza kama vile Walenisi na dunia, alipofurushwa Dzombo. Usambamba unaleta pamoja mandhari yanayojulikana kama namna ya kukejeli moja kwa kudhihirisha ubaya wake na kupendekeza mengine kwa kuwaweka na uhalisia mazuri yanayoambatana na mandhari hayo. Mandhari ya kibepari na uhalibusi yanaoambatana na yanaojulikana huku upande mmoja mandhari ya kibepari yanaojulikana huku vuli ya kijamaa na kisosiolisti, usawa usawa angefaele na ukuwa na uhalisia na kujitenganya uhalisia sawa na anavyosema More.


Dzombo anasema kuwa kwao duniani, tabaka la Mtu Lilijulikana kwa nguo aliyofaa, chakula alichokila, nyumba aliyosha na shule walioenda wanao. Dzombo analinganuliwa dunia na Wawalenisi ambapo wote wote walifaa nguo saka na Mtu Mbinguni kwa nyanza na enzi wao kwa Mbinguni.

Kwa hivyo, kutokana na usambamba ambao unaambatana na ulinganuajia wa mandhari, duniani alipotoka Dzombo inakejeliwa kwa ukali huku Walenisi ikipendekezwa kama mbadala wa mfumo wa kibepari unaambatana na dhuluma nyangi na tofauti nyingi za kitabaka. Walenisi ni mandhari ya kipekee ya kisiosiolisti ambapo watu walikuwa sawa. Hakuna tofauti za kitabaka na ukosefu wa usawa. Ni mandhari ya kipekee yanayopendekezwa katika riwaya ya Walenisi, huku kwa upande mwingine mandhari yanayopendekezika katika mfumo wa kibepari yakikashifiwa.


5.0 Wahusika wa kiajabu na wakakamavu


Katika Riwaya ya Mafuta, wahusika kama: Mtue, Ti, Matope na Dubwashwa ni wakakamavu na wa kidhahania kwa sababu wansafanya mambo yasiyo ya kawaida na kutumiza dhamira ya riwaya. Ti na Mtue wanajitolea mhanga na kuingia kwa wateule na kufichua siri ya uteule na mwoho wanaepuka kifo kinyume na ilivyokutoa siri. Naye kutoa siri. Ni kupitia kwa wahusika kama: Mtue, Ti, Matope na Dubwashwa, ndipo tunapoelewa

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uwongo kuhusu uteule na tunapoonyeshwa harakati za kupigana na hali hii iliyokuwa na ubepari mwingi. Mwisho uteule unaangamizwa na hali mpya ya ujamaa unapishwa.

Kwa kuhitimisha, Wahusika warioangiwi katika riwaya ya Walenisi na Mafuta kuwa wa kiajabu na wakamavu wanatekeleza jukumu la kuonyeshwa ubaya ambao ambapo katika jamii na kuchukua jukumu la kubadilisha mambo ya kubadili mambo ili kuleta mfumo mpya wa kisiosioliisti kijamaa unajumuisha kwa kijamaa unaoandamana na udhahania na fantasia nyingi.

6.0 Sayansi na teknolojia
Maendeleo ya kisayansi na kiteknolojia yanayodhihirika katika Walenisi yanalengwa kutoa tawira ya mandhari na mfumo wa maisha wa kisiosioliisti ambao unachangia uwasilishaji wa masuala kidhahania inayodhirihirika katika nchi ya Walenisi. Vitanda, meza, bafu na sayari inayotumiwa na Dzombo ni matokeo ya maendeleo haya ya sayansi na teknolojia. Sayari inamwezesha Dzombo kusafiri kutoka duniani au ni ambapo wajikumbuka kwa kisiosioliisti unapendekezwa katika riwaya ya Walenisi.

Vyonomba vya kisayansi na kiteknolojia vinafanya maisha kuwa kwagani na mambo yanaweza kufanywa kwa nchi na kufurahia na kuona masuala kidhahania unayotumika katika Walenisi. Kwa hivyo udhahania unayotumika katika riwaya ya Walenisi kwa nchi na kijamaa unapendekeza jukumu la kubadilisha mambo ya kibepari na hata waweze kubadili mfumo mpya ya ujamaa.

7.0 Jazanda za Walenisi na Mafuta

Kwa upande wa Matope katika riwaya ya *Mafuta*, yanatumiwa kama muhimu kwa wachache waliotumia katika riwaya ya *Mafuta* ambayo aligundua kuwa yalioko kula mafuta na maji kwa njia mpya ambayo kwa upande wake wakiwapa kikosa matumaini na uwezo wa kukumbana na maisha na hivyo hivyo aliweza na anaweza kwa kawaida wa uwakilishi wa kawaida wa uhalisia.

*Mafuta* inatumia jazanda za mafuta, maji na matope kuwakilisha mageuko kutoka tabaka la chini mpaka la juu kwa njia mpya ambazo zinatoa mafuta na maji kwa njia mpya ambayo ingeepuka uwakilishi wa kawaida wa hivyo kwa inavyodhihirika katika *Mafuta*.

8.0 Hitimisho

Kwa kuhitimisha, uchunguzi huu uligundua kuwa udhahania katika *Walenisi* na *Mafuta* ulidhihirishwa kwa namna kadhaa kwa njia mpya ambazo inapatikana kwa mafuta na maji na kawaida wa hivyo ambazo zinatoa mafuta na maji kwa njia mpya ambayo ingeepuka uwakilishi wa kawaida wa hivyo kwa inavyodhihirika katika *Mafuta*.

*Walenisi na Mafuta* ulidhihirishwa kwa namna kadhaa kwa njia mpya ambazo zinatoa mafuta na maji na kawaida wa hivyo ambazo zinatoa mafuta na maji kwa njia mpya ambayo ingeepuka uwakilishi wa kawaida wa hivyo kwa inavyodhihirika katika *Mafuta*.
Katika *Mafuta* ni kwamba, jazanda zinakuwa kama madaraja baina ya mfumo miwili ya maisha, yaani mtu akitaka kabudili kutoka tabaka la chini la kijama mpaka tabaka la kiteule na kibepari, alifaa kujitahidi mpaka apate mafuta. Mafuta haya yangempa fursa ya kuwingia uteuleni. Matope yaliwezesha mtu kutoka uteuleni na kuwingia katika ujamaa, mtu alifaa kulala katika matope kwa siku kadhaa kabla ya kuaminiwa na kukuwaliwa kuwa alikuwa ameamua kwa yakini kuwa ameingia kwa takaba la kina yakhe lililokuwa na ujamaa.

Uwakilishi wa udhahahania ulilenga kudhirishwa mfumo mpya katika jamii, yaani usosiolisti ambaa uneambatanishwa na masuala mengi kama vile: utu, usawa, haki na ukweli uliokithiri mipaka. Mfumo huu unapinga hali iliyo katika jamii inayoambatana na mambo mengi ya kibepari, mgawanyiko wa kitabaka, chuki, dhuluma na kupenda pesa.

9.0 Marejeleo


IMPACT OF POOR GOVERNANCE ON DEFORESTATION IN AFRICA
Paul Mwari Maina
Department of Development Studies, St Paul’s University P. O. Private Bag, Limuru - 00217, Kenya.
Email: mainapaul72@gmail.com

ABSTRACT
According to the United Nations Food and Agriculture Organization (FAO), the world loses 18 million acres through deforestation each year. Africa is the only continent in the world where deforestation is on the increase threatening the continent scarce water resources, efforts by the region to combat climate change, and exacerbating the vulnerability of rural communities to poverty and effects of climate change. Deforestation over the decades has been blamed on poverty and burgeoning population increase. Demand for wood in Africa which is a source of energy could triple by 2050, straining the continents dwindling forest resources according to UN report. The study based on library research examines the extents to which poor governance and corruption which have been pervasive in Africa and have significantly contributed to the loss of the continent’s forest cover. Thirty published research papers were reviewed with the following objectives, to, i) analyse the extent of corruption in the forest sector, ii) to examine the extent to which corruption contributes to deforestation in Africa, ii) examine ways in which poor governance and weak institutional arrangements exacerbates corruption in the forest sector, iii) explore the extent to which corruption undermines the effectiveness of Community Forest Associations in combating deforestation in Africa, and iv) explore opportunities and challenges of community forest association in combating corruption in the forest sector. The study further evaluated frameworks previous researchers have employed to examine forest governance, compared to the emerging recent models of forest governance. From the previous research, it is apparent that corruption has potential to decimate a nation’s forests. Few studies in Africa have however examined the extent of this phenomenon. There is urgent need for such studies that provide further explanation on the extent to which corruption plays in the continuing loss of forest cover against the backdrop of all the reforms to improve the performance of the forestry sector.
Keywords: Community forest associations, governance, corruption, institutions

INTRODUCTION
The world has lost about 40% of forest area to deforestation and globally and which contribute to the livelihood of 1.6 billion people according to World Bank report (2007). Kenya has one of the highest rates of forest degradation. According to the U.N. FAO, (2010), 6.1% of Kenya was forested. Between 1990 and 2012, Kenya lost 0.32% of forest cover per year which translates to 6.5% of her forest cover. Deforestation in developing countries exacerbates the effects of climate change. Africa is the only continent in the world where deforestation is on the increase, threatening the continent scarce water resources, efforts by the region to combat climate change, and exacerbating the vulnerability of rural communities to poverty and effects of climate change.

Forests are a source of NTFPs that constitute an integral component of the household economic activities mostly among women (Chamshama et al., 2014). According to Brockington, (2008), deforestation trends in Sub Saharan Africa are alarming. A study by FAO reported that during the decade from 1980 to 1990, the world’s tropical forests were reduced by an average of 15.4 million ha per year through deforestation. At the end of 1990, Africa had an estimated 528 million hectares but the rate of deforestation exceeded the global annual rate of 0.8 per cent mainly associated with human activity. In the early 1900s the forest cover in Kenya was at 12 per cent but reduced drastically to 2 per cent in 2000, equivalent to 3.5 million hectares of degraded land. Forest governance is often associated with principles such as transparency, participation and accountability according to GIF Framework, 2012. It was estimated that the original forest cover was approximately 6.0 billion hectares (Omoro, Starr, & Pellikka, 2013). Some of those identified causal factors are; increase in the population of forest adjacent communities (Zaman, E.Y. et
al., 2015), demand agricultural land under the PELIS program (Change et al., 2010), corruption, weak institutions, poor governance and high demand for timber (Matthews et al., 2014).

The research looked at the impact of poor governance and the strategies to combat deforestation. All governments in Africa have a forestry department. In Kenya, we have the Forest Service, a government parastatal which is the custodian of the forest as per the Constitution of Kenya 2010 and the Forests Act, 2005. More than 200 community forest associations (CFA) in Kenya in collaboration with stakeholders have managed to develop forest management plans and agreements which guide in joint forest management. The level of participation of CFA members in forest protection against deforestation activities is positively and significantly influenced by the level of perceived Participatory Forest Management (PFM) benefits and a decrease in deforestation in the forest is associated with CFA participation in PFM. Weak institution focuses on CFA governance structures within the ecosystem.

In Kenya, this new management approach has been facilitated by legal requirements as stipulated in the Forests Act No 7 of 2005 and Forests (Participation in Sustainable Forest Management) Rules 2009. These rules were gazetted vide Legal Notice No. 165 of 2009. The rules apply to participation of the private sector and forest adjacent communities in sustainable management of state forests. The Forests Act 2005 that has replaced the Forest Act Cap 385, which did not recognize participation of stakeholders in forest management and planning. The new Act introduced allows the local community to form and register Community Forest Associations (CFA) and to participate in preparation of a Participatory Forest Management Plan (PFMP). Then the community negotiates a Forest Management Agreement (FMA) with KFS that gives the CFA forest user rights and the two organisations (KFS, CFA) better working modalities with the assumption that the partnership arrangement will contribute to enhanced ecosystem conservation and local community livelihoods through access to forest user rights.

A study by Cuneyt Koyuncu & Rasim Yilmaz, (2008), on corruption, democracy, and environmental policy an empirical contribution to the debate. The study looks at corruption, democracy, institutions and the environmental policy. Chomba, Treue, & Sinclair, (2015) did a study on state failure, corruption, and warfare, challenges for forest policy. The role of stakeholders in understanding the problems in forest policies implementation and that governance weakness, corruption, and war constrain the achievement of conservation goals.

The study by Pellegrini, (2006) on social networks of corruption in cross-border timber trade helped to identify various forms of corruption and illegal trading of wood, corruption among the social networks that include bribery and failure to follow forest laws in Mt Kenya West ecosystem. The thirty papers reviewed helped to understand the influence of state failure, corruption, and warfare in relation to challenges for forest policy. The main issue discussed was on failure by the government to implement forest policies due to ignorance and corruption. The journals focused on the link between firm characteristics, bribery, and illegal logging in wood-based industries. The main governance issue being weak institutions structures whose failure has led to enhanced bribery and corruption. These challenges have led to the manifestation of negative practices being done by the wood industries in developing countries. Other journals concentrated on corruption, democracy, and environmental policy underlining the role of democracy and how corruption influence environmental policies that includes the broader issue on sustainable development goals that aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

To measure corruption range the papers used the corruption perceptions index (CPI) which is based on how corrupt a country’s public sector is perceived to be. It’s a combination of surveys and assessments of corruption, collected by a variety of reputable institutions. The CPI which is defined as the misuse of public power for private benefit is the most widely used indicator of corruption worldwide. The CPI
currently ranks 178 countries on a scale from 100 as very clean to 0 as highly corrupt. However, none of the papers went into details by naming the specific index for a particular country. One paper on the impact of corruption on deforestation, cross country evidence used corruption indices to operationalize the variables.
**Objectives of the study**

- Analyse the extent of corruption in the forest sector
- Examine the extent to which corruption contributes to deforestation in Africa,
- Examine ways in which poor governance and weak institutional arrangements exacerbates corruption in the forest sector,
- Explore the extent to which corruption undermines the effectiveness of CFAs in combating deforestation in Africa, and
- Explore opportunities and challenges for of community forest association in combating corruption in the forest sector

**Research Questions**

- What is the extent of corruption in the forest sector in Africa? How does corruption in the forest sector look like? Who form does it take? Who are the actors? What are the motivations?
- To what extent does corruption contributes to deforestation in Africa?
- How does poor governance and weak institutions exacerbate corruption in the forest sector?
- To what extent does corruption undermines the effectiveness of CFAs in combating deforestation in Africa?
- What is the opportunism and challenges of community forest association in combating corruption in the forest sector?

**Potential Benefits of Protecting of reducing deforestation from an Ecosystems Perspective**

More than 1.6 billion people around the world depend to depend to varying degrees on forests for their livelihoods, not just for food but also for fuel, for livestock grazing areas and for medicine. At least 350 million people live inside or close to dense forests, largely dependent on these areas for subsistence and income according to (Laurance et al., 2014). About 60 million indigenous people are almost wholly dependent on forests (World Bank 2000). Deforestation accounts for at least 11 per cent of global greenhouse emissions.

**Justification of the need to combat deforestation in Africa based on importance of forests**

(i) **Provisioning Ecosystem Services**
Provision of clean water by forests - Access to clean water is one of the most fundamental of human rights. Forested watersheds generally offer higher-quality water than watersheds under alternative land uses.

(ii) **Regulating Ecosystem services**
Forest in Africa regulates water governments by catching rainfall and regulating its flow through the hydrological system, maintenance of soil quality and the provision of organic materials through leaf and branch fall.

(iii) **Supporting ecosystem services**
Forests support species diversity and ecosystem diversity which includes include plants, animals and micro-organisms that are and form the life support system (Change et al., 2010). They support air and water purification, pollination, seed dispersal, climate modification, soil stabilisation, drought and flood control, recycling of nutrients and habitats.

(iv) **Cultural Ecosystem services**
Forests play a cultural role by being home to millions of people worldwide who depend on the forest entirely for survival. In Mt Kenya, we have squatters who live in the forest and their entire livelihood is dependent on forest products. They are involved in the PELIS forest programs which involve farming in the forest and participating in forest rehabilitation programs. Forest adjacent communities have strong cultural and spiritual attachments to the forests. Mt Kenya forest has well-established shrines for prayers which are deep into the indigenous forest. This enhances deliberate conservation of the identified sites.
Policy failure in Forest governance in Kenya

Environmental Management and Coordination Act 1999
Despite the fact that we have many policies in Kenya, deforestation rate continues to increase Environment and Co-ordination Act (EMCA, 1999) is a framework law on environmental management and conservation. EMCA established NEMA, which is mandated to develop regulations, prescribe measures and standards and, issue guidelines for the management and preservation of natural resources including indigenous forests and the environment. The community has the right to demand that all projects imagined to encourage deforestation must undergo Environmental Impact Assessment in consultation with NEMA.

Weakness of the policy
There have been challenges in the implementation of EMCA, framework law due to lack of political good will and poor governance structures that offer lenient penalties to illegal destructors involved in deforestation.

The Forest Act 2005
The key elements of the Forest Act are to contribute to poverty reduction, improve livelihood through sustainable use and conservation of forests and other allied resources and contribute to sustainable land use, water, soil and preservation of biological diversity.

Weakness of the Forest Act
The Forest Act 2005 has limitation since it does not explicitly outline benefit sharing mechanisms between the community and the Kenya Forest Service who are the custodians of the forest. Community benefits are weak and joint forest management plans is to some extent a theoretical blueprint.

The chapter on environment and natural resources emphasises on the obligations in respect of the environment, enforcement of environmental rights geared towards protection of the natural resources including forests.

Weakness in implementation
Poor governance, corruption and weak institutions have made the effective implementation of the 2010 constitution a dream.

Indigenous Forests Policy, 2009
It's emphasis on the community participation in sustainable forest management. The rules apply to enhance the involvement of the Community Forest Associations in the sustainable management of indigenous forests aimed at strengthening rural communities’ capacity as per the Kenya Forestry Master Plan (2004).

Weakness of the policy
The policy implementation is under Kenya Wildlife Service which is more concerned with wildlife protection rather than deforestation matters which has mainly targeted indigenous forest in which KWS is a custodian.

Wildlife conservation and management Act 2013
The Act recognises indigenous forests as a habitat for flora and fauna, and it’s also a habitat for wildlife especially the threatened ones like the bongo in Mt Kenya Forest. According to the Act, the conservation of indigenous forest is from Kenya Wildlife Service (KWS).

Weakness of the Act
Community participation in the wildlife Act is weak. Communities perceive that KWS values wildlife more that forest protection and human farms protection. This has led to consistent human wildlife conflict between KFS and forest adjacent communities.

The Forests (Charcoal) Rules, 2009
This policy helps CFAs and rural communities to regulate charcoal burning with the forests sustainably.

Weakness of the policy
Under these regulations, all commercial charcoal producers are expected to organise themselves and form Charcoal Producer Associations. However this does not happen and charcoal burning is done illegally by cartels that target indigenous forest hard wood. Kenya Forest Service, on the other hand, is supposed to
register and issue a registration certificate to Commercial Charcoal Associations hence regulating and restricting the use of indigenous trees to make charcoal. Due to corruption, law enforcers are compromised hence exacerbating the problem.

**The Indigenous Forests (Harvesting) Rules, 2009**
The joint forest management plan and Forest Act 2005, gives communities powers to deny harvesting of indigenous forest if they were not involved in tendering process. The Forests (Harvesting) Rules, 2009 were gazetted vide Legal Notice No. 185 of 2009.

**Weakness of the rules**
Under the rules, no person is permitted to harvest timber or bamboo in any of the forests without a valid license approved by all stakeholders but this rarely happens and forest managers and leaders allow illegal harvesting to happen and the perpetrators walk free.

**Indirect drivers of deforestation in Africa**

*Economic drivers of deforestation*
The demand for forest products has contributed to the disappearance of forests in Africa. There is high demand for timber/wood, carvings, commercial herbs, Non-Timber Forest Products and commercial wild fruits.

*Social and political drivers*
Accelerated forest disappearance through destruction occurs when institutional configurations allow abuse and create an opportunity for forests to become incorporated into patronage networks which create incentives for state actors to increase accumulation of indigenous forest resources for political purposes with no concern for sustainability in the long run.

*Cultural and religious drivers*
Cultural factors influence consumption behaviour of forest and values related to environmental stewardship, and it’s an important driver of environmental change. Forests play a cultural role by being home to millions of people worldwide who depend on the forest entirely for survival.

*Science and technology drivers*
The impact of scientific and technological on the forest is most evident in the case of flora and fauna. Forests are unique sources of scientific knowledge and essential for research purposes and in some ways it has contributed to the disappearance of forests in Africa. A lot of the investigation is done on herbal medicine and requires accessing the plan roots, stem and leaves.

**The direct drivers of deforestation in Africa**

*Logging / Deforestation*
Illegal logging or commercial logging/ deforestation involve cutting indigenous trees for sale as timber or pulp without proper permission or guidelines. The indigenous timber is used to build homes, furniture, carvings. There is high demand for timber/wood since indigenous forests form the basis for a variety of commercial industries.

*Drought/ Climate change*
Drought affects indigenous forests directly by slowing or arresting growth and by increasing their susceptibility to wildfire, insect pests and disease. Prolonged drought results to weak radial growth in post-drought years because food stores are quickly used up resulting to dieback of the crown of the tree.

*I nvasion of forest by alien species*
Invasive species threaten indigenous forest biodiversity by causing disease, acting as predators or parasites, and acting as competitors. They also alter the habitat severely affecting growth.

*Land use change*
This involves the clearing of indigenous forests to create land for farming. More than 80,000 farmers are involved in the PELIS system in central Kenya converting indigenous forests to plantation forests.
Literature Review

Theory of Compliance and the Efficiency of the Legal and Regulatory Framework
Theory of compliance deals with the fundamental question of why people obey the law the perspective of forest law compliance (Irland, 2008). It states that people are rational individuals who obey laws because of expected costs and benefits of compliant and non-compliant behaviour.

Gary Becker’s Theory of Crime and Punishment Behaviour
The theory states that obedience to law is not taken for granted, and public and private resources are spent in order both to prevent offences and to apprehend offenders. In the second place, the conviction is not considered sufficient punishment in itself; additional and sometimes severe punishments are meted out to those convicted.

Theory of Democracy and Environmental Policy
Theoretical and empirical studies have shown that democracy and corruption influence environmental policies. Democracy could affect environmental policy stringency given that countries with a history of democratic rule tend to be less corrupted.

Theory of World Systems
System theory talks about a group of things which have something in common and operate as a cluster can be seen as a system whereby one of the communities which together comprise an even greater system, the region or territory in which they all are located. The forest sector operates social networks and systems. Communities operate under social systems named Community Forest Associations - an umbrella system forming the user groups which are involved in corruption networks and grass root institutions. KFS as the custodians of the forest operate under a system governed by the national government.

Corruption, Taxation and Economic Growth Theory and Evidence
The theory analyzes the interaction between corruption, taxation and economic growth. It discusses corruption in the public expenditure and corruption in the public revenue. It argues that corruption can affect growth rate positively and it can also exert an adverse effect through fiscal revenue.

Adam Smith Economics Theory of Value - Supply and Demand
The theory talks about the perceptions of peasants about livelihood and basic needs. Poverty has a correlation with corruption. It talks about what’s the value of good and what dictates the relative price, level of prices and the best measure of welfare. Marketing of deforested logs is dependent on their value and factors that determine their price.

Empirical review
Previous researchers posed various research questions. Why are forest policies simply not working having spent a lot of resources to develop them? What factors contribute to the lack of commitment and ignorance to implement the policies? To answer the question the main issue noted was on failure by the government to implement policies due to ignorance and corruption. Lack of commitment, state weakness and failure, corruption, and war has significantly contributed to governance issues and are well captured by the author.

Corruption
Corruption is defined as a dishonest or fraudulent conduct by those in power, typically involving bribery. This is related to issues of governance. The custodians of the forest trade off indigenous forest resources for their gain. The main areas include allowing illegal cultivation in the forests, facilitating deforestation and illegal logging and allowing unsustainable harvesting of non-timber forest products from the indigenous forests. Example is the on-going bark harvesting of Prunus Africana in Hombe forest.

Broader perspectives of analyzing forest governance – the Governance of Forests Initiative (GFI) Indicator framework
There is need to consider adopting the GIF framework to assist in forest management aimed to combat deforestation. The first step is to diagnose and assess strengths and weaknesses in forest governance. This will help to navigate decisions about how to design and implement the indicators. The first action is to organise the indicators by thematic areas and sub-themes which may include land tenure, land use, forest management, and forest revenues, cross cutting institutions and cross cutting issues. The indicators will
be tailored and contextualised to fit local needs e.g. in Kenya context the forest blocks are classified as beats. Data collection technique will involve elements presented by a distinct research question guided by the GFI manual. Potential sources of data will be identified and applied appropriately. Scoring of the indicators will be done where necessary.

The GFI indicator works on the five principles of good governance which includes transparency, participation, accountability, co-ordination and capacity. It builds on the principal of participation that involves diverse and meaningful inputs to help in decision making. It embraces accountability that exists when the actions and decisions taken by an actor meet the objectives and responds to needs of stakeholders they are meant to benefit. Coordination exists when different actors whose decisions impact forest works together and share information in order to advance common objectives.

The GFI works on six thematic areas which include which reflect key forest related issues of common interest and concern that includes land tenure, land use, forest management, forest revenue, crosscutting institutions and cross cutting issues. It’s imperative to adopt the GIF analytical framework since it’s a global recognised framework since it promotes policies and practices that strengthen forest governance to support sustainable forest management and improve local livelihoods. The indicators under GIF will be able to help partners to carry out evidence based advocacy for governance reforms at local, national and international levels and it’s a suitable tool to assess forest governance in Kenya, however the tool must be customised to address the local context issues.

KEY FINDINGS AND CONCLUSIONS
Forest concession can work to sustain forest, economies and livelihoods in the 21st century and it should be adopted. Concession refers to the process whereby the government confers user rights of state owned forests to a private entity through a contractual agreement aimed at enhancing sustainable forest management. A study done by Cuneyt Koyuncu & Rasim Yilmaz, (2008), on corruption, democracy, and environmental policy an empirical contribution to the debate looks at role of forest concession in sustainable forest management. The study underlines the need to embrace the pillars of participation of stakeholders, forest concession, capacity development and empowerment of grass root institutions like the Community Forest Associations. The forces behind the demand for timber products that fuel deforestation cannot be overlooked. This means that the forests in Africa are under threat.

The stakeholders have a role in combating deforestation in Africa. The role of stakeholders in understanding the problems in forest policies implementation and that governance weakness, corruption, and war constrain the achievement of conservation goals. The research looked at stakeholders in the sector and how they determine the appearance of forests in a country. The study by Pellegrini, (2006) on social networks of corruption in cross-border timber trade helped to identify various forms of corruption and illegal trading of wood, corruption among the stakeholders, cartels and social networks. Non Timber Forest Products projects can be an alternative to reduce pressure on timber products. Poverty is one of the factors exacerbating deforestation in Africa and exploration on potential of NTFPs can be a solution. Forests are a source of NTFPs constitute an integral component of the household economic activities mostly among women (Chamshama et al., 2014).

RECOMMENDATIONS
There is need to consider adopting the GIF framework to assist in forest management aimed to combat deforestation. The first step is to diagnose and assess strengths and weaknesses in forest governance. This will help to navigate decisions about how to design and implement the indicators. The first action is to organise the indicators by thematic areas and sub- themes which may include land tenure, land use, forest management, and forest revenues, cross cutting institutions and cross cutting issues. The indicators under GIF will be able to help partners to carry out evidence based advocacy for governance reforms at local, national and international levels and it’s a suitable tool to assess forest governance in Kenya.
Future research should explore the relevance of forest concession as an important tool for sustainable forest management, considering that majority of forests in the developing countries are government owned. Forest concessions embrace private sector participation in forest management and if implemented well can help to sustain forests, economies and livelihoods in Africa. The future research should address the relationship between weak governance and implementation of forest laws.

Future research needs to explore the level of involvement of communities in the development of forest laws. Community participation can help to combat deforestation especially where benefit sharing model balance sustainable conservation and sustainable livelihoods. Future research should confirm whether Community Forest Association members involved in the evidenced ecosystem degradation and if the current forest user right for livelihood improvement contributes towards ecosystem degradation.

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ASSESSING KNOWLEDGE LEAKAGE ON PERFORMANCE AMONGST TEACHING STAFF IN PUBLIC UNIVERSITIES IN KENYA

¹Anne Koster Mugalavai, and ²Alice Wafula, ³Cephas Odini

¹School of Information, Communication and Media Studies, Rongo University, P. O Box 103–40404, Rongo, Kenya.
²Department of Library, Records Management and Information Studies, School of Information Sciences, Moi University, Eldoret.
³Correspondence: mugalavai@gmail.com, konalbwangu@yahoo.com, 0724921977, akituyi@hotmail.com, 0701176585

ABSTRACT

Although universities in Kenya recognize that knowledge retention amongst teaching staff enhance universities’ performance, there are gaps that hinder collaboration, linkages, knowledge sharing and management, and improved Information Communication Technology physical infrastructure. Today, poorly established platforms where knowledge can be shared amongst the teaching staff are common in most of the universities. Technologies that speedily transfer knowledge are poorly retained and maintained, reliable knowledge management systems that are integrated in the available IT infrastructure are missing and knowledge sharing and management policies have not been understood. This study determined ways in which knowledge leakage has impacted on innovations in public universities in Kenya and; Proposed suitable knowledge sharing and management strategies that can be used to enhance performance of knowledge workers in Kenyan public universities. The study adopted descriptive research. The population consisted of 23 chartered public universities. The study used systematic random sampling to select six universities from the 23. The sample size was 308 respondents. Data was collected through structured questionnaires and analyzed using descriptive statistics aided by Statistical Package for Social Sciences (SPSS) and presented in percentages, frequencies, means, tables and graphs. Knowledge leakage leads to the loss of specialized expertise with a high significant association between knowledge leakage and impact on innovations ($\chi^2(6) = 21.631$, $P=0.001$) which was <0. Thus public universities should provide for consistent skill training to mitigate knowledge leakage, and incentives for retention.

Keywords: Knowledge retention, Innovation, Performance, Teaching staff.

INTRODUCTION

According to Durst, S., Aggestam, L. and Ferenhof, H. I. (2015), knowledge leakage is the loss of knowledge intended to stay within an organization but is degraded over time. This loss can affect the organization either positively or negatively. Positive loss is where knowledge spills over to other organizations through collaborations while negative leakage is when knowledgeable members leave an organization or external partners misappropriate knowledge from the organization in question or when an organization becomes redundant. To minimize knowledge leakage, Anderson, (2012) advocates for knowledge sharing through consistence skills training which also improves organizational performance. These findings are applauded by Mohamed, Souad, Mynors, Diane, Chan, Paul W., Grantham, Andrew and Walsh Kathryn (2007 who encouraged organizations to train everyone including new hires and transferees practically while retaining both in-house knowledge and experience with realistic examples. This will be a way of maintaining skills learnt especially tacit knowledge which does not leave ones brain. Due to financial constraints within universities, the outsourcing of teaching expertise has become a common practice. This inadvertently leaks out information about the outsourcing organization and is happening at a time when most organizations are shifting to globalization in an attempt to appreciate knowledge economy. It therefore calls for an understanding of the nature of knowledge within a given organization and how this knowledge can boost its performance and competitiveness (Tsui, 2006). According to Dalkir (2005), although studies affirm that organizations reap knowledge from others through dynamic interactions, there is need for organizations to harness knowledge capabilities of their workers so as to minimize information leakage.

The paper argues that an established organizational repository requires that all academic staff deposit all their research outputs such as datasets, theses, lecture notes, learning objects, conference proceeding and any other valuable grey literature generated within the university to provide access to the university community members. The staff within these repositories digitizes, organizes and categorizes the
knowledge for easy access. This provides a common platform where scholars within the university can contribute scholarly knowledge for inter-disciplinary research. Eventually, this electronic explicit knowledge gains global visibility while allowing measurable research output by the university. To this end, many universities in Kenya are yet to develop working institutional repositories through which the academic staff can channel their research output.

Koulikov (2011) notes that generating knowledge is a costly venture and for one to willingly transfer it to another party may require incentives that can motivate the knowledge owner to share. The author explains that Knowledge organizations may create some awards for knowledge owners who transfer their knowledge to others and that money can also be directly given to individuals as a motivation factor to prompt knowledge owners to share knowledge. Gagne (2009) in “A Model of Knowledge sharing” motivation has a different perception. Gagne argues that tangible rewards like money to researchers are insufficient and can be detrimental to the motivation to share knowledge. Instead the author advocates for appropriate reward systems and sharing opportunities within organizations.

1.2 Statement of the problem

Universities lose a lot of their treasure they have generated over a long period through knowledge leakage without notice. It is evident that in various universities teaching staff change or leave employment for one reason or another. It may be as a result of retirement of very experienced knowledgeable staff in a specialized field or resignation to change to a better employer. When they quit, they do not prepare handover notes about specific knowledge they own to the new comers. Again, there is no evidence of universities hiring mentors to assimilate new comers into the gaps left by those who exit. In addition, there is an assumption that knowledge is useful in a particular situation and there is no need to retain and maintain old knowledge. Because such knowledge is only retained in the mind of the creator, it is easily leaked out when the employee exits. There exists a gap within the Kenyan universities where dynamic knowledge that is rich for innovations is lost. Because the dynamic knowledge is not retained and maintained through sharing, a particular university cannot remain a champion of a specific innovation

1.3 Objective of the study

1. Determine the ways in which knowledge leakage has impacted on innovations amongst teaching staff in public universities in Kenya
2. Propose suitable knowledge sharing and management strategies that can be used to enhance performance of knowledge workers Kenyan public universities.
3. To achieve the objective, the study generated a conceptual framework shown in figure 1

![Figure 1: A conceptual framework for knowledge leakage](image)

The framework postulates that knowledge leakage and poor knowledge management deny universities dynamic knowledge that could otherwise be translated into innovations. However such a loss can be mitigated if there are guidelines and programs to be adhered to during knowledge management activities
2.1 Methodology
The study used descriptive research design to solicit data and information on assessing knowledge leakage on performance amongst teaching staff in public universities in Kenya. Specifically, the study systematically sampled six public universities namely Chuka, Egerton, Masinde Muliro University of Science and Technology, Laikipia, University of Kabianga and Kibabii from 23 chartered public universities. This sampling technique was adopted because it is bias free (Kothari & Garg, 2014). The unit of analysis was the teaching staff of these universities. The study determined its sample size (308) using the Saunders, Lewis and Thornhill (2012) formula. The sample size was determined from the target population of 1852 through interpolation. The study further used disproportionate stratified sampling to establish the sample size for each category: namely university librarians, academic deans, academic heads of departments and teaching staff shown in table 1(Kothari & Garg, 2014). This was used to avoid over representation and allow for separate analysis for each stratum.

<table>
<thead>
<tr>
<th>Respondents</th>
<th>MMUST</th>
<th>Laikipia</th>
<th>Chuka</th>
<th>Egerton</th>
<th>UoK</th>
<th>Kibabii</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>University librarians</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Academic Deans</td>
<td>9</td>
<td>4</td>
<td>4</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>38</td>
</tr>
<tr>
<td>Academic Heads of Departments</td>
<td>15</td>
<td>11</td>
<td>9</td>
<td>32</td>
<td>16</td>
<td>26</td>
<td>109</td>
</tr>
<tr>
<td>Teaching staff</td>
<td>35</td>
<td>15</td>
<td>18</td>
<td>51</td>
<td>21</td>
<td>15</td>
<td>155</td>
</tr>
<tr>
<td>Total Number of Respondents</td>
<td>60</td>
<td>31</td>
<td>32</td>
<td>93</td>
<td>45</td>
<td>47</td>
<td>308</td>
</tr>
</tbody>
</table>

Simple random technique was then used to select the respondents for teaching staff category (stratum) while librarians’, academic heads of departments and academic Deans strata sampled all cases. Data was collected through closed ended questionnaires. Descriptive and inferential statistics were used for data analysis with statistical computations that included percentages, frequencies and means and presented in tables and graphs. Thereafter inferential was done to test dependence of the performance of teaching staff in Kenyan public universities on knowledge leakage using chi-square test. The study established the relationship between the independent variable and the dependent variable using associations.

FINDINGS AND DISCUSSION

Demographic Data
The study obtained demographic information based on; period worked in the positions they were in, highest academic qualification, age bracket, and length of time worked in the university. The data collected was analysed and the results obtained from analysis captured in this section. The results obtained on respondents’ gender were captured in Figure 4.1.

The results in figure 2 show that 30% of the total number of respondents were female while 70% were male, a pattern exhibited across all the 6 universities surveyed. It was observed that male officers exceeded two thirds of the total number of respondents as the females were less than a third of the total number of respondents, creating gender imbalance against 2/3rd gender rule enshrined in the constitution of Kenya 2010 (Republic of Kenya [RoK], 2010).
Levels of Education of the Surveyed Population
The academic qualification of the respondents from the analysis were captured in table 2.

Table 2. Frequencies and percentages of the highest academic qualification of university teaching staff in Kenya

<table>
<thead>
<tr>
<th>Staff category</th>
<th>Highest level of education</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bachelors</td>
<td>Masters</td>
<td>PhD</td>
<td>Total</td>
</tr>
<tr>
<td>Librarians</td>
<td>No.</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>33.33</td>
<td>50.00</td>
<td>16.67</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching Staff</td>
<td>No.</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>9.68</td>
<td>70.32</td>
<td>20.00</td>
</tr>
<tr>
<td></td>
<td>155</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deans of Schools</td>
<td>No.</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0.00</td>
<td>30.00</td>
<td>70.00</td>
</tr>
<tr>
<td></td>
<td>38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heads of Departments</td>
<td>No.</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0.00</td>
<td>48.00</td>
<td>61.00</td>
</tr>
<tr>
<td></td>
<td>109</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>171</td>
<td>120</td>
<td>308</td>
</tr>
</tbody>
</table>

Source: Research data (2017)

The study findings showed that majority of the librarians (50%) had Masters education, and only 33% had Bachelors Education while 16.67% had PhD. This is a clear indication that librarians have a reason or the motivation to seek higher education. Majority of the teaching staff, 70% of had Masters Degrees, 20% indicated that they had undergraduate degrees and 10% were PhD holders. All the teaching staff members, who had showed that they possessed bachelor’s degrees, indicated that they had enrolled for masters programmes as a condition by their respective schools/faculties. They were serving either in the positions of graduate assistants or part-time lecturers. A number of the teaching staff showed that they were pursuing PhD programmes. Despite CUE upholding the November 2018 deadline for all lecturers to be PhD holders, there is an alarm over the low PhD enrolment rate in Kenya (Ayiro & Sang, 2011). With only 20% teaching staff having PhDs means it may be hard to meet the deadline come November 2018.

While 44 % Heads of departments indicated that they possessed masters degrees, 56% showed that they possessed PhDs and none had undergraduate degrees as their highest academic qualification. This shows that many universities are raising the knowledge bar in giving promotions to head various departments.
The level of education is critical in assessing aspects of knowledge management, knowledge leakage, information sharing, and the knowledge communities.

Age Bracket and Years of Experience of Respondents
The age bracket, specified by the study, to choose from were; less that 25 years, 26 to 35 years, 36 to 45 years, 46 to 55 years and above 56 years. The results on analysis by age according to the position held was captured in table 3.

Table 3: Frequency and percentage of teaching staff in age brackets according to their positions in Kenyan universities

<table>
<thead>
<tr>
<th>Age Bracket</th>
<th>Librarians</th>
<th>Teaching Staff</th>
<th>Deans of Schools</th>
<th>Heads of Departments</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 25 years</td>
<td>0</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>% in Group</td>
<td>0.00</td>
<td>10.32</td>
<td>0.00</td>
<td>0.00</td>
<td>5.19</td>
</tr>
<tr>
<td>26-35 years</td>
<td>0</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td>31</td>
</tr>
<tr>
<td>% in Group</td>
<td>0.00</td>
<td>20.00</td>
<td>0.00</td>
<td>0.00</td>
<td>10.06</td>
</tr>
<tr>
<td>36-45 years</td>
<td>2</td>
<td>31</td>
<td>19</td>
<td>44</td>
<td>96</td>
</tr>
<tr>
<td>% in Group</td>
<td>33.33</td>
<td>20.00</td>
<td>50.00</td>
<td>40.37</td>
<td>31.17</td>
</tr>
<tr>
<td>46-55 years</td>
<td>4</td>
<td>62</td>
<td>19</td>
<td>54</td>
<td>139</td>
</tr>
<tr>
<td>% in Group</td>
<td>66.67</td>
<td>40.00</td>
<td>50.00</td>
<td>49.54</td>
<td>45.13</td>
</tr>
<tr>
<td>&gt; 55 years</td>
<td>0</td>
<td>15</td>
<td>0</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>% in Group</td>
<td>0.00</td>
<td>9.68</td>
<td>0.00</td>
<td>10.09</td>
<td>8.44</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>155</td>
<td>38</td>
<td>109</td>
<td>308</td>
</tr>
</tbody>
</table>

Source: Research data (2017)

From Table 3, it is only amongst the teaching staff that there were respondents aged below 25 years, totalling 16 (10.32%). There was no respondent aged below 25 years amongst the heads of department as well as the deans or even the librarians. The majority of those surveyed aged below 25 years were serving as Graduate assistants and part-time lecturers. Two (2) out of the 6 librarians surveyed were aged 36 - 45 years while 4 of them were aged 46-55 years. Of the heads of departments and school deans, 40% and 50%, respectively were aged between 36 and 45 years. On the other hand, 67% librarians, 49.6% heads of departments, 50% deans and 40% teaching staff members were aged 46-55 years. On the other hand, 10.09% heads of department and 9.68% members of the teaching staff members were aged above 56 years. The overall analysis by age bracket is captured in table 4.

Table 4: Frequency and percentage of teaching staff in different age brackets in Kenyan universities

<table>
<thead>
<tr>
<th>Age Bracket</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 25 years</td>
<td>16</td>
<td>5.19</td>
</tr>
<tr>
<td>26 to35 years</td>
<td>31</td>
<td>10.07</td>
</tr>
<tr>
<td>36 to 45 years</td>
<td>96</td>
<td>31.17</td>
</tr>
<tr>
<td>46 to 55 years</td>
<td>139</td>
<td>45.13</td>
</tr>
<tr>
<td>above 55 years</td>
<td>26</td>
<td>8.4</td>
</tr>
<tr>
<td>Total</td>
<td>308</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Source: Research data (2017)

Overall, as shown in table 4, those aged less than 25 years were the least (5.19 %) followed those above 56 years at 8.4%. The highest population of teaching staff (45.1%) was in the age bracket of 46-55 years. This implies that 46-55 year age bracket was the modal age of the respondents. The respondents provided information of the period worked in the present positions and results of analysis captured in table 5.
Table 5: Percentages of period of experience of university academic staff in Kenya

<table>
<thead>
<tr>
<th>Staff category</th>
<th>1-5</th>
<th>6-10</th>
<th>11-15</th>
<th>&gt;15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Librarians</td>
<td>83.33</td>
<td>16.67</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Teaching Staff</td>
<td>54.84</td>
<td>45.16</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Deans of Schools</td>
<td>00.00</td>
<td>00.00</td>
<td>00.00</td>
<td>00.00</td>
</tr>
<tr>
<td>Heads of Departments</td>
<td>90.83</td>
<td>09.17</td>
<td>00.00</td>
<td>00.00</td>
</tr>
<tr>
<td>Overall</td>
<td>73.70</td>
<td>26.29</td>
<td>00.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Source: Research data (2017)

From Table 5, it is clear that the modal number of years of experience across the surveyed population is 1-5 years. In numbers this represents 227 out of 308 (73.70%) of the total population surveyed. This means no dean had more than 5 years experience, pointing to the modal period tied to deanship in the knowledge industry. Given that the librarians had between 1-5 years experience, it shows that they do not stay at their work stations longer.

All deans had years of experience in brackets 6-10 years and beyond. Comparing their years of experience to their ages, with 50% of them aged 46-55 years, and 50% of them aged 36-45 years, with none aged over 56 years, shows that rise to management levels credits some consistency in career development. In any management, the policy drafters are as important as the policies drafted (Frost, 2014). In this study, there are elements on policy, procedures, and performance, and the people driving this are obviously defined by their level of understanding of the entire system, basically function of their experience, exposure and education.

Knowledge Leakage across the Academic Deans

The respondents’ perception of the effect of a staff member switching positions within the same university or moving to other institutions on the deprivation of valuable operational knowledge and the results of analysis are captured in figure 3.

![Figure 3: Knowledge leakage perception by departing staff member](source: Research Data (2017))

As to whether leaving members of staff from their school deprived them of valuable operational knowledge, 60.53% of all the deans strongly agreed to it as 26.32% agreed, 10.53% indicated they were neutral, and the remaining 2.63% disagreed to the assertion. The study established that majority of the
respondents strongly agree that departure of staff members deprived the university valuable operational knowledge. The causes of members switching positions within the university or moving to other institutions are shown in figure 4.

Figure 4: Challenges leading to knowledge leakage via staff members
Source: Research Data (2017)

From figure 4, 70.00% of the respondents indicated that resignation was a cause of sudden departure of lecturers leading to knowledge leakage as 30.00% indicated that it was not. As 60% indicated that transfer was a cause of sudden departure of lecturers leading to knowledge leakage, 40.00% showed that it was not. However, 89.50% indicated that retirement was not a cause of 86.00% of sudden departure of lecturers leading to knowledge leakage. As 86.00% showed that death was not a cause of sudden departure of lecturers leading to knowledge leakage, 85.00% also showed that dismissal was not. According to these results, resignation was the most highly ranked cause followed by transfer.

The above means that generally lecturers in Kenyan Public universities have issues with existing administrations and are more likely to take a transfer to another work station-which still can be a component of resignation, than they are likely to work until retirement. Death is a natural phenomenon and unless there are epidemic cases, it is naturally expected that it occurs late in one’s life. In most work stations, cases of dismissal border on disciplinary issues between the dismissed and the organization. Others factors leading to disharmony can set up conditions leading to dismissal. Since it is a process that must have created disharmony, it scores low at 15% as a cause for exit of staff.

Other effects of teaching staff departure on the institution’s work activities were incomplete work leading to heavy workload amongst the remaining labor pool as indicated by 80%. Others quipped that the challenge also lead to loss in certain specialized expertise within the teaching, administrative and research ranks of the universities. The fact that some attempts to replace the departed members of staff can lead to bringing in incompetent replacements, exacerbates the case. Such potential challenges as mentioned above better be mitigated proactively, actively and reactively. However, 80% of the respondents did not clearly state what measures their universities were taking to mitigate such expected setbacks. About 20% hinted on the following:

(i) Retirement and succession planning to take care of what may arise upon retirement of a dependable member of teaching staff;

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(ii) Conducting exit interviews for members of teaching staff leaving to be able to loop the necessary mitigation for those still serving and if possible, try to do it for those who are leaving to see if an immediate reversal is feasible.

(iii) Conduct prior counseling sessions, issue warnings prior to dismissal in order to give affected teaching staff an opportunity to rectify;

(iv) In the event they do not rectify as in stated (iii) above, conduct exit interviews for them to understand the reason for dismissal. Such will instill confidence in the remaining teaching staff because it will portray the institution’s administration professional, supportive, and concerns about the success.

(v) In case of death, support the family that has lost and seek replacement (of the teaching staff)
None of the teaching staff mentioned about elaborate staffing plans based on sustainable staff: student ratios and where the schools or faculties are constantly seeking to uphold and sustain such standards. This would ensure continuity and assure the efficiency of knowledge delivery, especially if the replacements are equal to the tasks. On mechanisms put in place to retain a departing member of staff’s knowledge, only 15 % mentioned that they are:

i. encouraging documentation of knowledge and skills;
ii. arranging forums for more experienced teaching staff sharing experiences with other staff;
iii. supporting continuous training in relevant skills especially through conferences;
iv. Facilitating and organizing open lectures presided over by experienced teaching staff from various schools or faculties and
v. Establishing elaborate information storage and retrieval mechanisms;

On critical knowledge to be tapped from departing lecturers, respondents enlisted research skills, course content development, lecture preparation, teaching skills, exam setting, and marking skills as crucial. They also felt it imperative for those skills to be immediately passed on any new incoming teaching staff to ensure continuity. On the recommended mechanism of tapping the knowledge, they suggested that documentation of processes, lecture notes, laboratory procedures information sharing forums be put in place. None mentioned creation of opportunities to showcase and promote innovations in various capacities. Only 21.5 % of the respondents agreed that they had had innovations in their respective careers. None strongly agreed, and 20 % was neutral. Shockingly 30% strongly disagreed and a staggering 28.5 % opted not to respond to it.

Knowledge Leakage among Teaching Staff
While 70% of all the members of the teaching staff strongly agreed that leaving members of staff deprived them of valuable operational knowledge, 10% agreed, 15% remained neutral, 5% disagreed and none strongly disagreed. This is in comparison with the dean’s survey which revealed that 60.5 % of all the deans (23 out of 38) strongly agreed; 26.3 % (10 out of 38) agreed; 10.5% (4 out of 38) opted neutral; and the remaining one (1 out of 38 or 2.6%) disagreed. None strongly disagreed. Table 4.6 illustrates this cross-cutting comparison between the teaching staff members and the deans:

<table>
<thead>
<tr>
<th>Category</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deans</td>
<td>60.50</td>
<td>26.30</td>
<td>10.50</td>
<td>2.60</td>
<td>0.00</td>
</tr>
<tr>
<td>Teaching Staff</td>
<td>70.00</td>
<td>10.00</td>
<td>15.00</td>
<td>5.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Source: Research Data (2017)
From the above table, the total percentage of the deans agreeing (i.e., agreeing and strongly disagreeing) is 86.8% of their population surveyed while that of the teaching staff sums up to 80% of their surveyed population. In both cases, it shows that the majority are in agreement that members of staff who leave research organizations are likely to deprive the organization valuable information if the organization exists under similar circumstances as those surveyed. A comparison between those disagreeing and those remaining neutral does not give much difference. This is evidence that the two categories operate under similar circumstances, carry out related teaching jobs, with the uniqueness that the deans are in middle management positions.

The above is also evidence that knowledge leakage is a potential risk under certain operational conditions which need further investigation. Such crucial operational knowledge can be leaked when members of staff retire, take a transfer to other institutions, decide to resign, are dismissed or even die. It is premised on this that the research was prompted to survey across the 6 universities as pertains to knowledge leakage through such means shown in Table 7.

Table 7: Status of Challenges leading to knowledge leakage through teaching staff members in percentage

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retirement</td>
<td>20.00</td>
<td>80.00</td>
</tr>
<tr>
<td>Transfer</td>
<td>60.00</td>
<td>40.00</td>
</tr>
<tr>
<td>Resignation</td>
<td>70.30</td>
<td>29.70</td>
</tr>
<tr>
<td>Dismissal</td>
<td>20.00</td>
<td>80.00</td>
</tr>
<tr>
<td>Death</td>
<td>20.00</td>
<td>80.00</td>
</tr>
</tbody>
</table>

Source: Research Data (2017)

From the table 7, resignation – rated at 70.3% by the surveyed population, is the leading cause of sudden departure of teaching staff leading to knowledge leakage. Transfer closely ranks at 60%. Retirement as well as death rank lowest at 20% each. Death is a natural phenomenon and unless there are epidemic cases, it is naturally expected that it occurs late in one’s life. It is not much likely that it becomes a prevailing challenge amongst those leading to knowledge leakage. In most work stations, cases of dismissal border on disciplinary issues between the dismissed and the organization. Dismissal scores low at 20% as a cause for exit of staff.

On the effect of knowledge leakage to the institutions work activities. Incomplete work leading to heavy workload amongst the remaining labor pool dominated, with at least 60% of the respondents indicating so. This was especially so amongst respondents who supported the view that transfer and resignation are challenges in knowledge leakage. Others quipped that the challenge also lead to loss in certain specialized expertise within the teaching, administrative and research ranks of the universities. Such potential challenges need to be mitigated proactively, actively and reactively. Proactive measures taken by an institution can come in handy. However, 60% of the respondents did not clearly state what measures their constituent departments or schools or university as a whole were taking to mitigate such expected setbacks. About 40% hinted on the following:

(i) General: recruitment and training;
(ii) HR planning; and appointing part-time teaching staff;

The above list compliments the points already raised by the deans on the same issue. Just like the deans, none of the members mentioned about elaborate staffing plans based on sustainable staff: student ratios and where the schools are constantly seeking to uphold and sustain such standards. This would ensure continuity and assure the efficiency of knowledge delivery.
On mechanisms put in place to retain departing staff’s knowledge respondents suggested the following:

(i) Mentoring other staff to be able to handle work;
(ii) Keeping records of all the CATs, notes, exam results, and published papers;

The two points, again compliment what the deans had already proposed.

On critical knowledge to be tapped from departing lecturers, those who contributed enlisted preparation of e-learning material and exam setting; course outline, content organization and delivery. These, except preparation of e-material had already been mentioned from the deans’ survey. The members of the teaching staff surveyed also suggested that new members of staff be inducted on course on preparation and class control; teaching techniques; how to handle students; and modern diagnostic techniques for lecturers in environmental studies. On the recommended mechanism of tapping the knowledge, those who responded suggested that field experience knowledge be documented at every stage. Just like the deans, no teaching staff member surveyed mentioned creation of opportunities to showcase and promote innovations in various capacities as a way of tapping and retaining knowledge from more experienced scholars and researchers, yet innovation is at the core of knowledge dynamism and creation.

Most brilliant scholars find expression in bringing about new ideas and approaches to problem solving. The most important side of our universities should be providing a platform for knowledge sharing and management that would lead to solving real time challenges the society goes through. However, when asked about innovations, only 10 % of the respondents agreed that they had had innovations in their respective careers. 10% strongly agreed, and 10 % remained neutral. 20% disagreed, and another 20% strongly disagreed while 30 % opted not to respond to it. Table 8 summarizes the comparison between ratios posted by the heads of department and those by the teaching staff.

**Table 8: Percentage of response on problems related to knowledge retention by Heads of Department and Teaching Staff**

<table>
<thead>
<tr>
<th>Problems</th>
<th>Head of department</th>
<th>Teaching Staff</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of information</td>
<td>80.00</td>
<td>70.00</td>
<td>74.62</td>
</tr>
<tr>
<td>Information overload</td>
<td>70.00</td>
<td>80.00</td>
<td>76.14</td>
</tr>
<tr>
<td>Reinventing the wheel</td>
<td>40.00</td>
<td>60.00</td>
<td>51.89</td>
</tr>
<tr>
<td>Knowledge loss when staff exit</td>
<td>95.00</td>
<td>60.00</td>
<td>74.62</td>
</tr>
<tr>
<td>Poor sharing of knowledge</td>
<td>95.00</td>
<td>60.00</td>
<td>74.62</td>
</tr>
</tbody>
</table>

Source: Research Data (2017)

Eighty percent of the respondents from the teaching fraternity indicated that knowledge retention is suffering the setback of ‘information overload’. This is in comparison with the 70% ratio of the respondents from amongst the heads of department. Other comparisons are as shown in table 8. The differences may be as a result of varied roles in teaching and management. Also, generational gaps may bring about differences in opinion.

Seventy percent of the teaching staff respondents held that the university’s perception is that knowledge creation is each and everyone’s job, compared to 90 % of the respondents from among the heads of departments who held that knowledge creation is part of their performance contract is the notion of their respective universities. The two were the views held by the majority from the respective surveyed populations. If knowledge creation is everyone’s job, then to fill the gap left by, for instance more experienced members of teaching staff should be filled by anybody. Yet in reality that cannot be the case. A long serving teaching staff who has climbed through the ranks to re-known researcher, on his exit, cannot be replaced by a less experienced teaching staff. Similarly, if it is part of the employee’s contract, then the administration has the duty to support the employees deliver on the mandate just as it has the
duty to monitor such delivery. This calls for a fresh approach to showcasing the relevance of knowledge management. This opens up an opportunity for fresh ideas on knowledge management to be infused for more support with the universities.

Answer lies in analysis of the cost and benefits accrued. This is the position of realigning priorities. According to this survey, over 80% respondents believe that effective knowledge management can bring about improved competitive advantage; help improve research and development; enhance innovations; bring about employee development; and better decision making. At least 60% of the surveyed representative populations believe it can bring about improved quality, delivery, and cut down on overall operational costs in an educational, research and development organization, like a university. Despite all this great promise, there are a number of hurdles identified. Over 75% of the respondents rated lack of top management commitment to KM top'. This position does not conflict with the noting that the respondents equally believe top management can act on this. It only strengthens the argument that beyond the capacity to act, and the willingness to do so, there must be commitment. On the other hand, top management may argue in terms of constrained resources and the simple

Inferential Analysis
The study sought to establish the level of association between the independent variables and related dependent variable (Figure 1) indicators. Chi Square was used to address whether any relationship in the sample population was strong enough for the study to justify making inferences about the larger population from which the sample had been drawn (Newmark, 1975). The study first obtained contingency table for each association to explain the relationship and then produced chi-square results. The Chi-Square ($\chi^2$) is given by: $\chi^2 = \sum (\text{Observed Frequency} - \text{Expected Frequency})^2 / \text{Expected Frequency}$ (Kingoriah, 2004).

The importantly considered interpretation of Chi-Square ($\chi^2$) output is the significance probability, which should be less than 0.05 for the association to be translated as being significant (Garth, 2008). That is the study used the 5% (0.05) level of significance (95% confidence level). Before interpreting Chi-Square it is important to look at the “Minimum Expected counts”. Chi-Square test requires that the value for the expected count should not fall below 5 in more than 25% of the cells, to justify in carrying on with the interpretation of the Chi-Square statistics.

Chi-Square for Knowledge Leakage and Impact on Innovations
The study obtained the contingency for the impact of Knowledge leakage on innovations amongst teaching staff and the results captured in Table 9.

<table>
<thead>
<tr>
<th>Knowledge Leakage</th>
<th>Impacted on innovations</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
<td>Count</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>% within Knowledge Leakage</td>
<td>100.00</td>
</tr>
<tr>
<td>Neutral</td>
<td>Count</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>% within Knowledge Leakage</td>
<td>100.00</td>
</tr>
<tr>
<td>Agree</td>
<td>Count</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>% within Knowledge Leakage</td>
<td>28.60</td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Count</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>% within Knowledge Leakage</td>
<td>100.00</td>
</tr>
</tbody>
</table>

The results in table 9 show all those who indicated that there was no knowledge leakage (100%) indicated that knowledge leakage impacted on innovations amongst teaching staff. The results show that all those
who showed that they were not sure on whether there was knowledge leakage (100%) indicated that knowledge leakage had an impact on innovations amongst teaching staff. A majority of those who indicated that there was knowledge leakage (57.10%) indicated that knowledge leakage did not impact on innovations amongst teaching staff. Majority of those who indicated that there was knowledge leakage (73.30%) indicated that knowledge leakage did not impact on innovations amongst teaching staff.

Chi-Square tests were carried to establish relationship between knowledge leakage and its impact on innovations amongst teaching staff in public universities. The Chi-Square tests results are in table 10.

Table 10: Chi-Square Tests knowledge leakage and impact on innovations

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>21.631</td>
<td>6</td>
<td>0.001</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>22.548</td>
<td>6</td>
<td>0.001</td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>13.119</td>
<td>1</td>
<td>0.000</td>
</tr>
</tbody>
</table>

N of Valid Cases 27

a. 11 cells (91.7%) have expected count less than 5. The minimum expected count is .26.

The Chi-Square value obtained in Table 10 show that the association between knowledge leakage and impact on innovations was 21.631 with 6 degrees of freedom (df) and a significance probability of 0.001, which was less than 0.05. That is \( \chi^2(6) = 21.631, p=.001 \) which less than 0.05. These results show a high significant association between knowledge leakage and impact on innovations. Based on these result, there is enough evidence that there is an association between knowledge leakage and impact on innovations in the public universities of Kenya. The study concludes that there is a very significant association between knowledge leakage and impact on innovations in the public universities of Kenya.

The results on the symmetric measures are shown in table 11.

Table 11: Symmetric Measures for knowledge leakage and impact on innovations

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Asymp. Std. Error</th>
<th>Approx. T</th>
<th>Approx. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal by Nominal</td>
<td>Phi</td>
<td>0.895</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cramer’s V</td>
<td>0.633</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Interval by Interval</td>
<td>Pearson’s R</td>
<td>0.710, 0.093</td>
<td>-5.046</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Spearman Correlation</td>
<td>0.744, 0.109</td>
<td>-5.563</td>
<td>0.000</td>
</tr>
</tbody>
</table>

N of Valid Cases 27

The symmetric measures results in table 11 indicate that the size effect based on phi test was very high at 0.895 (\( \phi = 0.895 \)). Thus, according to these results, mitigation of knowledge leakage within the public universities of Kenya would significantly impact on innovations positively.

SUMMARY

Survey results indicate that there is knowledge leakage amongst teaching staff in Kenyan public universities as staff members are constantly moving from one school to another and also from departments and universities. This has deprived universities of valuable operational knowledge. The study further established that knowledge leakage within Kenyan public universities is perpetuated through resignations, retirement and transfer of members of staff. Survey results indicate that retirement, dismissal, and death are not common challenges within Kenyan public universities.

CONCLUSIONS

The study concludes that knowledge leakage highly impacts on innovations amongst teaching staff in public universities in Kenya, leads to loss of specialized expertise within the teaching, administrative and research ranks of the universities and is a potential risk under certain operational conditions.
POLICY RECOMMENDATIONS
In an effort to minimize effects of knowledge leakage, the mitigation measure to be employed should include; retirement and lecturer succession planning, conducting exit interviews for members of staff leaving, conduct prior counseling sessions, and issuing warnings prior to dismissal in order to give affected members an opportunity to rectify. This would instill confidence in the remaining members because it will portray the institution’s administrative, professional, supportive attitude towards the organization and the employee. This would ensure continuity and assure the efficiency of knowledge delivery, especially if the replacements are equal to the tasks.

Other mechanisms that could be used to mitigate knowledge leakage should include: encouraging documentation of knowledge and skills; arranging forums for more experienced dons to share experiences with other staff, supporting continuous training in relevant skills especially through conferences, facilitating and organizing open lectures presided over by experienced dons from various schools, and establishing elaborate information storage and retrieval mechanisms. Critical knowledge from departing lecturers should be tapped through research skills, course content development, lecture preparation, teaching skills, exam setting, and marking skills. The skills should be immediately passed on to any new incoming lecturer to ensure continuity. The mechanisms put in place to retain a departing member of staff’s knowledge include; mentoring other staff to be able to handle work; and keeping records of all the CATs, notes, exam results, and published papers.

Proposed Knowledge Sharing and management Strategies that are Integrative of Inputs and Outputs in Public Universities
Critical knowledge from departing lecturers should be tapped through; research skills, course content development, lecture preparation, teaching skills, exam setting, and marking skills. The skills should be immediately passed on to any new incoming lecturer to ensure continuity. The tools to be used for tapping the knowledge includes; documentation of processes, lecture notes, laboratory procedures information sharing forums (between experienced members and less experienced ones.

In an effort to avoid the impact knowledge leakage the universities should tap from departing lecturers by acquiring from their; e-learning material, exam setting; course outline, content organization and delivery. The members of the teaching staff should be inducted on course on preparation and class control; teaching techniques; how to handle students; and modern techniques for lecturers. Importantly, experienced and innovative members of staff should be given a chance to share out such knowledge so that in the event of their exit, the system is not hit in terms of the loss of knowledge.

REFERENCES
PSYCHOLOGICAL EFFECTS OF DIVORCE ON ACADEMIC ACHIEVEMENT AMONG PRIMARY SCHOOLS PUPILS IN KANGETA DIVISION, KENYA

Tabitha Muthamia, Mburugu Beatrice, Kamoyo John, John Kobia
Chuka University P.O Box 109, Chuka
Corresponding author email: tabbykiambi@yahoo.com

ABSTRACT
Divorce is dissolution of a marriage relationship. Divorce jeopardizes children emotionally, psychologically and intellectually. It affects the pupils’ psychological well-being, as they go through adjustment of living without one parent. Therefore, this study sought to investigate the effects of divorce on academic achievement among primary schools pupils in Kangeta Division, Kenya. The study adapted a descriptive survey research design. The population of the study was 18,697, comprising of 398 teachers, 26 head teachers and 18,247 pupils from 26 in the study area. The sample size was 343 respondents, derived from 8 primary schools. Simple random sampling and purposive sampling methods were used to obtain the sample size. Three sets of questionnaires were employed as research instruments for data collection. Validity of the research instruments was improved through opinions and judgement of University experts. Reliability of the questionnaires was improved through a pilot study conducted in two primary schools in Maua Division. The reliability was estimated using Cronbach’s Alpha Coefficient and a reliability coefficient 0.70 considered appropriate. Reliability for pupils’ questionnaire was 0.846, class teachers were 0.782 and head teachers were 0.707. Data was coded for analysis through a computer programme; the Statistical Package for Social Sciences (SPSS) version 20.0. Data analysis was by both descriptive statistics and inferential statistics. Qualitative data was analyzed thematically. The study findings revealed that pupils from divorced homes were psychologically affected. Therefore, this affected their academic achievement as they were easily irritated, depressed, and lacked attention in class. The study established that primary school pupils from divorced homes are psychologically affected hence affecting their academic achievement. The study recommends that Guidance and Counselling Services in primary schools should be encouraged to enhance positive psychological and social well-being with respect to academic achievement. The findings and recommendations should provide valuable reference for parents, teachers, school administrators, child psychologists and policy makers in education on effects of divorce on academic achievement among pupils from primary schools.

Keywords: Psychological, Effects, Divorce, Academic achievement

INTRODUCTION
Divorce is dissolution of a marriage relationship. The term divorce came from the Latin term divortere, meaning to turn in different ways or separate. According to Bradshaw (1999) divorce is the final termination of marital union cancelling the legal duties and responsibilities of marriage and dissolving the bonds of matrimony between the two parties. Divorce has adverse effects that touch not just the family involved but the entire society. When spouses divorces, that divorce affects relatives, friends, neighbors, employers, teachers clergy and scores of strangers.

According to Collins (2003) divorce in the United States of America (USA) rose by fifty percent and have been on the increase since that time. Emery (2006) records that thirty-eight percent of white children and seventy-five percent of black children born to married parents will experience divorce prior to sixteen years of age and this leads to poor academic achievement. Statistics in Canada (1997) data indicated that there were approximately 77,000 divorces granted in Canada, a rate of 262 per 100,000 people. Therefore, when parent’s separate and the father is denied the custody may be detrimental to academic achievement of the pupils.

In Africa according to Cloete (2005) divorce is highest in South Africa. Cloete (2005) notes that South Africa has an exceptionally high divorce rate and further asserts that the stressful nature of parental separation and divorce result in a high susceptibility of children to psychological, social, academic and health problems. According to South African Law Commission (SALC) of 2002 divorce is invariably
traumatic for all concerned, but especially for children of such a marriage relationship hence affecting the academic achievement. According to Cohen (2002) over one million children are living in divorced families each year in South Africa. According to South African Law Commission (2002) divorce or separation is invariably traumatic for all concerned, but especially for children of such a marriage or relationship which may affect their academic achievement.

In Kenya according to Mwaniki (1984) 22% of marriages end in divorce due to misunderstanding between the spouses. Mwaniki (1984) asserts that in case where divorce was permitted, children may suffer emotionally and psychologically being brought up by one parent, a relative or a grandparent and this may lead to poor academic achievement. According to Sakwa (2014) the number of cases filed for child custody is alarmingly on the rise in Kenya. In 2012, there were 1775 cases filed for custody, in 2013 the number went up to 1865 and in January 2014 a total of 170 cases related to divorce had already been filed in Kenya. This indeed reflects the rates of divorce in Kenya which may not only affect the spouses concerned but also the academic achievement of the pupils from divorced families.

Kangeta is popularly known for Miraa (Khat) growing. High rates of divorce have been experienced as a result of miraa (Khat) farming in the area. This is also supported by Sikiru and Babu (2009) who estimated that about one-third of all wages were spent on miraa consumption at the expense of vital needs, indicating dependence. Further, Kalix and Khan (1984) adds that family life is harmed because of neglect, dissipation of family income and appropriate behaviour which in many cases leads to parental divorce and negligence. Pupils’ academic and emotional well-being if properly monitored will go a long way in ensuring that potentials in pupils’ academic achievement are harnessed, and put into use for national development and for realisation of vision 2030.

RESEARCH METHODOLOGY
This study adapted a descriptive survey research design. The descriptive survey research is a process of collecting data in order to test hypotheses or answer questions concerning the current status of the subjects under study. It determines and reports the way things are and it attempts to describe such things as possible behaviour, attitudes, values and characters (Mugenda & Mugenda, 1999). The research design was suitable for this study because the researcher conducted an assessment of effects of divorce on academic achievement among pupils from primary schools in Kangeta Division, Igembe South Sub-County of Kenya without manipulating any of the study variables.

The study was carried out in Kangeta Division, Kenya and focused on pupils and teachers in primary schools within the division. Divorce rates in Kangeta Division are high and it affects the academic achievement of pupils. Primary schools in Kangeta Division, Kenya were preferred because reports from the AEO (2013) indicate that Kangeta Division academic achievement of pupils is a major concern. Statistics from Igembe South Sub-County Education Office year 2014 showed the target population as 18,697 pupils, 389 teachers and 26 head teachers in the 26 public primary schools within the Sub-County. The accessible population was 2132 respondents comprising of 2080 class seven pupils, 26 head teachers and 26 class seven teachers. Kangeta Division has 26 primary schools with a population of 2080 class seven pupils. Simple random sampling was used to select 8 primary schools.

The Ministry of education recommends an average class size of 40 pupils per class. Therefore 40 pupils were selected from each school using simple sampling technique. The sample size of pupils was distributed among the 8 primary. According to Kathuri and Pals (1993) the sample size for an accessible population of 2080 class seven pupils is 327 respondents. The other respondents in the study included 8 class seven teachers from each of the sampled schools and 8 head teachers also from the sampled schools. These were selected by purposive sampling since they had the required information with respect to the objectives of study. The total number of respondents was 343.
Table 2: Summary of the Sample

<table>
<thead>
<tr>
<th></th>
<th>Total Number</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head teachers</td>
<td>26</td>
<td>8</td>
</tr>
<tr>
<td>Class teachers</td>
<td>26</td>
<td>8</td>
</tr>
<tr>
<td>Pupils</td>
<td>2080</td>
<td>327</td>
</tr>
<tr>
<td>Total</td>
<td>2132</td>
<td>343</td>
</tr>
</tbody>
</table>

This study employed questionnaires as research instruments for the purpose of gathering information from respondents. According to Mugenda and Mugenda (1999) a questionnaire is a group of printed questions which have been deliberately designed and structured to be used to gather information from respondents. The questionnaires were appropriate to this study because they could be used on a large number of respondents simultaneously. Borg and Gall (1996) point out that questionnaires are appropriate for the studies since they collect information that is not directly observable as they inquire about feelings, motivation, attitudes and accomplishment as well as experiences of individuals.

Questionnaires had been chosen on the bases of these strengths. After data cleaning, the quantitative data was coded and entered in the computer for analysis using Statistical Package for Social Sciences (SPSS) version 20.0 for windows. Levesque (2007) recommends that SPSS can be used for data analysis. The quantitative data that were obtained from the questionnaires was analysed using descriptive statistics such as frequency counts, means and percentages. Inferential statistics of chi square were also used to analyze the data. The qualitative data obtained from the open ended question items were analysed and discussed thematically.

RESULTS AND DISCUSSION
The first objective sought information about primary school pupils’ psychological effects of divorce on academic achievement. Information on Table 5 shows the extent to which pupils agreed or disagreed with given statements on psychological effects of divorce towards academic achievement. The results of data analysis are represented on a five level likert scale:

Table 5. Pupils’ Opinions on Psychological Effects of Divorce on Academic Achievement

<table>
<thead>
<tr>
<th>Statement</th>
<th>SD (%)</th>
<th>D (%)</th>
<th>U (%)</th>
<th>A (%)</th>
<th>SA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils from divorced homes have difficulties in completing home work</td>
<td>4.5</td>
<td>9.6</td>
<td>13.0</td>
<td>43.2</td>
<td>27.3</td>
</tr>
<tr>
<td>which affects their academic achievement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils from divorced homes do not participate in group discussion</td>
<td>6.8</td>
<td>13.2</td>
<td>11.4</td>
<td>43.2</td>
<td>25.5</td>
</tr>
<tr>
<td>hence poor academic achievement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils from divorced homes are absent minded</td>
<td>3.2</td>
<td>8.2</td>
<td>14.6</td>
<td>45.9</td>
<td>28.2</td>
</tr>
<tr>
<td>hence have learning difficulties</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils from divorced homes look depressed most of the time and</td>
<td>1.8</td>
<td>5.5</td>
<td>8.2</td>
<td>52.3</td>
<td>28.2</td>
</tr>
<tr>
<td>therefore perform poorly in class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils from divorced homes find it hard to forgive when offended</td>
<td>5.5</td>
<td>3.2</td>
<td>9.1</td>
<td>50.9</td>
<td>32.3</td>
</tr>
<tr>
<td>hence affect class concentration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils from divorced homes do not appreciate others in school and</td>
<td>0.9</td>
<td>4.5</td>
<td>10.0</td>
<td>52.7</td>
<td>31.4</td>
</tr>
<tr>
<td>this isolates them from class discussions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils from divorced homes lack attention and this affects the studies</td>
<td>4.5</td>
<td>4.5</td>
<td>12.7</td>
<td>50.0</td>
<td>31.8</td>
</tr>
<tr>
<td>Pupils from divorced homes poorly attend school leading to low</td>
<td>4.5</td>
<td>5.9</td>
<td>11.4</td>
<td>48.6</td>
<td>29.5</td>
</tr>
<tr>
<td>grades in the exam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils from divorced homes are highly irritated when offended hence</td>
<td>4.5</td>
<td>9.1</td>
<td>9.1</td>
<td>50.9</td>
<td>29.5</td>
</tr>
<tr>
<td>do not do well in class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>4.0</td>
<td>7.1</td>
<td>11.1</td>
<td>48.6</td>
<td>29.2</td>
</tr>
</tbody>
</table>
Information on Table 5 shows that 77.8% of the pupils agreed while 11.1% disagreed and 11.1% were undecided with most of the negative statements on psychological effects of divorce on academic achievement.

Information was sought further on any other feeling over parents’ divorce that affects academic achievement and the pupils’ responses generated the following thematic clusters; lack basic needs like food and clothing which affects their concentration, lacks parental guidance and love and lacks the role model from the significant other hence contributing to poor academic achievement. These results are in line with the findings of Clark-Stewart (1996) who stated that there are deleterious psychological effects of divorce on pupils’ self-esteem, achievement in school and psychological adjustment. Clark further asserts that when pupils’ self-esteem is lowered the academic achievement is greatly wounded.

The study sought for opinions of class seven teachers concerning the psychological effects of divorce on academic achievements. Table 6 shows the results from a five level Likert scale on which the class seven teachers noted their opinions about the extent of agreement or disagreement with the indicated statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>SD(%)</th>
<th>D(%)</th>
<th>U(%)</th>
<th>A (%)</th>
<th>SA(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils from divorced homes have difficulties in completing homework hence performing poorly</td>
<td>0.0</td>
<td>12.5</td>
<td>12.5</td>
<td>50.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes do not participate in group discussion and do not benefit academically</td>
<td>0.0</td>
<td>12.5</td>
<td>0.0</td>
<td>62.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes are absent minded in class hence have learning difficulties</td>
<td>0.0</td>
<td>12.5</td>
<td>12.5</td>
<td>50.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes look depressed most of the time hence performing poorly in class</td>
<td>0.0</td>
<td>12.5</td>
<td>0.0</td>
<td>75.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Pupils from divorced homes find it hard to forgive when offended hence affect class concentration</td>
<td>0.0</td>
<td>25.0</td>
<td>0.0</td>
<td>50.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes do not appreciate others in class and this isolates them in class discussions</td>
<td>0.0</td>
<td>0.0</td>
<td>12.5</td>
<td>75.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Pupils from divorced homes lack attention when in class and affects their studies</td>
<td>12.5</td>
<td>12.5</td>
<td>25.5</td>
<td>50.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Pupils from divorced homes poorly attend school leading to low grades in the exam</td>
<td>12.5</td>
<td>12.5</td>
<td>0.0</td>
<td>62.5</td>
<td>12.5</td>
</tr>
<tr>
<td>Pupils from divorced homes are highly irritated when offended and do not do well in class</td>
<td>0.0</td>
<td>12.5</td>
<td>0.0</td>
<td>75.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Average</td>
<td>12.5</td>
<td>12.5</td>
<td>7.5</td>
<td>55.6</td>
<td>18.6</td>
</tr>
</tbody>
</table>

Results on Table 6 shows that 74.2% of class teachers agreed while only 25% disagreed with the statements on psychological effects of divorce on academic achievement of pupils. This support the previous results obtained from pupils’ opinions on psychological effects of divorce on academic achievement.

Information was sought further from class teachers on any other psychological effects of divorce on academic achievement of pupils. The main feeling was that pupils from divorced families are chronically out of school especially older ones taking care of their siblings. There was another view that they look withdrawn most of the time. Some class teachers attested that some pupils got engaged into drugs and this affects their academic achievement. These findings correspond to the views of Clark-Stewart and Hayward (1996) in their studies purporting that there are deleterious effects of divorce on children’s achievement in school and psychological adjustment.
Head teachers indicated their opinions with regard to pupils’ psychological effects of divorce on academic achievement. Table 7 contains the data analysis results on the head teachers’ opinions about pupils’ psychological effects of divorce on academic achievement.

**Table 7: Head Teachers’ Opinions on Psychological Effects of Divorce on Academic Achievement**

<table>
<thead>
<tr>
<th>Statement</th>
<th>D(%)</th>
<th>SD(%)</th>
<th>U(%)</th>
<th>A (%)</th>
<th>SA(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils from divorced homes have difficulties in completing homework which affects academic achievement</td>
<td>12.5</td>
<td>0.0</td>
<td>12.5</td>
<td>62.5</td>
<td>12.5</td>
</tr>
<tr>
<td>Pupils from divorced homes do not participate in group discussions hence poor academic achievement</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>75.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes are absent minded in class hence have learning difficulties</td>
<td>12.5</td>
<td>0.0</td>
<td>12.5</td>
<td>50.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes look depressed most of the time hence do poorly academically</td>
<td>12.5</td>
<td>0.0</td>
<td>25.0</td>
<td>37.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes find it hard to forgive when offended hence affects concentration</td>
<td>0.0</td>
<td>12.5</td>
<td>0.0</td>
<td>62.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes do not appreciate others in school and this isolates them from discussions</td>
<td>12.5</td>
<td>0.0</td>
<td>12.5</td>
<td>62.5</td>
<td>12.5</td>
</tr>
<tr>
<td>Pupils from divorced homes lacks attention when studying and affects their studies</td>
<td>0.0</td>
<td>12.5</td>
<td>0.0</td>
<td>62.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Pupils from divorced homes poorly attends school leading to low grades in the exam</td>
<td>12.5</td>
<td>0.0</td>
<td>0.0</td>
<td>75.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Pupils from divorced homes are highly irritated when offended hence poor class performance</td>
<td>12.5</td>
<td>0.0</td>
<td>12.5</td>
<td>62.5</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>8.3</td>
<td>12.5</td>
<td>8.3</td>
<td>61.1</td>
<td>19.4</td>
</tr>
</tbody>
</table>

Results on Table 7 indicate that 80.5% of head teachers agreed while 20.8% disagreed with the listed negative statements on pupils’ psychological effects of divorce on academic achievement. Majority of pupil participants in this study comprising of on average 77.8% pointed out that they have psychological problems on academic achievement. This suggests that most primary school pupils from divorced homes exhibit a negative psychological effect of divorce on academic achievement.

Data analysis results on academic achievement shows that most pupils have difficulties in completing work; do not participate in group discussion; are absent minded most of the time; depressed most of the time and mind wandering away most of the time. It can therefore be concluded that pupils from divorced homes have negative psychological issues which affects academic achievement. These findings correspond to the views of Clark-Stewart and Hayward (1996) in their studies purporting that there are deleterious effects of divorce on children's self-esteem, achievement in school and psychological adjustment. When pupils are not able to adjust psychologically after parents’ divorce and exhibit problems which were not there before, then mental block develops culminating in low achievement.

Rohner and Veneziano (2001) in their studies suggest that the overall father love appears to be as heavily implicated as mother love in offspring’s psychological well-being and health, as well as in an array of psychological behavioural problems and towards achievement. Father involvement is positively correlated with children’s overall social competence, social initiative, social maturity, and capacity for relatedness with others (Olsen, 2005). Hayward (1996) in his studies suggests that it was important for both parents to remain responsible to the upbringing of children. If children were to experienced psychological growth and strength, in most cases children repeatedly loved both of their parents and strongly wanted contact with both. Hence, it is important for the non-custodial parent to spend time together with children, for children preferred to do everyday tasks with the non-resident parent, such as doing homework, watching television or just talking.
The class seven teachers and head teachers viewed pupils as being depressed most of the time and expressed that most pupils had problems with completing work. As indicated by Dubowitz (2001) studies; pupils whose fathers are involved in their care are more likely to be securely attached to them, be better able to handle strange situations and be more resilient in the face of stressful situations. Parents’ involvement is positively correlated with children’s overall life satisfaction and their experience of less depression. According to studies by Mischel (1998) children who have attention from non-custodial parents are better able to manage their emotions and impulses in an appropriate manner.

DISCUSSION
This study aimed at investigating the effects of divorce on academic achievements among pupils from primary schools in Kangeta Division, Kenya. The findings of this study indicated that majority of primary school pupils from divorced homes exhibited negative psychological effects of divorce which has impacted negatively on academic achievement. This is reflected by having difficulties in completing homework, being absent minded most of the time, are depressed, getting highly irritated and not submitting assignments to the teacher, mind wandering away when studying.

The following recommendations are made from the findings of this study: Parents should have an important role to play in the outcome of children’s reaction to their divorce. How parents handle divorce may be the most important factor in determining the psychological well being of children. Parents therefore should handle divorce in a more mature and healthy way to allow the children a strong chance of making a positive adjustment to divorce.

REFERENCES


TAHAKIKI YA MOTIFU YA SAFARI KATIKA KUHIFADHI MAZINGIRA KATIKA UTENDI WA KALEVALA.

Jackson Ndung'u Mwangi
Idara ya Lugha, Isimiu na Fasihi. Chuo Kikuu cha Lukipia,
SLB 120-20300 Nyahururu. Email: jigmwas@gmail.com, Simu: 0720112251.

IKISIRI

Maneno ya kimsingi: Tahakiki, motifu, magajina, ekolojia, uhifadhi, mazingira.

Utangulizi.
Uhamiki wa fasihi kiekologio unahusu kuchunguza kazi za kifasihi kwa kuzingatia mtazamo unaolena za kikibinafsi wa ekolojia. Utafiti huu ulijishughulisha na kuchunguza jinsi motifu ya safari kama mojawapo na kipengele cha fasihi inavyoangazia kutambulisha suala la umkombozi wa kimazingira kutokana na uharibifu wa kibinadamu. Katika harakati za kurejesha uhai wa mazingira na lazima fasihi ichukue nafasi ya kipekee katika kuhamisha mwanadamu kuhusu umuhimu wa uhifadhi wa mazingira na hasara za kutohifadhi mazingira.

Ekolojia yetu imo katika hali ya hatari ya maangamizi kutokana na matendo ya kibinafsi ya kibinadamu. Matendo kama vile: kukata miti, kujenga nyumba katika maeneo oeu, kuongezeka kwa teknolojia haribifu za kisasa na ukosefu wa uongozi adilifu katika masuala ya ekolojia, yamesababisha mitandao ya viungauhui kudhoofika. Mwishe wa matendo haya ni kwamba jotohewa limeongezeka na kuvuguta sayari yetu, magonjwa yamezidi, vifo vimekithiri na mazao katika jamii zetu yamepungua hivyo kusababisha njaa. Athari hizi zinatatiza maisha ya binadamu na maendeleo endelevu.
Kupitia ung’amuzi muhimu mwamba utegemezi mkubwa upo kwenye dunia tunamoiishi, kongamano hili lilitoa misingi muhimu ya kimazingira baadhi yake ikiwa: ili kufikia maendeleo endelevu, uhifadhi wa mazingira utabaki kuwa sehemu muhimu katika mhakato wa maendeleo, mataifa yawe na sheria faafu za kimazingira, mataifa yaweze kuunda sheria ya kitaifa kuhusu fidia kwa wahasirwa wa uchafuzi wa he wa matozi mengine ya kimazingira, wanawake wana jukumu muhimu katika maendeleo na utunzaji wa mazingira hivyo kujumuishwa kwao ni jambo la busara katika kufikia maendeleo endelevu. Hii ni baadhi tu ya misingi muhimu iliyojadiliwa ingawa utunzaji mazingira ndilo lililokuja wazo ku ni kuepuka madhara ambayo yaliathiri kukuwa kwa uchumi na afya bora ya mwanadamu. Vile vile, mashirika ya kimatinga yameendelea kulipa swala hilii la mazingira umuhimu mkubwa hivi kwamba yanazidi kufadhili shughuli zilizo na umuhimu katika uhifadhi mazingira.

Juhudi za uhifadhi mazingira ni lazima zitekelezwa na watu wa nyanja tofautitofauti wakiwemo wasomi na watunzi wa fasihi kando na wanasyanshi ili waweze kumfikia binadamu wa tabaka la chini zaidi anayehusika nayo moja kwa moja. Fasihi huwa na lengo la kufikia jamii ili iweze kuikosoa, kuvelimisha na hata kutahadharisha kuhusu matendo mabaya ya mwanadamu. Malengo hula huishia katika kutatua matatizo yanayojokeza katika jamii ni ambayo yanatishia uhai wa wanajamii na viumble vilivyomo. Fasihi ina mchango wa kuhamasisha binadamu kuhusu masuala ya kimazingira hasa uharibifu unaotendwa na binadamu ndiposa watunzi mbalimbali wamejitosa uwanjani kuliandikia suala hili. Watunzi hawa ni kama vile Mbogo Emmanuel katika riwaya ya Bustani ya Edeni na Kithaka Wa Mberia katika mkusanyiko wa mashairi Bari Jingine ambapo baadhi ya mashairi yanazungumzia jinsi binadamu anavyoharibu utando wa ozoni hasa shairi la Ngao’ Hata hivyolo kila mtunzi ana mtazamo wake wa kiekololoja na jinsi ya kuukabilii.


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Utafiti huu ulihusu kutathmini nafasi ya motifu ya safari kwa wahusika wakuu katika kutambilisha maswala ya kiekolojia katika utendi wa Kalevala. Madhumuni makuu yaali wiki na kubainisha mkoo wa majagina kwa kikoni ya motifu ya safari kwa kipekee katika kuendeleza na kumkuza maudhui ya uhifadhi wa mazingira.

Mwega wa nadharia


Katika mlango wa pili, ukurasa wa kumi na nne, Mwanamwini ambaye ni mhusika mkuu na shujaa wa kutambulika katika nchi ya kalevala anafunga safari kwenda kwenda nchi ya Pelawini akiwa katika aru ya kuafikia jaala yake. Akiwa safari, anakutakaa na mhusika wa kipekee aliye kuwa Samsa. Samsa alikuwa ni mbilikimo lakini alikuwa nilikuwa ni kimatae wa kusajabisha kutokana na juhudi zake za kutia bidii katika maisha yake. Moyoni mwayne, alikuwa na musukumo wa kipekee na kukuza na kuendeleza uhifadhi wa mazingira. Anamstaajabisha Mwanamwini kutokana na juhudi za kipekee za kuhiifadhi mazingira. Inabainika kuwa alijuhaitsa kwa hali na mali katika kuhifadhi ardhi kwani aliushia kupinda miti ya aina yote katika nchi ambayo alikuwa iliyojua jangwa na mashamba yote katika sehemu yote yake. Moyoni mwayne, alikuwa na msukumo wa kipekee na kukuza na kuendeleza uhifadhi wa mazingira.

Mwana- nchi Pelawini. Samsa mwana shambani.
Pelawini mbilikimo atayefanya kilimo,
Akapanda mbega chini mashambani mabwawani.
Akapanda mchangani, majiweni milimani.
Akapanda uwandani misunobari mitini.
Miti yote imekua, mashina ikainua
Ikaota na majani na matunda matawini.
Mimea ya kila aina imekua na kufuata mazingira.(uk 14)

Katika mlango wa pili, ukurasa wa 15, baada ya Mwanamwini kufurahishwa na juhudi za uhifadhi wa kimazingira zilizotendewa na Samsa, anatamauka na kuudhihika mno baada ya kukutana na kundi la wanawake wane akiwa safari, wanawake wawili wa kukuza na kuendeleza uhifadhi wa mazingira. Inadaaiwa kuwa sababu kuu ya kuwadake hawa huhihi na misitu na kuwadake hawa na kuhihihi na misitu. Inaotaka kuwa mwananchi anaweza kusafiri kutoka nchi moja moja na kusafiri kutoka miziki moja moja.

Akiwa safari, akaona wali wane wazuri wasimuone
Kisa wanawake hawa wakaja na visa vyao
Wakakata wakavuna wakafanya kazi sana.
Tusa mkubwa akatoka majani, katia moto nyasini.(uk 15).

Katika juhudi za kuchukua kuhifadhi na kula mazingira, Mwanamwini anaweza kuendeleza wa kua kuiharibu na kuhihihi na kuhihihi na mazingira. Mwanamwini anaweza kuendeleza wa kua kuiharibu na kuhihihi na mazingira. Mwana wa bahari aliyevaa sufuri.

Baada ya mazungumzo ya muda mrefu, yule Mtema Mitu alitilia maana raia ya Mwanamwini na kuamua kuwa atakomashe tabia yake mbaya ya kuikata miti miti ila atachukua jukumu la kuitinda na kuikutuza, jambo linalomfanya Mwanamwini kuwa mtetezi wa kipekee katika juhudi za uhifadhi wa maswala ya kiekolojia. Suala hili linadhirisha kuwa kwa kweli, kuna uwezekano kuwa baadhi ya mashujaa katika tendi waliokuwa na majukumu muhimu katika jamii zao ya kuleta mabadiliko ya kipekee katika Nyanja mbalimbali hali zikimoza za kifani kuwa kati mazingira kama alivyofanya mwanamwini.

Mwanamwini kama shujaa katika suala la uhifadhi wa mazingira, anachukua jukumu la kipekee na kuamua kuwa atakama mipekee na mtema la hekima, akatamka kalmia. Mwanaamini alitilia maana rai ya Mwanamwini na kuamua katiwa katika juhudi za uhifadhi wa mazingira. Suala hili linadhirisha kuwa kwa kweli, kuna uwezekano kuwa baadhi ya mashujaa katika tendi waliokuwa na majukumu muhimu katika jamii zao ya kuleta mabadiliko ya kipekee katika Nyanja mbalimbali hali zikimoza za kifani kuwa kati mazingira kama alivyofanya mwanamwini.

Katafuta mwanamwini, ufukoni kwa mtoni
Akavumbua mwishoni mbegu sita mchanganzi
Ufukoni mwa mtoni, kwa uziwa ukongoni
Mbegu sita au saba, vini vipya vya haba.
Mzee kazi chukua moja moja akidondoza
Kazishika mkononi kazitia mfukoni
Akachukua azima, kaanza kulima
Kapata pahali pema, ili kupanda mtama.


Katika mlango wa saba, juhudi za Mwanamwini kama mwanamazingira zinatambulika kwani uhifadhi na utunzaji wa maswala ya kiekolojia una umuhimu katika maisha ya viungo wa ujumla. Akiwa safari mji uko lako ni mla nyama na licha ya kuwa aliokuwa safari kwenye ardhi kabla abao wanaoalipitishwa huku akifanya dua ili mvua iweze kunyesha kwenye ardhi ile. Dua yake ili adhibiti na baadaye mvua kuwa kubwa iliyeshwa kwa mune wa mtema la hekima na kuwizia uliopokwa kwa nchi la msaidizi wa kufanya nje. Mwanaamini alinamwili wa hekima, akatamka kalmia. Mwanaamini alitilia maana rai ya Mwanamwini na kuamua katiwa katika juhudi za uhifadhi wa mazingira. Suala hili linadhirisha kuwa kwa kweli, kuna uwezekano kuwa baadhi ya mashujaa katika tendi waliokuwa na majukumu muhimu katika jamii zao ya kuleta mabadiliko ya kipekee katika Nyanja mbalimbali hali zikimoza za kifani kuwa kati mazingira kama alivyofanya mwanamwini.

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Kati ya ule msitu, palilala yule jitu.
Alilala usingizi katikati ya mizizi.
Nyasi nyingi na mimea, juu yake yaenea
Mwanamwini akashika mikonooni yake shoka.
Akakata miti yote, mimea na nyasi zote
Kamwona jitu mwishoni kimkanyaga usoni
Kafukua ile pua jitu kaanza kupumua. (uk 94)

Licha ya kuwa katika utendi wa Kalevala majagina wengi wanaonekana kujihusisha na masuala ya kuhifadhi na kutunza mazingira, kuna baadhi ya mashujaa wengine ambao wanashirikisha matendo ya uhariibu wa mazingira wakiwa katika safari zao ili kuafikia jaala zao. Katika utendi huu, kuna shujaa aliyeitwa Ilmarini ambaye alitambulika na wanajamii ili kuwakumbuka kawaida kwa uwezo wake wa kuchimba madini na kutengeneza vyombo na bidhaa za vyumu. Akiwa safarini katika harakati ya kutafuta mahala pa kuchimba madini, aliutumia na msichana mrembo mno. Baada ya mazungumzo na kwa msichana kuwakumbuka, wakatema miti mingi sana ili kutengeneza vyombo na bidhaa wa safari. Baada ya mazungumzo na kuahitaji kuhakikisha juu yake yaenea, mwanamwini akashika kuwa mikononi shoka. Ukataji miti huu wa kiholela ulisababisha uhariibu mkubwa sana wa kimazingira. Katika urahisi wa 109, inabainika pia kuwa kufuata kwa msichana mrembo mno,lililosababisha uhariibu mkubwa sana wa mazingira.

Baada ya kuchinjwa ng'ombe watu wakafanya pombe.
Tembo araki na jinni, kwa kunywiwa na wageni.
Wakatema miti mingi, watie mioto mingi.
Na moshi utanganyaa na watu wakashangaa.
Wakauliza: “mtaona arusini
Wakapika nyama nyingi, pombe hujaa mitungi. (uk109).

Mwanamwini anapofikia umri wa kupata mchumba, anasafiri hadi Pohiola katika ardhi ya Sariola kwani nchi hii ilitambulika kuwa na wasichana warembo zaidsi na wenye nisho na tabia za kupendeza. Alipoika nchii hii, ile, alitambulisha kwa malkia wakafanya uchumbu na wawili hawa wakaahidiana kufungu ndoa. Wazazi wake malkia huyu wanaachakua mawaidha mengi kuhusu maisha yakiwemo uhindhani na utunzaji wa mazingira.

Mapema enda shambani bila kukawa njiani.
Fungwa macho tazama, enda kupanda mitama,
Na njegere na mbaozi na pateto na viazi.
Na kebiji na letisi, ng'ombe pamoja na ndama.
Usisahau wanyama, ng'ombe pamoja na ndama.

Inadhirika wazi wazi kuwa suala la utunzi wa mazingira na la kimisingi mmo katika jamii hii ya Kalevala. Ni wazi kuwa kwa kweli, suala la uhifadhi wa mazingira lina umuhimu wa kipekee katika jamii.

Hitimisho
Utafiti huu ulitambua kuwa motifu ya safari katika uchambuzi wa tendi huwa na umuhimu wa kipekee katika kukuza dhana mbalimbali katika utendi. Pia imebanika waziwazi kuwa majagina katika utendi wa Kalevala wanatumia mbinu ya safari katika kuhamisha na kutambulisha suala la uhifadhi na udumishaji wa mazingira kwa jamii. Katika tendi, suala la safari huwa bainifu mno kwani shujaa katika tendi husafiri kutoka sehemu moja hadi nyingine wakiwa katika mkee ya kuwa kuuja jaala zao. Utendi wa kalevala umetambulisha suala mojawapo ya majukumu makao ya mouldinga katika utendi huu ni suala la uhifadhi wa mazingira, jambo ambalo wanafikekeleza kwa umakini mmo ili kuhakikisha kuwa jamii
na viumbe wengine hawaangamii siku za usoni. Tunaapendekeza kuwa tafti za usoni zishughulikie suala la mchango wao wawakoloni katika fasihiku ndiye hazi kuendeleza uharibifu wa mazingira na pia waslushughulikie nadharia mbalimbali za kiekolojia na mchango wao katika kushughulikia suala la uhifadhi na udumishaji wa mazingira.

**Marejeleo**


Schulz, B. U. (2001:201-203) _Habari za Miti na Mitishamba Miongoni mwa Wamijikenda na Waswahili_‘ in _Swahili Forum_ viii 201-203

_Proceedings of the Fourth International Research Conference_ 237
ABSTRACT
The political independence in Africa was welcomed with joy and a heap of expectations, as Africans believed that the new African governments would bring sustainable development after years of subjugation, exploitation and oppression. At independence the new governments promised to bring prosperity and sustainable development. Conversely, this has not been the case. Today, many years after the attainment of the political independence, many African nations largely remains underdeveloped with poverty, diseases, poor communication network, illiteracy, tribal animosity, economic challenges, injustices, and so on affecting every aspect of the people’s life. Using Kenya as an example, this study was undertaken to investigate the cause of this. The involved eight counties (Nairobi, Mombasa, Meru, Uasin Gishu, Kakamega, Kirinyaga, Homabay & Garissa) purposely selected for their centrality to cover the former 8 regions or provinces in Kenya. The targeted population was about 10,103,778 (2009 population census). The sample size was 384 respondents as per Research Advisors (2006). Post-independent Kenya and Africa continue to lag behind in development as well experience perennial problems due to lack of responsible leadership. Although Kenya is endowed with numerous resources, it suffers from the lack of responsible political leaders. Leaders are available in abundance but very few are concerned with the welfare of the people. The majority are keen to retain power and acquire wealth at the expense of the suffering of the people they lead. This has created a very horrendous situation in Kenya as well as in other African nations as people struggle for the poorly managed resources. No sustainable development can be attained in a situation where leaders have failed to be responsible. To attain sustainable development as well address the many challenges facing Kenya and the entire Africa, we must start to think about our leadership. Thus government policies, curricula of learning institutions, constitutions etc must emphasize on the need for developing responsible leaders in Africa. Responsible leadership and sustainable development are closely interwoven.

Keywords: Africa, Kenya, Sustainable Development, Responsible Leadership

INTRODUCTION
I remember a song we used to sing as children in the 1980s and every evening at least when there was moonlight many of us would assemble in my grandmother’s compound and repeatedly sing it. It went like this:

You white man who told you that Kenya is yours? We chased you away.
Stay in your country and if you dare to come back I will force you to dig trenches,
Like the ones you forced our people to dig with children on their backs.
We are free, we are free! No more suffering, we are free!
We are going forward! We are going forward! Let’s eat the fruits of independence.

This song was sung about 20 years after the attainment of political independence in Kenya, which was gotten in 1963. It gives us a picture of the high expectation of an African child after independence. The children like any other African are acknowledging that with the expulsion of the colonial government and its subsequent replacement with a new government of the Africa people, there will be no more suffering. We are moving forward as we enjoy the fruits of independence. At independence, African leaders had promised to tirelessly develop Africa. For example, in Kenya Mzee Jomo Kenyatta’s government pledged to fight ignorance, poverty and disease, the great enemies of humanity (Githiga, 2001). Today, many

1 Mzee Jomo Kenyatta was the first President of the Republic of Kenya
years after the attainment of the political independence, African nations, Kenya included continue to be ranked behind others in terms of development. What is the problem? Why has the continent largely remained underdeveloped? Why has the continent continued to experience problems such as poverty, tribal conflicts, economic challenges and others while we are ruling ourselves? Why has Africa not attained sustainable development? These questions are disturbing every African. Using Kenya as an example, this paper aims at answering these questions. It mainly focuses on underscoring the relationship between leadership and sustainable development in the post-independent Africa.

**METHODOLOGY**

The study employed descriptive survey design to investigate the relationship between leadership and sustainable development in Kenya. This design was preferable because, as noted by Kothari and Garg (2004), it involves describing the state of affairs at it exists presently without much manipulation of the variables. The study involved eight counties namely Nairobi, Mombasa, Meru, Uasin Gishu, Kakamega, Kirinyaga, Homabay and Garissa purposely selected for their centrality to cover the eight regions in Kenya, that is, Nairobi, Coast, Eastern, Rift Valley, Western, Central, Nyanza and North Eastern. The targeted population was about 10,103,778 according to the 2009 population census. The Research Advisors (2006), recommend that for a population of about 10,000,000, a sample of 384 is ideal, with a 5.0 % margin of error. In each county, 48 respondents were randomly selected to fill in the questionnaires or, where possible, be orally interviewed. The total respondents were thus 384. In each county a research assistant, mainly my Masters or undergraduate school based students from the region, assisted in gathering information. Data from the field was qualitatively analyzed noting the number of times that views were expressed and the number of respondents who expressed a similar view. We then calculated the percentages of responses that we used to interpret the data and draw conclusions. The study also extensively employed secondary data.

**The Post-independent African Situation: Illustrations from Kenya**

The post-independent Africa was anticipated to give Africans joy, hope, freedom and relaxation after decades of perpetual subjugation, exploitation and oppression by the colonial governments. Although the Europeans believed that they were bringing civilization to Africa, they denied Africans their own civilization (Kagema, 2014). Mugambi (1989) elucidates that the colonial administration, beyond ‘civilizing’ their subjects, was interested in entrenching colonial political power abroad and hence, facilitating exploitation of the resources in the colonies for the benefit of colonial powers abroad. Colonialism was the worst human exploitation that has ever happened in history. The 1884/85 Berlin Conference commonly referred to as ‘Scramble for Africa’ (Ogutu & Kenchanchui, 1991) was a dark moment for this continent.

The colonial history of Africa begins with this Conference when Africa was partitioned by several European powers as their spheres of influence. This was the period when Europe was scrambling for control of Africa for its own interest (Nthamburi, 1991). It prepared the way for new comers to the African scene by requiring that claims to colonies or protectorates on any part of the African coastline should be formally notified to the other powers taking part in the conference, and by insisting that such claims must be backed by the establishment of an effective degree in the area concerned (Oliver & Atmore, 1967). At this Conference, boundaries of African countries were arbitrary drawn by European powers without any consideration of ethnic territories and interests (Mugambi, 1995). Sadly, no African was consulted. Soon afterwards, there was an influx of Europeans in Africa with an agenda of spreading Christianity, civilizing Africans, exploring the world and so on. Their main interest, however, whether missionaries, agriculturalists or colonial administrators was ‘trade’, and their common aim was to reap as much as possible from the African soil. In reference to this scenario, John Baur uses the famous Kikuyu saying, “Gutiri Muthungu na Mubea” meaning that there was no marked difference between a colonial administrator and a missionary” (Baur, 1994).
Colonialism was an evil Africans cannot forget. From the very beginning Africans were made to believe that they were not fully human, sometimes being classified with dogs. For instance, Nthamburi (1991) observes that in Meru town where he grew up there was a restaurant with inscription ‘Africans and dogs are not welcome’. The white people were treated as more unique and superior than the black people. There were thus “white only” hotels, churches, schools and other social amenities. There was forced labour and the best arable land was alienated for use by the white settlers (Nthamburi, 1991). On top of this, the white people, especially missionaries and anthropologists, were very negative to the African cultural and religious heritage. They regarded the African people, their cultures and religions as primitive, heathen and pagan (Mugambi, 1989). The African way of life was termed as evil and unacceptable, while Africa was regarded as a ‘Dark continent’. According to Kibicho (1990), the term ‘darkness’ in the minds of the westerners implied extreme backwardness and primitivity in all realms of life, including social, economic, political, cultural and religious. Africans were in ‘darkness’ and the only way to see the ‘light’ was to accept the European way of life as an outward indication of salvation and civilization. In view of this Mugambi (1989) explicates that the assumption of the Europeans was that Christianity and Western civilization were inseparable and synonymous and African converts had to abandon their cultural and religious backgrounds and adopt Western cultures as an outward indication of conversion to Christianity.

It is therefore clear that the colonial governments with the support of the Church reduced their subjects to mere objects in the hands of the colonizers. Sadly, they did this in the name of progress in their endeavour to create a favourable climate for development and civilization (Davidson, 1974). In that kind of environment, the rich African cultural heritage was eroded in confrontation with the dominant foreign culture. The vital natural resources were taken away to Europe to make life even more comfortable to the Europeans while Africans languished in poverty (Nthamburi, 1991).

In due time, Africans found themselves struggling to liberate their continent from this domination and conquest. During the period of resistance to colonial rule, Christians and non-Christians found themselves in the struggle for liberation (Nthamburi, 1991). They fought to liberate themselves from what dehumanized the community, including poverty, disease, ethnic rivalries, corruption, illiteracy, unemployment, etc. There was a lot of hope and expectation that after independence African nations would be inexorably progressive socially, politically, economically, religiously etc. In Kenya, for example, Mzee Jomo Kenyatta, founding father and first President, made a solemn pledge that his new government would tackle the three big challenges of poverty, ignorance and disease. This was a bold statement of confidence in his government’s ability to drive the country towards a more prosperous future and it was a direct jab in the eye of British who used all three as tools of colonial domination (Greste, 2014). Githiga (2001) denotes that Kenyans saw Kenyatta not only as their political leader, but also their saviour. They even sang political songs with Christian tunes where they used Kenyatta’s name instead of Christ. One such song is cited by Anderson (1977) where they sang that “We see the love of Kenyatta. He gave his life to save us.” Many believed that with him as their leader their anguish would be the thing of the past. It is this hope and expectation that made Africans of all walks of life join hands to fight for independence. But was their dream realized?

According to Nthamburi (1991), Africans had hoped that with the end of colonialism their ills would be a thing of the past. But alas, they discovered that human nature is such that it loves to oppress and exploit. Where independence was gained, people discovered that leaders of the liberation movements were absorbed into leadership roles by virtue of their education and influence. Consequently, many became part of the new elite and supported the status quo. Unfortunately, African leaders who took over leadership after independence started to behave like their colonial masters. They were ‘Wabereru’ (colonial masters) in black skin’. They therefore perpetrated all forms of evil against their fellow Africans: Injustice, corruption, nepotism, tribalism, land grabbing, silencing of political opponents through detention and death, etc. (Kagema, 2004). The first Vice President in the post-independent Kenya, Oginga Odinga unearths the situation in Kenya soon after independence. In his resignation letter
of 1966 quoted by Bienen (1974), he says that ‘Future generations will question my sincerity, when they would learn that I allowed myself to hold a secure post in the midst of poverty and misery in our country’. Although Kenyatta’s government and the succeeding governments had pledged to combat poverty, ignorance and disease, the three enemies of development continued to wreck the country immensely. Kagema (2012) confirms this observation by his assertion that, Kenya and the rest of Africa face numerous crises today. Authoritarianism, ethnic clashes, environmental degradation, poverty, hunger, corruption, diseases, internally displaced persons, nepotism, tribalism, unemployment have created a very desperate situation in Kenya.

While I agree with Greste (2014) that major strides have been made in the fight against these vices, especially after President Moi’s regime, it is a fact the vices have continued to affect every sector of the Kenyan society. We asked respondents in this study to identify the major setbacks to development in Kenya today. Interestingly, all the above issues were raised, with poverty leading with a 293 (76.3%) responses, followed by corruption 266 (69.3%); then tribalism/nepotism 261 (68%); unemployment 244 (63.5%); ethnic clashes 235 (61.2%) and so on. Archbishop Desmond Tutu explains the poignant situation in the contemporary Africa, The picture is bleak and the prospect one of seemingly unmitigated gloom. It is as if the entire continent was groaning under the curse of Ham and was indeed in all aspects of the Dark Continent of antiquity. Africans may well ask: “Are we God’s step children? Why has disaster picked on us so conspicuously?” We appear to be tragically unique in this respect (Tutu, 2004).

This has created endless conflicts as people struggle for resources and power. For instance, Kunhiyop (2008) affirms that in Africa in recent years, there have been many conflicts in many nations. This is confirmed by Thomson (2003) who says that “The continent of Africa is filled with ethnic conflict, wars over resources and failed states. From south to north, west to east, fighting burns or simmers in Africa.” Adeyemo (1990) attributes the many current ethnic conflicts in Africa to unequal distribution of national resources (80% of the national cake/wealth is enjoyed and controlled by only 5% of the population); land tenure and ownership (land is owned by the rich/elite minority); socio-economic and political struggle (bribery and corruption is on the increase). Power controlled by a small elite leading to poverty and class struggles amongst the majority the population. Once in leadership it becomes a right with little regard to the responsibilities of office. Two distinct classes are emerging, the rich powerful minority and the poor powerless majority. Conflicts in post independent Africa will never cease if this situation is not addressed.

In Kenya for example, although there has been many ethnic conflicts since independence, it was the 2007/08 Post-election violence (PEV) that proved rather challenging to the Kenyan people. The violence was so grave that about 1,133 Kenyans lost their lives, at least 350,000 were internally displaced, more 2000 became refugees, there as unknown number of sexual violence victims, 117,216 private properties were destroyed and 491 government-owned property (offices, vehicles, health centers, schools) were annihilated (Center for Strategic and International Studies, 2011). The 2007/08 ethnic tension was a major setback to the Kenya Vision 2030 which had just been launched after many years of economic meltdown, social injustices and political instability (Wasonga, 2016). The aim of Vision 2030 was ‘To transform Kenya into a newly industrializing, middle-income country providing a high quality life to all its citizens by the year 2030’ (Kenya Vision 2030, 2007), a dream that was fatally shattered by the 2007/08 PEV.

Due to the grave effect of the 2007/08 PEV, We wanted to know from the field research whether Kenyans know its cause. Asked whether they had heard of it all the respondents (100%) affirmed that they were aware of the 2007/08 PEV. They were then asked to say whether it had affected them in any way. 224 (58.3 %) said it had affected them directly where they had either lost a relative, displaced or their property destroyed; 157 (40.9%) said it had affected them indirectly and 3 (0.78%) said that it had not affected them in any way. This shows that the 2007/08 PEV affected many Kenyans. Respondents were then
asked to say what they termed as the main cause of this violence. 221 (57.6%) respondents cited the disputed Presidential election in which the Chair of the Electoral Commission of Kenya, Samuel Kivuitu could not tell who between Mwai Kibaki of the Party of National Unity (PNU) and Raila Odinga of the Orange Democratic Party (ODM) had won as the main cause. 159 (41.4%) cited unequal distribution of the national resources as the cause, while 4(1.04%) said that it was as a result of poor leadership where President Kibaki failed to take control. Therefore majority of Kenyans think that the 2007/08 crisis was as a result of the weak electoral system.

This is interesting because while the said violence is highly attributed to the disputed Presidential election results, the truth of the matter is that it was a manifestation of a failed state than just election results, as 42.44% of the respondents affirmed. Thus the factors raised by Tokunboh Adeyemo above as the main causes of ethnic conflicts in Africa cannot be disassociated from the Kenyan 2007/08 PEV. This can be confirmed by the report of the Commission of Inquiry on Post-Election Violence (2008) that investigated Kenya’s 2007/2008 Post-election violence. According to this Commission, Kenya’s history of ethnic violence, the 2007/08 PEV included is a combination of long-standing conflict drivers. These include,

i) The perception of historic marginalization by certain ethnic groups as a consequence of alleged inequalities associated with the allocation of resources – in particular land.

ii) A system of governance based on highly centralized and personalized executive, where the President and his ruling circle had historically maintained enormous control over institutions that would normally serve as checks and balances, e.g. judiciary, legislature as well as the police.

iii) The long-standing problem of high youth unemployment.

iv) An entrenched culture of impunity, where despite Kenya’s history of electoral and other sectarian violence, the country had failed to bring justice to any of those responsible for prior abuses.

To conclude this section, one cannot fail to see the problem of leadership and governance in Africa. The afflictions in the post-independent Africa are as a result of poor leadership than lack of resources. Tutu (2004) sees the correlation between leadership and the challenges facing Africa today.

He says that ‘Africa faces a mammoth crisis in leadership’. He goes on to explain that as a result of poor political leadership, we are all accustomed to military dictatorships, coups, corruption, refugees, civil wars, diseases, injustice, and so on.

**Relationship between Leadership and Sustainable Development in the Post-independent Africa with reference to Kenya**

The term ‘leadership’ may mean different things to different people. Kagema (2010) defines leadership as the “ability to influence others”. Elliston (1988) shares the same view with Kagema and defines “leadership as the process of influence”. In most cases, this influence is systematically carried out by one person called the leader of the group. Sustainable development, on the other hand, is that development that meets the needs of the present without compromising the ability of future generations to meet their own need (World Commission on Environment and Development, 1987). Its tenets are environment, society and economy that are intertwined and not separated (Darkey-Baah, 2014). Okulu (1984) defines development as ‘transformation of one thing into another’. To what extent is sustainable development linked to leadership in Africa? Respondents were asked to say whether the type of leaders a nation has affects development in any way. All of them (100%) affirmed that leadership affects the nation’s sustainable development and that the two are linked. This view is supported by Darkey-Baah (2014) who argues that there is a close correlation between effective leadership and sustainable development.

African nations continue to lag behind in development as compared to nations in other continents. There is an ongoing narrative in Kenya that at Independence Kenya was at par with Malaysia in terms of economic development, which was about 6.8% of the GDP for both. Today 54 years later, Kenya has gone down to 5.9%, while Malaysia has gone up to over 40%. The ideal question is ‘What went wrong in Kenya?’ Njino (2008) contends that we are in the third millennium yet Africa has little to show towards
self-reliance and sustainable development. She is still subject to continuous begging and dependence on 
foreign aid for the sustenance of her programmes. One doubts the independence of African nations if they 
still continue to rely on their colonial masters for survival. To what extent can a beggar be independent?

Fifty years after the achievement of constitutional independence, African nations seem to have returned to ‘square one’ whereby the former colonial masters have to bail out economies in ruins and political 
institutions that have collapsed (Cf. Mugambi 1995). This has not been without some cost on the part of 
Africa. Very similar to what happened prior to 1884/5 Berlin Conference, when European missionaires, 
mercenaries, businessmen and adventurers plunged into the continent for plunder and self-gratification, 
then called on their metropolitan governments to protect their loot, today Africa has become a ‘no man’s 
land’, a continent without borders, where anybody can come from any where and do whatever he/she 
wants. Mugambi (1995) elucidates that by portraying Africa as a continent unable to help itself, people 
from other continents (mainly Europeans and North Americans), drawn by their self-gratification have 
come here claiming to be ‘saviours’ without whom Africa would perish. They claim the right to enter 
every African country without restriction, even though there is no reciprocal arrangement for Africans to 
enter the countries from which they are based. By claiming to help Africa, they have plunged African 
nations into huge debts, which have to be paid the by common African people whom Adeyemo (1990) 
says that are gripped by poverty across the whole shapes of their lives. As noted by Ezehuiri (2016), the 
problem of foreign debt has been a major and persistent setback for the African development. This is 
mainly as a result of the fact that most African nations in debt are still underdeveloped and therefore 
depend on foreign loans to sustain their economy. Thus foreign powers continue to exercise influence and 
control over African nations by financial means (Chipenda, 1993). I agree with Mugambi (1995) that 
there is no society that can be cited where external initiative has produced sustainable development. 
Therefore, no sustainable development will be realized if African nations continue to rely on former 
colonial powers to sustain themselves. Independence was supposed to give Africans freedom to innovate 
and freedom to identify solutions for accumulated problems. But this has been repressed rather than 
encouraged (Chipenda, 1993). If we want sustainable development we must wake up and learn from 
Desmond Tutu’s assertion that ‘Freedom is cheaper than repression’ (Tutu, 1990).

According to Bishop Henry Okullu, the term development in its popular usage in Kenya as in other 
African nations means economic advancement, the increase the national product to bring national wealth 
that will be eventually spread among individual members of the community. It means living in better 
houses, better water supply, tarmac roads to facilitate easy transportation, better agricultural methods, 
more schools, colleges and universities, more dispensaries and hospitals, quicker means of 
communication and so on (Okullu, 1974). It means transformation of one thing into another (Okullu, 
1984). It is this transformation that lacks in many Africans nations, Kenya included as exemplified by 
impassable roads, food insecurity, lack of water supply, few health facilities, unaffordable education, 
insecurity, poor communication network, et cetera. It is true that as acknowledged by Ezehuiri (2016) and 
African Development Plan (2015), Africa has made major strides in economic growth, where undoubtly, 
some African nations such as Ivory Coast, Tanzania, Kenya, Senegal, Rwanda and Djibouti have the 
highest growing economies in the globe (Africa Business Forum, 2016), but the continent still remains 
largely underdeveloped (Global Forum Policy, 2014). Although Africa is endowed with immense natural 
and human resources as well as great cultural, ecological and economic diversity, most of its nations 
continue to suffer from military dictatorships, corruption, civil unrest, wars, underdevelopment and deep 
poverty (Global Forum Policy, 2014). As observed by M’lkunywa (1986) majority of African peoples 
whether in urban or rural areas live in abject poverty many years after political independence. It is 
because of this reason that most of the countries classified by the United Nations as least developed are in 
Africa (Global Forum Policy, 2014). The ideal question is ‘What is the problem?’ As Desmond Tutu asks 
‘Is Africa under the curse of Ham?’ (Tutu, 2004). What makes African nations continue to suffer many 
years after the attainment of political independence?
The Challenge of Leadership in Africa

We enquired from the respondents whether they know what has made Kenya and other African nations continue to lag behind in terms of development as well as why we have continually experienced other problems, yet Africa is a continent endowed with numerous resources. Interestingly, 381 (99.2%) respondents cited poor leadership as the main cause of Africa’s afflictions, while 3(0.8 %) were not quite sure. This shows that Kenyans just as other African peoples are aware that they suffer due to their leaders’ failure to be responsive to the needs of the people they lead. This is supported by Tutu (2004), who blames the current predicaments facing Africa to Africa’s political leadership. He argues that “Africa faces a mammoth crisis in leadership, especially in politics”. Similarly, Ngara (2004) is of the view that that the problems that we encounter in Africa: terrorism, corruption, ethnic and civil wars, economic meltdown, political instability, underdevelopment, poverty and others are all linked to failed leadership. Kwasi Dartey-Baah denotes that there is a close link between leadership and sustainable development. He says that leadership experienced in post-independence Africa has manifested several instances of incompetence, ineffectiveness and unresponsiveness to the needs of the present and even future generations. This has really hampered the realization of sustainable development in Africa, as sustainable development cannot be attained where leadership is weak (Dartey-Baah, 2014). Leadership is thus imperative in promoting sustainable development (Sharma, et. al, 2009).

According to M’Ikunywa (1986), small pockets of wealthy and powerful elites have replaced former colonial masters in Africa. These are the ones who control and determine the direction society will take, often to the detriment of the majority who are poor and powerless. They are the ones responsible for the desperate situation in which Africa is. This view is supported by Adeyemo (1990) by his elucidation that the coming of political independence in Africa brought a lot power. Ironically, power came and remains not in the hands of the masses but in those of small elite. The dream of our freedom fighters to unite the shattered fragments of a bitterly divided continent and create an earthly paradise remains utopian and in some areas has turned into a nightmare. Many African national leaders treat their national offices as an exclusive right rather than an open responsibility. No sustainable development can be attained where only a few selfish leaders control the national economy while majority of the citizens are languishing in poverty. For instance in many African nations, 80% of the national wealth is enjoyed and controlled by only 5% of the population (Adeyemo, 1990), mainly the leaders and their cronies. It is sad that some African countries earn a lot of money from the natural resources, yet they remain underdeveloped due to lack of good leadership. For example, Kunhiyop (2008) informs that despite Nigeria earning billions of dollars from oil production, there has been no tangible development.

Nthamburi (1991) denotes that there is a close correlation between poverty, exploitation and oppression in Africa. Kagema (2016), for example, indicates that the low social and economic status of the African people and the general underdevelopment of the continent as a whole is as a result of exploitation and oppression, first by the colonial governments and then by the African leaders who took over after independence. There is so much poverty in Africa that George Kinoti reports that “One out of three Africans does not get enough to eat” (Kinoti, 1994). What is however clear that Africa is poor and underdeveloped not because African peoples do not work hard but because of exploitation by their leaders. In view of this Nthamburi (1991) says that we cannot exonerate independent African states for their contribution to the suffering of their peoples. While the quality of leadership can be measured by the degree to which a leader is able to direct social reconstruction without destabilizing the society in which he or she leads Mugambi (1995), African leaders have continually destabilized their societies through corruption, selfishness, nepotism, tribalism, bribery and et cetera with little cognizance of the effect of this to the development of Africa and without minding of the future generations. This means that if we want to address the afflictions facing African nations including underdevelopment, poverty, corruption, ethnic conflicts, tribalism, illiteracy, diseases and others, then we need to think of leadership. Without good leadership, it will be difficult to realize sustainable development in Africa.
Responsible Leadership for Sustainable Development in Africa

The Oxford Advanced Learner’s Dictionary defines the term ‘Responsible’ as having a job or duty of doing something or taking care of something, so that you may be blamed if it goes wrong. In view of this, Gathaka (2005) defines leadership as being in a position of responsibility. Thus if one accepts to be a leader he/she should be ready to take the blame if anything goes wrong. This is true because I have observed that here in Kenya, whenever something goes wrong, it is the President and his government who are blamed. For instance, whenever there is drought, floods, high cost of living, insecurity, tribal wars/conflicts, strikes, etc, it usually the President who is blamed. When schools perform poorly in national examinations, the Principals are the ones blamed. When companies are running at losses the managers are blamed and similarly when Church members are running away from the Church, the bishop or pastor is the one who takes the blame. Responsible leadership therefore implies that the leader is in charge, in control and is willing to take the blame if anything goes wrong.

Stuckelberger and Mugambi (2005) remark that leaders are available in abundance, but responsible leaders are hard to find. They continue to observe that to be responsible, a leader must be responsive to the needs, concerns and interests of those whom he/she leads. Respondents in this study were asked to say whether in their view their leaders are responsive to their needs, concerns and interests. 351 (91.4%) said ‘No’, while 33 (8.6%) said ‘Yes’. When they were told to explain their answers, 329 (85.7%), argued that their leaders are busy enriching themselves, their families and friends while the people they lead are left suffering. This is a sad situation for Kenya and the rest of Africa. The continent has many leaders, but only a few of them (just about 8.6%) are responsible leaders. The leaders who mind of the welfare of their people are very few. The majority of the leaders are selfish, self-centred, greedy and only concerned with their bellies at the expense of the impoverished masses. No sustainable development can be attained when a nation has such leaders. In Kenya more than 80% of the national wealth is enjoyed and controlled by only 5% of the population, who are mainly political leaders and their cronies (Adeyemo, 1990).

One of the characteristics of responsible leadership is willingness of the leader to hand over power after his/her term expires. The coming of political independence in Africa brought a lot of power (Adeyemo, 1990). Power in Africa goes with a lot of prestige: wealth, a fleet of escort cars, a posse of bodyguards, unquestioned authority, many wives and concubines and so on. Because of the satisfaction associated with power, many African leaders do not want to let it go once they get it. Hendriks (2014) alludes to this fact by asserting that ‘Today, the relationship between leadership and power may be the biggest problem that we face in our continent’. He elucidates that African leaders do not want to give away power after they get it. For instance, apart from Nelson Mandela, no African President has ever given away power after only one term in office. The result of this has been endless mass uprisings, ethnic conflicts, election violence and military coups as people try to force them out. Such conflicts have recently been experienced in Rwanda, Democratic Republic of Congo, Kenya, Ivory Coast, Egypt, Libya, Zimbabwe, Somalia, Nigeria, Uganda, Sudan, Tunisia, Algeria, Morocco, Southern Sudan, Eritrea, Ethiopia and Cote d’voire among others (Shah, 2014; Kunhiyop, 2008). This has really hampered the development of Africa as no sustainable development can be attained in the midst of conflicts as affirmed by the United Nations Chronicle (2016), titled ‘No Peace no Sustainable Development’.

Responsible leadership entails good stewardship (Gitari, 2005). Respondents were asked to say the extent to which they think responsible leadership involves good stewardship. 243 (63.3%) said to a larger extent, 125 (32.6%) cited to an extent, 14 (3.6%), said to a low extent and 2 (0.5%) said no extent. Therefore, leadership and stewardship are closely connected as affirmed by 95.9% of the respondents. This implies that leaders are stewards. The Greek word for ‘steward’ is ‘oikonomos’, which is closely connected to the English word ‘economist’ (Stuckelberger, 2005). The word Oikos means a home, house or household (Kagema, 2016). Thus, the oikonomos is the housekeeper who keeps the house in order (Stuckelberger, 2005). Leadership is the realization that all that we posses, including the people we lead is entrusted to us.
by God for his service. Gitari (2005) possibly explains the expectations from a responsible leader as a steward by his assertion that,

A steward is a person who is appointed to manage a house or property of his employee. The household or property does not belong to him, it belongs to another person. His work is to manage. He can be a good or a bad steward. But in the final analysis he has to give account of his management.

In this regard, one does not fail to see the correlation between leadership and management. A responsible leader is a good manager. It is unfortunate that Africa, a continent with lots of resources continue to experience incessant underdevelopment and other problems. This is a manifestation of lack of good managers of our resources. Koontz et. al (1984) see a connection between good management and development and observe that,

... the importance of management is no where better dramatized than in the case of many undeveloped or developing countries ... provision of capital or development does not ensure development, the limiting factor in every case has been lack of quality and vigour in the part of the managers.

Stuckelbereger (2005) prefers to use the term ‘good manager’ when referring to a ‘responsible leader’. For the development of Africa, African leaders must start to realize that they are accountable before God. As noted by Gitau (2000), they have a responsibility towards African land, natural resources, ecology, human resources and everything else placed under their care by the Creator. The following biblical principles high lightened by David Kadalie are vital guidelines for any person called to be a leader in the post-independent Africa:

i) God owns and retains ownership of everything and everyone
ii) God has made steward on earth, to till and keep the land
iii) God will judge each of us in respect of our stewardship during our stay here on earth.
iv) God intends that our stewardship be that of a guardian, curator, manager or an executor
v) God warns us to understand our roles. We are stewards not owners.
vi) God, as the owner sets the standards and expectations for stewardship. It must be done according to his will before he gives rewards. It must be managed assertively for the future. It must be guarded (Kandalie, 2006).

In Luke 16:1-13, Jesus gives the parable of the shrewd manager or the unjust steward, who instead of caring for his master’s possessions was wasting them (v.1). In our case, this manager exemplifies the character of an irresponsible leader. A key challenge for responsible leadership is the management of resources, including energy, water, air, soil (natural resources), property of goods and services (material resources), financial resources, human resources and structural resources (Stuckelberger, 2005). Africa is richly endowed with all these resources. In the midst of underdevelopment, environmental degradation, poverty, incurable diseases, endless ethnic clashes, corruption, illiteracy and other vices, God/master is asking us ‘What is this I hear about you? Give an account of your management because you cannot be manager any more’ (Lk. 16: 2). African leaders need to be responsible with what has been entrusted to them. This is what is will ensure a sustainable development in the post-independent Africa.

CONCLUSION
Leadership is the biggest challenge that the post-independent Africa faces. We are under-developed or poor not because of deficiency in resources but due to poor management of these resources. Although Africa has many leaders, responsible leaders are not there. While leaders should be responsive to the needs of their followers (Responsible leadership), African leaders, especially political leaders have ignored their people concentrating on amassing wealth for themselves, their relatives and cronies. This has put the entire continent in a very desperate situation of underdevelopment. Africa is endowed with a variety of resources yet the African children continue to experience extreme poverty, poor transport and
communication network, poor health facilities, high living standards, perpetual ethnic conflicts, illiteracy and so on. Of recent there have been numerous talks of the need for the African people, governments and donors to focus their attention on developing Africa. At least most of the conference adverts, governments’ policies, learning institutions curricula, Universities statutes and organizations’ guidelines that I have seen have sustainable development as their main goal. What we have however not realized is that sustainable development cannot be attained where there is no responsible leadership. For the development of Africa, the African people and policy makers must start to think on how we can have responsible leaders. In this regard, no African should take voting lightly as the kind of leaders we elect largely determines the route our continent takes in terms of development.

RECOMMENDATIONS

It is therefore imperative that the following recommendations are made if at all we have to attain sustainable development in Africa today:

a) Incorporate ‘responsible leadership’ in the curricula for the learning institutions in Africa, where it must me made a core part of the curricula. It should be made compulsory to the students in all disciplines as these are usually the ones who become leaders in their nations after the completion of their studies.

b) The importance of responsible leadership for sustainable development in Africa should be emphasized in all forums, e.g. conferences, public gatherings, religious gatherings, workshops, etc.

c) Government policies in the African nations should be geared towards developing citizens for responsible leadership as this is what we are lacking.

d) Constitutions of the African nations should emphasize on the need for responsible leadership.

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ABSTRACT
Over the years, HIV and AIDS pandemic has brought enormous burden upon the lives of many people throughout the world. Since the first cases of AIDS were identified in 1981, millions of people have lost their lives. An estimated 70 million people are living with HIV and AIDS by now and more than 35 million people have died. As the burden of HIV and AIDS increases in different communities of the world, new organizations are being formed to help curb its impact. Kenya has about 1.6 million people living with HIV and AIDS and in 1999 it was declared a national disaster. It is in response to this that many development partners including the religious organizations, the government and NGOs came up with programmes to fight the scourge, yet there seems to be little success as new infections continue to be experienced. Christianity being the religion followed by the majority of the Kenyans and the Church being the most trusted institution has not been left behind as efforts to curb this pandemic is are made. This study assessed the effectiveness of Church based initiated programmes in curbing HIV/AIDS in Kenya. Selected programmes in Meru South Sub-County were used for the purpose of this study. These were Redeemed Gospel Church, Presbyterian Church of East Africa, Salvation Army Church and Baptist Church. The target population was 1040 subjects comprising 1000 Church members and 40 beneficiaries. The Church ministers/pastors were our key informants. Data was collected using questionnaires, interview schedule and focus group discussions. Systematic random sampling procedure was used to select 100 Church members. Beneficiaries of the HIV and AIDS programmes initiated by the Church were obtained using snowball sampling method. Selected programmes provided services such as HIV prevention education, orphan care, and support of people living with and personally affected by HIV and AIDS. Prevention activities that involved campaigns, and caring for the affected and infected. The programmes were successful in supporting those orphaned by HIV/AIDS, reducing stigma, organizing training, seminars and workshops, voluntary counselling and testing, among others. They were found to be effective in curbing HIV and AIDS, though they face the challenge of lack of adequate funding. There was also lack of trained personnel which hamper the effective implementation of these programmes. If the government, Church, development partners and other well-wishers support these religious initiated programmes the war against HIV/AIDS pandemic can be easily won as they are effective.

Keywords: Kenya, Meru South, Religious Initiated Programmes, Church

INTRODUCTION
The abbreviation HIV stands for Human Immunodeficiency Virus. HIV is a virus that attacks and suppresses the immune system of the body thus compromising the body’s defence against infections. AIDS stands for Acquired Immuno Deficiency Syndrome. AIDS is a condition that weakens a person’s immune system, making him/her vulnerable to opportunistic infections. AIDS is therefore caused by HIV, through the progressive destruction of the body’s defence cells- white blood cells. Due to the body’s inability to defend itself against the infections, the person’s health deteriorates (Lodiaga, Kimani & Wanjama, 2007). HIV transmission occurs through sexual contact with a person infected with HIV; mother to child transmission during birth or while breast-feeding; blood transfusion from an infected person; and also when HIV contaminated instruments for example needles, razor blades and knives are used for cutting or piercing (Barnett & Whiteside, 2003).

Over the years, HIV and AIDS pandemic has brought an enormous burden upon the lives of many people throughout the world. Since the first cases of HIV and AIDS were identified in 1981, millions of people...
have lost their lives (Goliber, 2009). An estimated 70 million people are living with HIV and AIDS and more than 35 million have lost their lives (UNAIDS 2017). Though the whole world is affected by HIV and AIDS, Africa and especially the sub-Saharan region has been reported to be the worst affected. This is possibly due to high poverty levels, lack of access to health facilities, and some cultural practices like wife inheritance, polygamy and female genital mutilation. Kenya, where many cases of infections have been recorded, lies fully in this region (Goliber, 2009). It is estimated that more than 1.6 million people are living with HIV and AIDS in Kenya by (NASCOP, 2016).

In Meru South Sub-County, the spread of HIV and AIDS and the stigma associated with it are high. According to the Kenya Health and Demographic Survey (2009) report, Meru South District had an HIV and AIDS prevalence of 7.3% which was among the highest in the then Eastern Province (Republic of Kenya, 2009). The high prevalence was attributed to high poverty levels and inadequate income generating ventures that led many people to engage in commercial sex to earn a living. In response to the rise in HIV and AIDS cases, some churches in the Sub County initiated programmes with the aim of curbing the spread of HIV and AIDS pandemic. In spite of this effort by the Church, HIV/AIDS continue to be a real challenge to the inhabitants of Meru South Sub-county just as in other parts of Kenya. This study that was conducted in selected Churches which are currently running the HIV/AIDS mitigation programmes aimed at investigating the effectiveness of these religious initiated programmes. The selected churches were the Redeemed Gospel Church, Presbyterian Church of East Africa, Salvation Army and Baptist Church. The study was important in that the Church is viewed as one of the most trusted institution in the society (Nkonge, 2012), and would be vital to underscore its contribution in fighting the perilous HIV/AIDS epidemic that has threatened the lives of many people. It is our strong belief that The Church of Christ has in its tradition theological and practical answers for people living with HIV and AIDS (Neville, 2006).

**Objectives**

The study was guided by the following objectives:

i) To investigate the types of programmes being used by selected Churches to curb HIV and AIDS pandemic in Meru South Sub-county.

ii) To evaluate the effectiveness of religious-initiated programmes in curbing HIV and AIDS pandemic in Meru South Sub-county.

**METHODOLOGY**

To understand the contribution of the Churches in Meru South Sub-County in curbing the spread of HIV/AIDS pandemic, we carried a study in the following selected Churches that have the HIV/AIDS mitigation programmes. These were Redeemed Gospel Church-Chuka, Baptist Church-Chuka, PCEA-Ndagani and Salvation Army Church-Chuka. According to the Kenya Health and Demographic Survey (2009) report, Meru South Sub County had a HIV and AIDS prevalence of 7.3% which was among the highest in Eastern region (Republic of Kenya, 2009). The study employed descriptive survey research design. The descriptive survey research design enabled the researchers to gather in-depth information concerning Church-initiated programmes and HIV and AIDS mitigation in Meru South Sub County.

The target population for this study was 1040 subjects comprising of all the 1000 church members and 40 beneficiaries of these programmes. The population of Redeemed Gospel Church was 290 members; Baptist Church 210 members; PCEA-Ndagani 230 members and Salvation Army Church 270 members totaling to 1000 members.

The Churches for study were selected using systematic random sampling where every 20th Church was picked from a total of 80 registered Churches in the division. This way four (4) Churches were picked. The researchers used systematic random sampling to obtain the sample size from the Church members. The Church members were got from the Church registers provided by the Church ministers. Every 10th
person in the target population was selected and included in the sample. The Redeemed Gospel Church had a population of 290 and therefore 29 members were sampled. Baptist Church had a population of 210 from which 21 members were sampled. PCEA-Ndagani had a population of 230 from which 23 members were sampled. Salvation Army Church had a population of 270 from which 27 members were sampled. The sample size for the Churches was therefore 100 members. The Church ministers of these Churches who were part of the population were key informants for this study.

Snowball sampling technique was used to get the beneficiaries of the programmes. The number of beneficiaries of the HIV and AIDS programmes from each church was as follows: Redeemed Gospel Church- 14 beneficiaries; Baptist Church- 6 beneficiaries; PCEA-Ndagani- 8 beneficiaries; Salvation Army Church- 12 beneficiaries. The total number of beneficiaries was thus 40. Each Church minister/pastor gave us one beneficiary of the HIV and AIDS programmes in his church who helped us in identifying other beneficiaries. The beneficiaries identified from each congregation formed a focus group to discuss questions provided by the researchers. The sample size for the four focus groups was 40. The sample size for this study therefore was 140 comprising of 100 church members and 40 beneficiaries.

The data was collected using questionnaires for church members, interview schedule for church ministers/pastors and focus group discussion for the programme beneficiaries. The study used triangulation method of data collection (John & James, 2006). This method involves the use of two or more research instruments to collect the necessary data (Ogula, 1998).

After collection of data it was cleaned by checking for logical consistency. Any unnecessary data was removed. Descriptive statistics including frequency counts and percentages were used to analyze quantitative data. Quantitative data obtained was analysed using Statistical Package for Social Sciences Version 21 for windows. Data elicited by interview and focus group discussion questions were analyzed qualitatively by arranging the responses thematically after which the main themes in the responses were identified and used to determine their adequacy, usefulness and consistency. This enabled the researchers to identify data segments that were critical in addressing the research questions. Data was analyzed according to the research objectives and presented using tables. We then calculated the percentages of responses which were used to make statements about the results, identify findings and make conclusions.

RESEARCH FINDINGS
Types of programmes being used by Churches to mitigate HIV and AIDS
We sought to find out the type of Church-initiated programmes being used to mitigate HIV and AIDS in Meru Sub-county. The members were asked to name the programmes that deal with HIV and AIDS mitigation in their Churches and cite the main activities of the programmes. Specifically, this research examined in detail the operational activities of the Redeemed Gospel Church-Chuka, Salvation Army Church-Chuka, PCEA-Ndagani and Chuka Baptist Church in the fight against the HIV/AIDS scourge.

The data established is captured on Table 1 below. Church response to HIV and AIDS pandemic refers to the various initiatives by the Church to address the impact caused by HIV and AIDS. This may take various forms: HIV and AIDS awareness raising and sensitisation in the Church and the community, Church leaders mobilisation of their congregations by motivating and inspiring them to act, formation of support and care teams to offer home-based care, advocacy in support of HIV and AIDS programmes, training some members of the congregation in HIV and AIDS issues, for instance counselling skills and involvement of Church social groups like, women groups, workers clubs, married people’s clubs to widen the support base.

A total of 96 Church members and 44 key informants (4 Church ministers and 40 beneficiaries) provided responses to this objective. Triangulation methods were used to collect information from the respondents and involved a questionnaire that was administered to Church members, interview for Church ministers
and focus group discussion for beneficiaries. Participants were asked mainly about the types of HIV and AIDS intervention programmes used. Key informants were consulted to verify information obtained from the Church members. We also visited the Participating Churches to further evaluate their HIV and AIDS programmes.

Table 1: Church Members’ Responses on HIV and AIDS Mitigation Programmes

<table>
<thead>
<tr>
<th>Programme</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orphan care</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Support of people living with and personally affected by HIV and AIDS</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Prevention activities that involve campaigns</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Pastoral care and support</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Outreach programmes</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Voluntary counselling and testing</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Palliative care</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Seminars and workshops</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>96</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

From the data shown on Table 1, it is evident that Churches are taking part in the fight against HIV and AIDS using different approaches. Among the programme activities ran by the Churches included orphan care, support of people living with and personally affected by HIV and AIDS, prevention activities through campaigns, pastoral care and support, outreach programmes, voluntary counselling and testing, palliative care and seminars and workshops.

In order to further support the Church to respond to the HIV and AIDS pandemic, there was need to establish the existing prevention, care and advocacy activities that the Church was undertaking and identify the resource capacities that the Church requires to implement these interventions with a recognised impact. This study has presented an analysis of the Church responses to HIV and AIDS and provided conclusions and recommendations for future action as the Church continues its fight against the HIV and AIDS pandemic.

In this study, qualitative data was analysed to strengthen the quantitative findings. An interview and a focus group discussion were conducted among the Church ministers and the beneficiaries respectively.

**Excerpt 1 (Interview)**

**Researchers:** What is the name of the programme that deals with HIV and AIDS mitigation in your Church? What are the main activities of this programme?

**Church Minister 1:** We have a programme called Redeemed Gospel Church HIV and AIDS programme. The main activities of the programme include: care and support of affected and infected. Specifically, we offer social support to orphans and the vulnerable children like paying their school fees and encouraging those infected to take ARVs. The programme also deals with HIV testing and counselling, behaviour change communication through awareness campaigns, posters and brochures. At times we train opinion leaders and peer counsellors through workshops on issues pertaining to HIV and AIDS and gender. The programme has also incorporated a youth programme called Visionary Art that goes to schools and colleges to meet peers and offer advocacy.

**Church Minister 2:** Our Church runs HIV and AIDS prevention programme known as Baptist Community Initiative. The activities carried out under the programme include: VCT that involves testing, counselling and referral; There is a youth programme called True Love Waits (TLW) that teaches the youth on abstinence. This program has an elaborate support group that meets once every month to share
experiences and support the OVCs. The Church conducts seminars and workshops where mothers are educated on PMCT (Prevention of Mother-to-Child Transmission) and the youth given cards, banners and T-shirts written “True Love Waits” and “True Love Stays” to distribute to the youth and married people respectively as a way of reaching the public.

**Church Minister 3:** Our Church runs a HIV and AIDS prevention programme known as PCEA-Ndagani HIV and AIDS programme. This programme deals with awareness and education of members and the community on HIV and AIDS. This is done through information education and communication where the youth mainly distribute materials with HIV and AIDS information to the community. Through this initiative, we have been able to offer home-based care for victims and home visitations to promote HIV and AIDS awareness. The Church also organizes workshops and seminars that provide a forum to train peer counsellors, distribution of condoms and advocacy. We have initiated motorcycle income generating projects for the youth where the youth are helped to buy motorcycles. This has helped to keep our youth busy and prevents them from engaging in sexual activities that may predispose them to HIV and AIDS.

**Church Minister 4:** Our HIV and AIDS mitigation programme is known as Salvation Army Community Caring Ministry (CCM). This program has its roots in the Church and goes beyond to the community. Under this programme, the Church conducts several activities. Indeed we care for orphans and widows, educate the youth on dangers of premarital sex and encourage people to disclose their HIV status. We have a prevention strategy called Prevention With Positives (PWP) where we appeal to infected persons not to infect others. We also visit the sick in hospitals and offer them some basic needs such as food and clothing. Through workshops and seminars we implore on discordant couples to use condoms to avoid spread. Lastly, through our Community Caring Ministry we offer counselling services.

**Excerpt 2 (Focus Group Discussion)**

**Researchers:** What HIV and AIDS Church programmes are available in your locality? Which among them do you participate in?

**Focus Group 1:** The programmes we are aware of are Baptist Community Initiative, Redeemed Gospel Church HIV and AIDS programme. We participate in Redeemed Gospel Church HIV/AIDS programme.

**Focus Group 2:** The programmes we are aware of are Redeemed Gospel Church HIV and AIDS programme and Baptist Community Initiative. We are members of the Baptist Community Initiative programme.

**Focus Group 3:** The Church HIV and AIDS programmes available in this region include Redeemed Gospel Church HIV and AIDS programme, Baptist Community Initiative and PCEA Ndagani HIV and AIDS programme. We are members of the PCEA-Ndagani HIV and AIDS programme.

**Focus Group 4:** We are aware of the the Salvation Army Community Caring Ministry and the Redeemed Gospel Church HIV and AIDS programme. We participate in the Salvation Army Community Caring Ministry. All the beneficiaries indicated that they were not receiving support from elsewhere apart from the Church-initiated programmes.

From the information given by the Church members, Church ministers and the beneficiaries, it is evident that Churches in Meru South sub-county which included the Redeemed Gospel Church-Chuka, Chuka Baptist Church, Salvation Army-Chuka and PCEA-Ndagani are running HIV and AIDS prevention programmes. These Churches were found to be involved in a variety of HIV and AIDS activities, ranging from counselling, orphan care, pastoral care and support, voluntary counselling and testing, seminars and workshops, distribution of information and resource materials in the region, home visits and behaviour
change communication through awareness campaigns, posters and brochures to orphan support and home-based care. The purpose of this study was to examine what Churches Meru South Sub-county were doing to deal with the impact of HIV and AIDS in their communities. It was therefore noted that there is a considerable effort to respond to the multifaceted aspect of the pandemic through Church initiatives. It can be adduced that the church is carrying out her mission in response to the HIV/AIDS pandemic in Meru South Sub-county.

**Effectiveness of Church Initiated Programmes in HIV and AIDS Mitigation**

This research assessed Church-initiated programmes and HIV/AIDS mitigation in Meru South Sub-county. The evaluation was meant assess the effectiveness of Church HIV and AIDS mitigation programmes in achieving their goals. To measure views and attitudes of the respondents to the programmes, a five point Likert scale was used in the questionnaires. Respondents were to say whether they “Strongly disagreed, Disagreed, Agreed, Strongly agreed or were neutral on the activities that the Churches were undertaking to fight HIV/AIDS through their programmes. Table 2 shows the percentage of responses for each question item that corresponded to the points on the rating scale used by respondents to provide their answers.

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Your Church has made sufficient support for people orphaned by HIV and AIDS.</td>
<td>40</td>
<td>46</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>96</td>
</tr>
<tr>
<td>ii. Your Church has made great contribution to reduce stigma on people living with HIV/AIDS.</td>
<td>43</td>
<td>45</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>96</td>
</tr>
<tr>
<td>iii. Your Church organizes trainings that help reduce the impact of HIV and AIDS in society.</td>
<td>37</td>
<td>54</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>96</td>
</tr>
<tr>
<td>iv. Your Church has elaborate care centres that benefit people living with HIV and AIDS.</td>
<td>23</td>
<td>29</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>96</td>
</tr>
<tr>
<td>v. Your Church has an effective voluntary counseling and testing programmes.</td>
<td>42</td>
<td>13</td>
<td>2</td>
<td>19</td>
<td>20</td>
<td>96</td>
</tr>
<tr>
<td>vi. Your Church has developed support programmes for people living with and affected by HIV and AIDS.</td>
<td>28</td>
<td>52</td>
<td>13</td>
<td>1</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td>vii. Your Church has effectively involved its members in prevention campaigns.</td>
<td>28</td>
<td>49</td>
<td>15</td>
<td>3</td>
<td>1</td>
<td>96</td>
</tr>
<tr>
<td>viii. Your Church organizes seminars and Workshops on HIV and AIDS.</td>
<td>50</td>
<td>36</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>96</td>
</tr>
</tbody>
</table>

The results shown indicate that about 40 (41.7%) of the respondents strongly agreed that their respective Churches had made sufficient support for people orphaned by HIV and AIDS while 46 (47.9%) agreed. Those that remained neutral accounted for 7 (7.3%), those that disagreed were 2 (2.1%) and those that strongly disagreed accounted for 1.0%. It can be adduced that the majority (89.6%) of the Church members attest to the effectiveness of the Church in supporting children orphaned by HIV and AIDS.

With regard as to whether the Church had made great contribution to reduce stigma on people living with HIV and AIDS, 43 (44.8%) strongly agreed, 45 (46.9%) agreed, while 7 (7.3%) remained neutral as 1 (1.0%) disagreed. This shows that the Church was doing enough to reduce stigma on people living with HIV and AIDS with 91.7% consenting.

Regarding whether the Church was effective in organizing training that helped in reducing the impact of HIV and AIDS in society, majority 54 (56.3%) of the Church members agreed while 37 (38.5%) strongly
agreed. Those that remained neutral on this aspect accounted for 5(5.2%). This implies that Churches were effectively fighting the impact of HIV and AIDS through training programmes.

When asked whether the Church they attended had elaborate care centres that benefited people living with HIV and AIDS, 29(30.2%) of the Church members on one hand agreed while 23(24.0%) on the other hand strongly agreed. Those that were either neutral or disagreed totaled to 14(14.6%) and 16(16.7%) strongly disagreed. The majority of the Church members therefore believed that the Church did well in caring for PLWHAS.

With regard to whether the Churches had effective voluntary counselling and testing programmes, 42(43.8%) church members strongly agreed, 13(13.5%) agreed, 2(2.1%) were neutral, 19(19.8%) disagreed while 20(20.8%) strongly disagreed. Inferring from the findings it can be said that most of the Churches in the study location had effective voluntary counselling and testing programmes as 57.3% of the church members affirmed.

When it came to the Church members’ evaluation of the effectiveness of the Church programmes that were developed to offer support to people that were living with and affected by HIV and AIDS, 52(54.2%) agreed that the Church did support them while 28(29.2%) strongly agreed. Those that remained neutral, disagreed or strongly disagreed were 15(15.6%), 3(3.1%) and 1(1.0%) respectively. From these responses, we concluded that the Church had effective programmes offering support to the people living with HIV and AIDS (PLWA) and their relatives or caretakers.

When Church members were asked to reflect their level of agreement to the fact that the Church they attended was effectively involving its members in HIV transmission prevention campaigns, the majority 49(51.0%) agreed while 28(29.2%) strongly agreed. The rest 15(15.6%) and 3(3.1%) were either neutral or disagreed altogether. From the findings it can be concluded that the Church was involving its congregants in the efforts to fight HIV and AIDS through awareness campaigns. The results also show that the Church was effective in organizing seminars and workshops on HIV and AIDS to the community as attested by 50(52.1%) Church members who strongly affirmed that the Church actually did organize seminars and workshops aimed at sensitizing people on HIV/AIDs prevention. On a similar vein, 36(37.5%) supported the idea while 7(7.3%) were neutral as 2(2.1%) and 1(1.0%) disagreed and strongly disagreed respectively.

The effectiveness of Church-initiated programmes in reducing HIV and AIDS spread was evaluated by the eight outcomes as indicated on Table 2 above. The effectiveness of the Church in HIV and AIDS mitigation in Meru South sub-county can be attributed to a number of identifiable characteristics. This study has found that churches have implemented several interventions such as media campaigns, increased access to VCT, and sex/HIV education workshops and seminars which were among the evaluation measures.

In an effort to enlarge the quantitative data obtained from the Church members using questionnaires, this study gathered qualitative information from key informants who were the Church ministers and the beneficiaries of Church initiated HIV and AIDS mitigation programmes. With regard to whether the Church-initiated programmes had helped to reduce the spread of HIV and AIDS, the Church ministers/patrons interviewed (Redeemed Gospel Church-Chuka, Chuka Baptist Church, PCEA-Ndagani and Salvation Army Church-Chuka) held the opinion that they cannot certainly report that there has been a reduction in the spread of HIV as a result of the scaled efforts by the Church. It was not possible to quantify because many people in the Church have not been tested for HIV and their HIV status is thus not known. The Churches have not kept epidemiological data on HIV and AIDS prevalence. However, they were quick to point out that Churches indeed had a comparative advantage in promoting the needed types
of behaviour change to reduce the spread among its congregants and the society at large by advocating
behavioural change since these behaviours conform to their moral, ethical, and scriptural teachings.

The Church ministers were also categorical in reporting that they had the power to believe that the
ministry of health statistics showing a decline in HIV prevalence in the division could be attributed to
Church programmes that have continued to give clear messages about sexual activity and condom or
contraceptive use and continually reinforcing that message in their campaigns.

The Church ministers reported that the programmes which have been effective in HIV and AIDS
mitigation included: Support for people orphaned by HIV and AIDS, reducing stigma through education,
organizing trainings that help reduce the impact of HIV and AIDS in society, Voluntary Counselling and
Testing programmes, organizing seminars and workshops. In addition, they seemed to recognise that
there are factors which contribute to the spread of HIV and AIDS which the Church may not adequately
mitigate and in particular poverty, which generally leads to rural exodus, migration and prostitution and
certain cultural practices including polygamy and wife inheritance among others. Some Church ministers
also pointed to National statistics supporting their argument by referring to secondary data that HIV
prevalence in Kenya had fallen from a peak of 10% in adults in the mid-1990s to 6.1% in 2010. However
the decline is not uniform throughout the country (UNAIDS 2011).

This study gathered qualitative information from the key beneficiaries to compare with that elicited from
the Church ministers with regard to the effectiveness of the Church-initiated programmes in mitigating
HIV and AIDS. In order to establish effectiveness, a focus group of the beneficiaries was required to
provide the benefits that they had accrued from engagement in HIV and AIDS programmes initiated by
the Church if any. The results generated show that there are a number of ways through which such
programmes have benefitted the participants. Two themes that were generated from the focus group
discussions relating to prevention of spread of HIV and AIDS included:

i) Psychosocial support: Beneficiaries acknowledged receiving aid from Church members in the form of
food, clothing and sharing of experiences. Beneficiaries were involved in numerous activities such as
visiting each other and group saving all of which helped improve their involvement in the programme.
This promoted active awareness of HIV and AIDS prevention that helped them integrate the information
into the context of their own lives.

ii) Establishment of prevention networks: The beneficiaries indicated that the Church programmes
provided them with a platform through which they were able to solicit for support from NGOs through
their networks. Typically, the programmes provided information about skills, demonstrated the effective
use of those skills, and then provided some type of skill rehearsal and practice for example verbal role-
playing. Some of the programs taught them different ways to say "No" to sex or unprotected sex, how to
insist on the use of condoms or other methods of contraception and how to use body language that
reinforced the verbal message.

The findings from the Church members, the Church ministers and the beneficiaries show that HIV and
AIDS mitigation programmes have been effective in Meru South sub-county as majority of the
respondents indicated. Although Churches were found to possess a number of distinct advantages in
delivering HIV and AIDS interventions, they were also found to suffer from certain limitations that
hampered their effectiveness. When asked what challenges they faced in carrying out HIV and AIDS
initiatives, most of the Church ministers identified their need for training in HIV and AIDS-related
technical skills that prevented them from establishing or expanding their activities. The second most
important challenge identified was lack of funding.
Having embarked on HIV and AIDS activities, the Churches now have an overwhelming desire to be more effective but inadequate funds to implement these programmes was a real setback. The Church ministers also indicated that one important constraint faced was that they lack personnel with the necessary skills to implement effective HIV and AIDS activities. The beneficiaries on the other hand indicated that the challenges that were facing the Church in her quest to mitigate HIV and AIDS were lack of funds to roll up their programmes to a large scale to reach many people in the community.

When asked to provide suggestions that can be incorporated in order to make the existing Church-initiated HIV and AIDS mitigation programmes more effective, a great deal of responses were elicited from the Church members. The responses generated are captured on Table 3 below.

<table>
<thead>
<tr>
<th>Proposed strategies</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Establishing well-coordinated outreach programmes.</td>
<td>75</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>96</td>
</tr>
<tr>
<td>ii) Open up more VCT centers to increase accessibility</td>
<td>77</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>96</td>
</tr>
<tr>
<td>iii) Encourage expectant mothers to attend antenatal clinic with their partners</td>
<td>84</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>96</td>
</tr>
<tr>
<td>iv) Encouraging attendance to VCT at night for those who fear to be seen during the day</td>
<td>32</td>
<td>64</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>96</td>
</tr>
<tr>
<td>v) Construction of a centre to support PLWHA/orphans and the most vulnerable members of the Church</td>
<td>86</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>96</td>
</tr>
<tr>
<td>vi) Develop a community based program of action</td>
<td>87</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>96</td>
</tr>
</tbody>
</table>

Results from Church member’s responses show that 75(78.0%) of them strongly agreed that the Churches can consider establishing well-coordinated outreach programmes to reach more people. The members also strongly held the opinion that Churches should open more Voluntary Counselling and Testing (VCT) centers to increase accessibility with 77(80.0%) assenting. The majority of members 84(87.0%) further suggested that expectant mothers should be encouraged to attend antenatal clinics with their partners for a check-up to prevent mother-to-child transmission.

Further responses from the Church members reveal that 64(67.0%) agreed that Churches would be more effective in mitigating HIV and AIDS by encouraging attendance to VCT at night for those who fear to be seen during the day. An overwhelming 86(90.0%) of the Church members suggested that construction of a centre to support PLWHA/orphans and the most vulnerable members of the Church would go along way in scaling the fight of the pandemic. To enhance effectiveness of Church-initiated HIV/AIDS mitigation programmes, 87(91%) of the Church members strongly agreed that the Church needed to develop a community based program of action.

The study elicited qualitative responses from the Church ministers and beneficiaries regarding the strategies that may be employed by the Church to effectively mitigate HIV and AIDS. Most of the Church ministers interviewed (3 out of 4) had the opinion that supporting the development of local networking initiatives would be an important strategy for strengthening Church HIV and AIDS initiatives. To raise awareness about HIV prevention, Church ministers suggested that the Church should strengthen its awareness campaign programmes and develop appropriate HIV and AIDS messages in the church in line with the existing Church policies. All the beneficiaries (40) supported formation of support groups that would help them to establish income generating activities to enable them provide care and support for those infected and affected by HIV and AIDS, orphans and vulnerable children care. Further, the beneficiaries suggested the following strategies through the focus group discussions:

i) Organizing HIV and AIDS awareness programmes in various Church congregations during a Sunday service. This may include having speakers to address relevant topics.
From the above suggestions from the beneficiaries, Church members and the Church ministers, the Church needs to incorporate more programmes to strengthen HIV and AIDS initiatives.

Religion is an important component of culture as it influences the thinking and behaviour of society members. According to the results, more than 82(85%) of the respondents agreed that they benefited from the Church-initiated programmes that are geared towards mitigating HIV and AIDS. This is through change of sexual behaviour, reducing stigma, taking care of the infected and the orphans in the society.

CONCLUSION
Religions play a significant role in transforming the societies in which they are found. For instance the impact of Christianity in Kenya, where it is followed the majority of the population (about 83.6%) cannot be overstated. This can be affirmed by the Church’s effort to fight the HIV and AIDS pandemic which is a national disaster in Kenya. As this study reveals the programmes ran by the Church to fight the HIV and AIDS scourge are effective. Using some selected Churches in Meru South sub-county, namely the Redeemed Gospel Church-Chuka, PCEA-Ndagani, Salvation Army-Chuka and Chuka Baptist Church that were already implementing HIV and AIDS mitigation programmes, it clear that the place of the Church in curbing this pandemic cannot be under-rated. Most of the programmes that churches are operating including Orphan care, support of people living with and personally affected by HIV and AIDS, prevention activities eg campaigns, pastoral care and support, outreach programmes, voluntary counseling and testing, seminars and workshops seem to be doing well. The analysis of the data provided showed that the programmes were effective in mitigating HIV and AIDS in Meru South Sub-county.

Therefore if these Church programmes are supported, the government, church and other development partners, major strides can be made in fighting the HIV and AIDS disaster in Kenya. The results show that although the Church initiated HIV and AIDS programmes are effective in curbing this pandemic, they face a serious challenge of lack of funds. The government and other development partners therefore can support them through funding. This way the war against HIV and AIDS can easily be won.

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INTERPRETATION OF EKEGUSII POP SONGS WITHIN THE GREAT CHAIN OF BEING METAPHOR

Ntabo, Victor Ondara, Gathigia, Moses Gatambuki and Moraa, Noam Nyarigoti
Department of Languages, Karatina University, P. O. Box 1957-10101, Karatina, Kenya.
Tel: +254722398115, 0721993915, Tel: 0710365915, Email: ntabovictor@gmail.com, gatambukimoses@gmail.com; mgathigia@karu.ac.ke, nnyarigoti@gmail.com; nnyarigoti@karu.ac.ke

ABSTRACT
A review of literature on pop songs reveals that composers use metaphors to communicate their feelings. In particular, the meaning of the metaphors in EkeGusii pop songs (EPS) needs to be interpreted to reveal the intention of the composers. The EkeGusii pop singer Christopher Mosioma’s songs have gained fame in Kenya because of their use of metaphors. The song amasomo (education) has gained acclaim from Kenyans since its launch in 2014. The song amasomo (education) is basically presented as a piece of advice to students to embrace education in order to optimally reap from its benefits. It is against this backdrop that this study identifies the metaphors in the song through the Metaphor Identification Procedure Vrije Universiteit (MIPVU) and interprets them. The study employs four coders (including the researchers) in the identification of the metaphors. The study also takes into account the folk conception of the generic Great Chain of Being Metaphor (GCBM) whose main aim is to assign a place for any phenomenon in the universe in a strict hierarchical system. The study found that, inter alia, human, animal, plant, object and vehicle metaphors are used in the song amasomo. The study concludes that the metaphors in the EkeGusii pop songs belong inherently to different levels of the generic Great Chain of Being Metaphor (GCBM).

Keywords: Amasomo, Great Chain of Being Metaphor, MIPVU, Pop Songs,

INTRODUCTION
The paper is based on Cognitive Semantics (CS) which is a branch of Cognitive Linguistics (CL). CL is an interdisciplinary approach to language that posits that there is a nexus among language, the mind and socio-cultural experience (Evans & Green, 2006). CL is viewed as a cognitive function as opposed to formal approaches to language (Finch, 2000). CS provides that meanings are represented in peoples’ mind in a configuration that has its unique rules (Croft & Cruse, 2004). Meaning therefore, is a mental activity. Finch (2000) notes that CS describes the semantic approaches to language that sees no separation between linguistic knowledge and general thinking or cognition. CS adopts a functional view of language as opposed to formal approaches of language. CS also provides that the meaning of words and other linguistic units is inseparably related to the hearer’s memory and experience (Evans and Green, 2006). Meaning thus, is not located in the actual world but in our heads.

Palinkas (2006) postulates that the CL was developed in protest to the formal approaches to Linguistics which treated metaphor, analogy and metonymy as deviant linguistic phenomena. Fauconnier and Turner (2002) therefore, developed a framework of evaluating the linguistic concepts like metaphor. The paper seeks to examine the interplay of the mind, language and socio-cultural experiences to reveal the meaning of the metaphors in the selected EkeGusii pop song (EPS) amasomo (education).

In the realm of CL, metaphors enable people to comprehend one domain of experience in terms of another (Lakoff & Johnson, 1980). Lakoff (2008) defines a metaphor as a tool that helps make sense of abstract notions through concrete ones. Metaphors not only play a role in human thought, understanding and reasoning but also aid in the creation of people’s social, cultural, and psychological reality (Lakoff & Johnson, 1980). Metaphors therefore, are primarily conceptual, universal and conventionally part of ordinary system of thought. Wheeler (1994) posits that metaphor is not only a specific figure of speech but it is also, in its broader sense the foundation of language. Lakoff & Johnson (1980) point out that our

2 The term metaphor comes from the two Latin words meta which implies over or across and pherein that stands for to transfer or to carry beyond (Glucksberg, 2001). Metaphor refers to transfer or carry over the attributes one thing or person to another.

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conceptual system, in terms of the way we both think and act is basically metaphoric in nature. Metaphor has become a valuable cognitive tool that people cannot do without (Kövecses, 2002). Language is indeed hardly metaphor free (Deignan, 2005). This study evaluates the metaphors in the EkeGusii pop song amasomo (education) to reveal the meaning of the metaphors employed.

The conceptualization of metaphors is normally guided by the folk conception of the generic Great Chain of Being Metaphor (GCBM) (Kövecses, 2002). The main feature of the GCBM is that all existing things in the universe have their positions in a divinely planned order. (Kövecses, 2002) further points out that the hierarchy is considered to be a vertical chain in which different things occupy their corresponding places on the basis of their characteristics. 3 The highest level is occupied by God, followed by Universe, Society, People, Fauna, Flora, Objects and Physical Things in that order (Kövecses, 2002). According to Krzeszowski (1997), each level is described by specific attributes that can be metaphorically inherited. 4

The GCBM will, therefore be employed to comprehend the metaphors in the EkeGusii pop song amasomo (education) by Christopher Mosioma (Embarambamba).

The term pop song was first recorded as being used in 1926 in the sense of music with a popular appeal (Hatch & Milward, 1987). Famous pop song singers and music groups recorded in history include: Crooners of the 1930s and 1940s, Beatles of the 1960s, the American Back street Boys of the 1980s and 1990s and Britney Spears and Mariah Carey of the late 1990s and early 2000 (Simon & Will, 2004). According to Sullivan (2013), pop songs have the following characteristics: aim at mass audience; the style changes significantly depending on the time and place to gain favour with many people; and a danceable rhythm, simple melodies, memorable and repetitive structures. The pop music includes the subgenres of: rock, jazz, rhythm and blues and some folk songs (Simon & Will, 2004).

Pop songs express social messages that can be traced to a conscious communicative effort of the composer (Bikknell, 2002). Bikknell further argues that pop songs are often emotional and they mostly relay issues related to love. The composers express poetic ideas and subjective emotional states through purely musical means (Scruton, 2005). 6

There is therefore need to evaluate such music in order to establish the composer’s intended message. EkeGusii artists have composed pop songs that convey messages on concepts of love, marriage relationships and education in different ways. 7

Christopher Mosioma, for instance, whose stage name is Embarambamba, composed and sang the EPS amasomo (education), which gained appeal because of the metaphorical language used.

STATEMENT OF THE PROBLEM

Embarambamba employs metaphors in his EkeGusii pop song (EPS) amasomo (education) to address various thematic concerns which are relevant in the contemporary society. The singer, for instance uses metaphors to advise the youths on the value of education in transforming society. The meaning of the metaphors in the song amasomo (education) may elude the audience of the EPS. The audience, therefore, need to be aided in unraveling the conceptual metaphors in the song amasomo (education) to objectively comprehend the issues addressed by the singer.

AIM OF THE STUDY

3 The GCBM posits that all kinds of objects constitute a hierarchical system in which every creature or thing belongs inherently to a certain level of the chain.
4 According to Lakoff and Turner (1989), the folk conception of the generic GCBM is a tool of great power and scope because it allows people to understand general human behaviour in terms of well-understood non human attributes
5 Sullivan (2013) posits that pop songs are the ever-changing music favoured by the public.
6 Since music is indeed meaningful to people and is much more than an object of entertainment (De Nora, 2001), the pop music is a fundamental reference for the construction and expression of who people are (McDonald, 2002).
7 Embarambamba’s song amasomo(education) was released in 2015. The song underscores the value of education and offers pieces of advice to the youth to embrace education to reap its benefits. Embarambamba’s other songs include: Amatindogoro, E weekend and Zipporah.
The meaning of the metaphors in songs need to unravelled to comprehend the thematic concerns addressed. Metaphor is not only a figure of speech but also a linguistic unit that can be used as conduit for communication. The study therefore aimed at evaluating the conceptual metaphors in Embarambamba’s song *amasomo* (education) using the cognitive semantics framework. The study also employed the folk conception of the Great Chain of Being Metaphor (GCBM) to aid in unraveling the meaning of the metaphors in the song. The conceptual mappings between the target domains (TD) and the source domains (SD) as highlighted by the Conceptual Metaphor Theory (CMT) were studied to reveal the meaning of the ontological mappings in the song.

**THEORETICAL FRAMEWORK**

The paper adopted the Conceptual Metaphor Theory (CMT). The CMT, which was propounded by Lakoff and Johnson (1980) is a commonly used cognitive model in Cognitive Linguistics. The CMT defines a metaphor as a cross domain mapping in the conceptual system which includes a conceptual correspondence from a source domain (SD) to the target domain (TD). The SD includes what is physical or more concrete while TD includes what is abstract (Lakoff, 1993). According to Ahrens (2002), the concrete domain is referred to as the source while the abstract is the target. The study employed the CMT to evaluate the mappings of the source domains which are physical to abstract domains which are mental concepts to reveal meaning. The meaning of metaphors therefore, is a result of the conceptual mappings. This validates Cameron & Low’s (1999) assertion that metaphor is a matter of the mind. The CMT uses capitalized mnemonics along the line of “TARGET DOMAIN IS/AS SOURCE DOMAIN.” Metaphors are mapped from the concrete source domain to the abstract target domain in the conceptual system using the copula (IS) or (AS).

**METHODOLOGY**

The study involved a qualitative analysis of the metaphors in the EkeGusii pop song *amasomo* (education) by Embarambamba. The song *amasomo* (education) was considered for study since it is rich in metaphors based on the Metaphor Identification Procedure Vrije Universiteit (MIPVU) (Steen et al., 2010). Creswell (2007) notes that a qualitative research reveals the way things are by educating the reader about phenomena as experienced by the study participants and interpreted by the researcher in a relevant context. The research also used four coders (including the researchers) to indentify the metaphors from the song using the MIPVU. The coders classified words as metaphors based on Steen’s et al (2010) provision that words are identified as metaphors if they are indirectly used and may potentially be explained by some form of cross domain mapping from a more basic meaning of the words. An inter rater reliability test was used to enhance precision in the identification of metaphors. Cameron’s (2003) argument that a word which attains at least 75% in the inter-rater reliability test is marked a metaphor was considered. Each coder therefore assigned 0.25 to the words considered a metaphor. Once at least three coders were in agreement that the word is a metaphor, 0.25 was multiplied by 3 to obtain 0.75 which 75%. The principle of the Great Chain of Being Metaphor (GCBM) (Kövecses, 2002) was further employed to classify the identified metaphors into the conceptual domains of: animal, human being, plant and object. Content analysis was adopted to guide analysis of the metaphors in Embarambamba’s song.

**FINDINGS**

The study classified the identified metaphors into four conceptual domains using the folk conception of the generic Great Chain of Being Metaphor (GCBM). The classes include: animal, plant, object and vehicle conceptual metaphors. The study also found that the animal, plant, object and vehicle metaphors

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8 Lakoff & Johnson (1980) propounded the Conceptual Metaphor Theory (CMT) in their seminal work titled: *Metaphors We Live By*

9 The song *amasomo* (education) was transcribed and translated to English to ensure accuracy in the identification of metaphors.

10 The MIPVU was developed by metaphor scholars at Vrije University, Amsterdam as a method of metaphor identification (Steen et al., 2010)
are employed as source domains in the formation of the metaphors related to people and education as discussed below:

Table 4.1: Animal, Plant, Object and Vehicle Metaphors in amasomo (education) EkeGusii pop song and their reliability measures

<table>
<thead>
<tr>
<th>No</th>
<th>EkeGusii</th>
<th>Gloss</th>
<th>Conceptual Metaphor</th>
<th>Reliability measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Omonto n’ embori</td>
<td>A human being is a goat</td>
<td>animal</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>2</td>
<td>Amasomo n’ ebinaagwa</td>
<td>Education is Mauritius thorns</td>
<td>plant</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>3</td>
<td>Omonto n’ rinani</td>
<td>A human being is a forest</td>
<td>plant</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>4</td>
<td>Amasomo n’ obong’aini</td>
<td>Education is wisdom</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>5</td>
<td>Amasomo n’ endagera</td>
<td>Education is food</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>6</td>
<td>Amasomo n’ eswag</td>
<td>Education is a style</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>7</td>
<td>Omonto n’ amabuta</td>
<td>A human being is oil</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>8</td>
<td>Omonto n’ MPESA</td>
<td>A human being is mobile money</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>9</td>
<td>Omonto n’ egetenge</td>
<td>A human being is a kîenge</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>10</td>
<td>Omonto n’ ekebeya</td>
<td>A human being is a tin lamp</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>11</td>
<td>Omonto n’ ekelele</td>
<td>A human being is noise</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>12</td>
<td>Omonto n’ ekomina</td>
<td>A human being is a church</td>
<td>object</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
<tr>
<td>13</td>
<td>Omonto n’ ekeragita</td>
<td>A human being is a tractor</td>
<td>vehicle</td>
<td>0.25 0.25 0.25 0.25 1.00</td>
</tr>
</tbody>
</table>

KEY: C – Coder

Animal metaphor
A human being can be conceptualized as an animal based on human-animal interactions. Feinstein (2015) posits that the human-animal interactions are based on the biophilia hypothesis which provides that an emotional and beneficial relationship exists between humans and nature in which there is an innate tendency to focus on life and life like processes. There are therefore, shared dynamic associations between human beings and animals.

Rearing of goats for instance, is considered beneficial since it has a nutritional gain through goat products like milk. Conceptualizing a human being as a goat is therefore common. Embarambamba for example compares a human being with a goat as in metaphor (1) below.

(1) omonto n’ embori (a human being is a goat).
Embarambamba, in the EkeGusii pop song (EPS) amasomo (education) sings that a human being who embraces education is EMBORI (A GOAT). Goats are useful animals since they produce milk, meat, hair and skins and are easy to tame. In instantiation (1) above, omonto (a human being) is the Target Domain (TD) while embori (goat) is the Source Domain (SD) based on the tenets of the Conceptual Metaphor Theory (CMT) by Lakoff and Johnson (1980). One of the corresponding conceptual mappings of the TD corresponding with the SD is: physical satisfaction corresponding to perception. Embori (goat) is food that can be eaten to physically satisfy one, thus can be compared to a scholar’s academic appetite. The singer employs (1) above to give a piece of advice to students to embrace education to attain its benefits. This suggests that amasomo (education) is a beneficial thing for human beings just like embori (a goat).

Plant Metaphors
Rosinska(2016) notes that speakers have coined plants related lexemes to comprehend and also represent human beings. The terms bud and weed are examples of lexemes given by Rosinska (2016) which can be mapped into the domain A HUMAN BEING in Polish. Ronsiska further posits that plants are well represented in cognitive storage structures for instance in categories, frames or idealized cognitive models. According to Kleparski (2008), plants are intermittently used to conjure up phenomena. The Great Chain of Being metaphor (GCBM) (Kővésces, 2002) as pointed out by López (2009) provides that when people are compared with plants, they are usually demeaned. In this research, Embarambamba has used plant metaphors to conceptualize human beings and the concept of education.

Ebinagwa (the Mauritius thorns) metaphor (2) below is used to depict the qualities students need to possess to acquire education. Ebinagwa (Mauritius thorns) is both used as a hedge plant to secure homes
and organizations against unauthorized entry and also as a weapon because the plant has sharp thorns that can be used to repulse perceived enemies as the thorns pierce the intruders (Beer, 1987).

(2) Amasomo n’ ebinagwa (education is Mauritius thorns)

Ebinagwa (Mauritius thorns), whose botanical name is caesaipinia decapetala is an aggressive exotic plant which was initially imported to Africa as a hedge plant (Beer, 1987). Beer describes ebinagwa (Mauritius thorns) as evergreen, scrambling woody shrubs with very sharp prickles. EBINAGWA (MAURITIUS THORNS) is the SD while AMASOMO (EDUCATION) which Lydia, a character in the song who is advised to imbibe education is the TD. Metaphor (2) reveals that the acquisition of education is challenging, tormenting, devastating and harmful like ebinagwa (Mauritius thorns) and students need to endure the hardships associated with the acquisition of education to gain from it. The conceptual mapping (2) above also depicts the misery, pain, disappointment and disagreeable experiences of life characterized with people who have not fully embraced education. Embarambamba therefore prevails on students to embrace education to reap its benefits. This is because education enables people to acquire skills, techniques and attitudes to guarantee quality living (Pallais, 2014).

Metaphors (3) below is used to conceptualize a human being.

(3) Omonto n’ rinani (a human being is a forest).

In the EPS amasomo (education), a human being is negatively conceptualized as rinani (forest). A forest is normally a large area dominated with different species of trees. According to Manaseh (2016), effective learning which culminates to acquisition of quality education should subscribe to the educational principle which requires a student to be objective, organized, goal oriented and to prepare to acquire the educational concepts one at a time. Metaphor (3) is appropriately employed to depict a student who lacks objectivity, organization, clear goals and is unable to acquire the educational concepts one at a time. A learner who does not comply with the education principle (Manaseh, 2016) is apparently the one whom Embarambamba negatively conceptualizes as rinani (a forest) in the EPS amasomo (education).

Object Metaphors

López (2009) posits that the process of comparing people with objects invokes the feelings of love and abhorrence depending on the things involved. Metaphors 4-12 in Table 4.1 highlight the conceptual metaphor A Human Being/Education is an Object in the EkeGusii pop songs (EPS) amasomo (education).

The value of education is underpinned in metaphor (4) since education is conceptualized as obong’aini (wisdom). The relevance of (4) is founded on the belief that education guarantees one a promising future.

(4) Amasomo n’ obong’aini (education is wisdom).

Startwood (2013) notes that wisdom involves knowledge, experience and deep understanding of certain aspects which enable the people deemed to be wise appreciated in society. Embarambamba, in the EPS obong’aini (wisdom) sings that people compare him with obong’aini (wisdom). In this case, Embarambamba is the TD while obong’aini (wisdom) is the SD. Since wisdom is a composition of knowledge, experience and deep understanding of issues (Startwood, 2013), Embarambamba is appreciated in society because of his superior mental abilities. Embarambamba exploits his prestigious position in society to beseech students to embrace amasomo (education) to gain obong’aini (wisdom).

Kövecses (1986) posits that food is something edible and indispensable for human beings. The indispensability of food is compared with amasomo (education) as highlighted in (5) below. Emasomo (education) is seen as an object of consumption that a human being cannot do without.

(5) Amasomo n’ endagera (education is food).

In (5) above, Embarambamba positively conceptualizes amasomo (education) as endagera (food) in the EPS song amasomo (education). Food is what is eaten to keep the animal and human body healthy, strong and free from diseases (Allen, 2017). The ontological mapping (5) above also has a biblical interpretation. In Matthew 4:1-11, the temptation of Christ by the devil is described. Jesus is put into test by the devil after spending forty days and nights without eating. The devil asks Christ to turn stones into...
bread but Jesus answers that man need not to live on bread alone but by every word which comes from the mouth of God (The Holy Bible, 1982). The word that comes from the mouth of God is tantamount to *endagera* (food) which is comparable with *amasomo* (education) as given by God to guide people to morality. In line with (5) above, *amasomo* (education) is *endagera* (food) which is indispensable for human beings.

In (6), *swag* (style) is also used to positively conceptualize *amasomo* (education) in EPS. The metaphor below looks at education as stylish.

(6) *Amasomo n’ eswag* (education is a style).

Robert (2004) describes the term *swag* as a slang word employed by the youths to imply stylish confidence. The word *swag* is often used in TV advertisement to promote stylish youths’ clothes and shoes. In metaphor (6) above, *amasomo* (education) is the Target Domain (TD) while *eswag* (style) is the Source Domain (SD). Therefore, one of the corresponding conceptual mappings of the TD corresponding with the SD is: perception corresponding to reality. Emarambamba, in (6) above therefore suggests that *amasomo* (education) is something fashionable that should be embraced by youths to alleviate illiteracy.

Instantion (7) is employed by Emarambamba in the EPS *amasomo* (education) to positively conceptualize scholars. An educated person is depicted as an attractive person.

(7) *Omonto n’ amabuta* (a human being is oil)

Beauty is an attractive appearance which normally draws peoples’ admiration (Rhodes, 2010). Human beings apply oil skins to keep their skin hydrated which protects the skin from drying up and making it smooth and oily (Eleanor, 200). Eleanor further notes that human beings acquire a positive self image and an implicit self-esteem by making oneself attractive through applying oil skins. Emarambamba sings that *omwana osomete* (an educated child) is *amabuta* (oil) in the EPS *amasomo* (education). Emarambamba correlates education with oil skins to insinuate that scholars are admirable people in society.

In metaphor (8), a human being is conceptualized as MPESA. MPESA is a mobile money transfer service which is associated with Safaricom, a leading mobile phone company in Kenya (Morawczynski, 2010).

(8) *Omonto n’ MPESA* (a human being is MPESA).

MPESA mainly offers a short message-based money transfer system that allows individuals to deposit, send and withdraw funds using their cell phone (Jack & Suri, 2010). Safaricom deals in cellular communication, internet, money transfer and payment services. MPESA is synonymously used with money in Kenya because MPESA is the largest and commonly used mobile money transfer service (Jack & Suri, 2010). A human being who is endowed with sufficient money enjoys a high social class status as money is viewed as a measure of wealth (Jenkins, 2011). Emarambamba compares *Daudi* (David), a character in the EPS *amasomo* (education) with MPESA. In this case, *Daudi* (David) is the Target Domain (TD) while MPESA which is synonymous with money in Kenya (Jack & Suri, 2010), is the Source Domain (SD). One of the corresponding conceptual mappings of the TD corresponding with the SD is: perception corresponding to physical appearance. This suggests that since *Daudi* (David) is an educated person, he is also wealthy. Money can also be compared with education because both are considered promising things obtained after hard work.

The *egetenge* (kitenge) metaphor is also used to conceptualize a human being. *Egetenge* (kitenge) is a colourful Swahili dress which is normally worn by women during social functions like: weddings, funerals or communal parties (Khamis, 2005).

(9) *Omonto n’ egetenge* (a human being is a kitenge).

In (9) above, Emarambamba implores Pamela, a character in the EPS *amasomo* (ducation) who is compared with *egetenge* (kitenge) to study. *Egetenge* (kitenge) is adored for its colourful decorations and patterns (Khamis, 2005). In the ontological correspondence (9) above, Pamela is the TD while *egetenge* (kitenge) is the SD. In this case, the conceptual correspondence between TD corresponding with SD is physical appearance against perception. Emarambamba therefore gives a connotation that Pamela is an
attractive person but still encourages her to embrace education. This suggests that education is normally considered to be more valuable than beauty.

A human being is also conceptualized as ekebeya (a tin lamb) as in metaphor (10) below. A tin lamb is used with a negative undertone to conceptualize a lighting system with inadequate light and characterized with smoke (Jones, 2006). Ekebeya (a tin lamb) is predominantly used as a source of light in the rural areas of Gusii land (Akama & Maxon, 2006) where electricity connectivity is either inadequate or the ability to own sophisticated lambs like lanterns and pressure lambs is beyond the reach of the rural dwellers. The use of ekebeya (a tin lamb) is therefore associated with poverty.

(10) Omonto n’ ekebeya (a human being is a tin lamb).
In metaphor (10) above, Embarambamba conceptualizes Fred, a character in the EPS amasomo (education) as ekebeya (a tin lamp). A tin lamp uses paraffin (kerosene) as a source of fuel (Jones, 2006). A wick or a mantle which is characterized with smoke is a source of lighting for Ekebeya (a tin lamp). Ekebeya (a tin lamb) is the SD while Fred is the TD as per the Conceptual Metaphor Theory (CMT). Since the light produced by ekebeya (a tin lamb) is inadequate and unclean as the lamp is characterized with smoke, Embarambamba insinuates that Fred is inadequate in terms of amasomo (education) and therefore beseeches him to embrace amasomo (education).

The metaphor of noise can be used to conceptualize human beings. Since noise is usually distractive, a human being who does not undertake education in an organized manner can be correlated with noise.

(11) Omonto n’ kelele (a human being is noise).
Emarambamba, in the EPS amasomo (education) warns that any human being who studies noisily will end up being ekele (noise). Scales and Snielder (1998) describe noise as unwanted sound judged to be unpleasant, loud or disruptive to the ear. Emarambamba thus insinuates that a human being can be compared with noise if such a person does not plan to acquire amasomo (education) in an organized manner. Since noise hinders the realization of the expected signal (Snielder, 1998), a student who is comparable with noise will hardly realize the educational objectives. The ontological correspondence (11) above is given as a piece of advice to students to avoid disruptive activities which might jeopardize their educational programmes.

The church metaphor (12) below is used in the EPS amasomo (education) to appreciatively conceptualize a scholar. In 1John 4: 8, Christ teaches about the value of love for God and humanity which is the embodiment of the church (The Holy Bible, 1982). Emarambamba draws parallels between a scholar and Christ’s teachings on the church.

(12) Omonto n’ ekanisa (a human being is a church)
Emarambamba compliments a scholar in the EPS amasomo (education) by referring to him as omonyakanisa (a church). According to Romans 5: 12-21 and 1 Corinthians 15: 45-49, a church is described as a new humanity where Christ is depicted as a new human being who made redemption for all human beings (The Holy Bible, 1982). The New Testament therefore, depicts saved persons as renewed human beings in Christ by spirit which is described as the church (Franklin, 2011). Franklin notes that formal education which was viewed as a new awakening for Africans was introduced in Africa by missionaries. In (12) above, Emarambamba positively conceptualizes a scholar as a saved person who is redeemed from bondage by education.

Vehicle Metaphor
Vehicles are employed as source domains to conceptualize human beings in the EkeGusii pop songs (EPS). The vehicle metaphor (13) below, in the EPS amasomo (education) is based on mechanical power and strength. In the Great Chain of Being metaphor (GCBM), vehicles fall under the level of inanimate things which is the lowest level in the GCBM (Kövecses, 2002). The comparison between human beings and vehicle metaphors transmits positive connotations. For example:

(13) Omonto n’ ekeragita (a human being is a tractor).
In metaphor (13) above, Embarambamba positively conceptualizes a human being as *ekeragita* (a tractor). Spivy (2007) postulates that a tractor is a large vehicle that is used especially for pulling farm implements or machinery and has a powerful gasoline or diesel motor and large, heavily treaded rear tires. A tractor normally has the capacity to deliver a high tractive effort since it has a powerful engine. In (13) above, *omonto* (a human being) is the TD while *ekeragita* (a tractor) is the SD as per the Conceptual Metaphor Theory (CMT). Embarambamba insinuates that an educated person is comparable with the power of a tractor. Embarambamba therefore, uses the ontological correspondence (13) above to prevail on people to acquire *amasomo* (education).

**DISCUSSION**

The folk conception of the Great Chain of Being Metaphor (GCBM) (Kövecses, 2002) helped to explain the metaphors in the EkeGusii pop song (EPS) *amasomo* (education) by Embarambamba. The main objective of the GCBM is to assign a place for everything in the universe in a strict hierarchical system (López, 2009). The study notes that human beings are devalued when they are compared with animals, plants and objects. This finding corroborates López’ (2009) assertion that the natural order of the cosmos is that higher forms of existence dominate lower forms in the GCBM. However, in the metaphors, *omonto n’ embori* (a human being is a goat), *omonto n’ obong’aini* (a human being is wisdom) *amasomo n’ eswag* (educan is a style), *omonto n’ amabuta* (a human being is oil) and *omonto n’ MPESA* (a human being is MPESA) may be said to have positive labelling in the *amasomo* (education) EPS. The use of the animal metaphor, for instance, contrasts people and animals in terms of the ability to think rationally. Human beings have the ability of taking control over their actions than animals. The study also notes that *omonto n’ ekeragita* (a human being is a tractor) (Table 4.1), the possession of a vehicle has positive labelling as it expresses the pleasant value of education.

Second, this study reveals that metaphor is a common instrument of conceptualizing phenomena in pop songs. This because coders identify metaphors in the EPS *amasomo* (education) using MIPVU (see Table 4.1) which are evaluated in this paper. This finding is in line with past studies which have found that metaphor is a basic and indispensable linguistic feature of human understanding (Kövecses, 2002).

The metaphors identified in the EPS *amasomo* (education) are also well accounted for in terms of the Conceptual Metaphor Theory (CMT) by Lakoff and Johnson (1980). The use of various metaphors to describe the concept of education illustrates Cienki’s (2005) provision that metaphors are tools for reasoning about one thing in terms of the other.

**CONCLUSIONS AND RECOMMENDATIONS**

The study sought to account for the interpretation of the metaphors in the EPS *amasomo* (education) based on the folk conception of the generic GCBM. The study first concludes that the generic GCBM is essential in understanding the animal, plant, object and vehicle metaphors in the EPS song *amasomo* (education). Second, the conceptual metaphors are vital tools of communication and should be explained using a cognitive semantics approach. Third, the Conceptual Metaphor Theory (CMT) propounded by Lakoff and Johnson (1980) aided the comprehension of the metaphors in the EPS *amasomo* (education) by studying the conceptual mappings between the target domain (TD) corresponding to the source domain (SD). The meaning the metaphors in the EPS *amasomo* (education) which may have been elusive to the audience of the song was revealed.

The paper recommends that for a better understanding of conceptual metaphors, the folk conception of the Great Chain of Being Metaphor (GCBM) should be used to classify and evaluate the metaphors in accordance with the strict hierarchical order which exists in the universe. In addition, the use of the Conceptual Metaphor Theory (CMT) theory should be considered to aid in understanding the metaphors in songs. Finally, an inter-rater reliability measure as suggested by Cameron (2003) should be employed to identify precise metaphors to be considered for analysis in songs.
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EFFECT OF MICRO-INSURANCE SEGMENT ON INSURANCE UPTAKE IN KENYA

Mutegi, Murithi Karugi and Mutegi, Tetu Mwenda
Department of Business Administration, Chuka University, P.O Box 109-60400, Chuka
Tel.: 0708526724, mkarugi@yahoo.com, 0710975971, Tetumwenda@gmail.com

ABSTRACT
Micro insurance is the protection of low-income people against specific perils in exchange for regular premium payment proportionate to the likelihood and cost of the risks involved. With insurance uptake in Kenya still low, micro-insurance has been identified as a critical segment to deliver new products to the low-income population; this is evidenced by the IRA’s decision to incorporate new micro-insurance regulations in the insurance Act in 2012. The specific objectives of the study were to find out the effect of micro insurance general premiums, micro insurance life premiums and micro insurance policies on insurance uptake in Kenya. Causal effect research design was used for the study. Secondary data on micro insurance general premiums, micro insurance life premiums and number of micro insurance policies for the period 2009 to 2014 was obtained by the use of the data collection checklists. The sample size was 10 Head of Department of either Underwriting or Finance Department in the insurance companies chosen to obtain the premiums, and number of scores for the years 2009 to 2014. The study used both descriptive and inferential statistics in analyzing the data. The multiple linear regression equation used took into consideration three independent variables for the 10 companies. The results revealed that micro insurance variables influencing insurance uptake in Kenya, namely; micro-insurance general premiums, micro-insurance life premiums and number of micro insurance policies influenced it positively. The study found out that the intercept was 0.790 for all years. Independent variables explain a substantial 69.3% of insurance uptake in Kenya as represented by adjusted R2 (0.693). The study recommends that all insurers should invest in market analysts to help them research more on favorable micro insurance products and this would improve insurance uptake. The study concludes that micro insurance segment has a significant effect on the insurance uptake in Kenya.

Keywords: Insurance, Micro insurance, Insurance Uptake, Micro Insurance Policy, low-income, risks.

INTRODUCTION
Background of the Study
Insurance has existed since at least 215 BC with a common goal of pooling related risks and offering a cushion to the unforeseen circumstances. This concept has been practiced in various forms for over 1400 years (IIBI Report, 2001). Despite this fact it is still a fact that insurance uptake is still very low, not only in Kenya but the world over. Insurance penetration is a global problem with developed markets like UK at about 11% and USA at about 8.6% (Swiss Re, Economic Research and Consulting, 2014).

The term micro insurance was first published around 1999 (Preliminary Donor Guidelines, 1999). Micro insurance according to International Association of Insurance Supervisors is insurance that is accessible to the low-income population, provided by a variety of different entities, but run in accordance with generally accepted insurance practices. Micro insurance can also be defined as the protection of low-income people (those living on between approximately $1 and $4 per day) against specific perils in exchange for regular premium payment proportionate to the likelihood and cost of the risks involved (Insurance Regulatory Development Authority 2013). The target population typically consists of persons ignored by mainstream commercial and social insurance schemes, as well as persons who have not previously had had access to appropriate insurance.

Majority of people all over the world live on small and irregular incomes. Paying for insurance is a challenge when low-income households are struggling to meet a multitude of needs with scarce resources. Micro insurers recognize this as a problem hampering access to insurance, and are trying different ways to overcome it. Greater flexibility in premium payment is required. Low-income households appreciate
paying in small installments (irregular, if possible) at their doorstep and to have their payments spread out over time (Collins et al 2009).

Low-income households are vulnerable to risks, a fact that is widely recognized as one of key contributor to under development (International Micro insurance Conference Nigeria, 2013). In Africa, a continent with many infectious diseases, limited infrastructure, largely agrarian populations and fragile economies, low-income people are exposed to a multitude of risks that keep them in a vicious cycle of poverty. As opposed to developed countries, African countries do not have the financial means to provide the necessary government safety nets to successfully mitigate significant portions of their risks. Failure of informal schemes and government led programs to address the population’s risk management needs opens a significant window of opportunity for micro insurance to mitigate low-income households’ vulnerability to risks and help smooth their way out of poverty.

Munich Re Foundation has established that Africa’s booming population, low insurance penetration and increasing demand presents a huge opportunity for growth of insurance. Demand is high but availability and uptake is incredibly low and this is a big opportunity for Insurance Providers through micro insurance (Reinhard, 2012). On average, each African paid US$66.4 in insurance premiums in 2012, roughly one-tenth of the global average. Most growth in the insurance industry over the past decade has come from the wealthy and middle income markets in emerging economies. The insurance penetration ratio, which is the gross value of insurance premiums as a percentage of GDP and growth ratio which measures how fast the number of clients is increasing or decreasing are often used as a measure of how the level of uptake is. The trend in the growth ratio is usually an important indicator of the programmes success over the period in question. This is especially true if participation is voluntary, in which case a positive growth ratio often indicates marketing success, product value, and appeal (Odemba, 2013). Insurance penetration measures the importance of insurance activity relative to the size of the economy. The penetration rate indicates the level of development of insurance sector in a country. The higher the penetration rate the more developed insurance market is in that particular economy (Onduso, 2014). According to the reinsurer Swiss Re’s global insurance report, total premiums in Africa amounted to US$71.9 billion in 2012, which translates into a penetration rate of 3.65%. As one would expect, this is well below the global average, which is 6.5%, though it is above the average for emerging markets of 2.65%. Africa performs better than some regions, including the Middle East, Central &Eastern Europe, and South& Central America. Still, it is notable that Africa’s insurance density (the ratio of premiums per capita) is the lowest of any region in the world. Premiums grew by 3.3% globally and by 11.8% in the emerging markets in that year. In part this was due to a growing number of clients moving into the wealthy and middle income brackets in these countries, but it is also attributable to insurance expanding into new markets through micro insurance (Swiss Re, 2013). Micro insurance was majorly incorporated as a form of financial inclusion and access both of which are necessary preconditions for increasing insurance uptake. By giving insurance access to the low-income and economically vulnerable households, the micro insurance agenda will support the Government’s financial sector policy objectives as outlined in the Vision 2030 (AKI, 2013). Micro-insurance premiums have been on the rise. By September 2014, a total of KES 444.42 million were reported under micro insurance segment compared to KES 202.54 million of premiums reported by the end on the previous year. (AKI 2014) Although micro insurance was introduced primarily to improve insurance uptake in Kenya the uptake by the low income earners is still very low and hence insurance demand is still very low at 3.44% and with our aspiration to get to at 6.5% by 2016. Although insurers are becoming more active in micro insurance and are optimistic about future profitability insurance uptake is
not still at par. The study therefore sought to find out the actual effect of micro insurance segment on insurance uptake in Kenya.

**Statement of the Problem**
Micro insurance was introduced primarily to improve insurance uptake in Kenya with the introduction of enhanced distribution channels like banc assurance it would have been expected that the Insurance uptake would have been enhanced. Unfortunately this has not been the case; the issue of insurance uptake remains a key concern for insurance practitioners and scholars as well as policy makers. The very low insurance penetration in Kenya implies an inherent problem in the economy. According to AKI reports (2014; 2015) the insurance penetration in Kenya is 3.44% percent of the country’s GDP which is low and not Consistent with our aspiration to be a middle-income country by the year 2030. For us to get there the contribution of insurance to the GDP has to get to at least 10%. The study therefore was seeking to find out why the uptake of insurance is still low despite introduction of microinsurance.

**Objectives of the Study**
The general objective was to assess effect of micro-insurance segment on insurance uptake in Kenya.

**Specific Objectives**
- To determine the effect of micro insurance life premiums on insurance uptake in Kenya.
- To find out the effect of micro insurance general premiums on insurance uptake in Kenya.
- To determine the effect of number of micro insurance policies on insurance uptake in Kenya.

**Research Hypothesis**
- H$_{01}$ There is no significant effect of micro insurance life premiums on insurance uptake in Kenya.
- H$_{02}$ There is no significant effect of micro insurance general premiums on insurance uptake in Kenya.
- H$_{03}$ There is no significant effect of number of micro insurance policies on insurance uptake in Kenya.

**Significance of the Study**
The findings of this research would be beneficial to scholars and researchers as it shall add to the existing body of knowledge in the field of Insurance and also act as a spring board for further research in the same area and other related areas. To the Development and Policy makers in Kenya, in reference to Millennium development goals and vision 2030, the findings will be critical because, they will contribute in the areas Enhanced insurance uptake will directly increase the country’ GDP, thus aiding the economic pillar of development under vision 2030.

**Scope of the Study**
The study focused on micro insurance segment; premiums, and number of micro insurance policies written from micro insurance companies in Kenya. The targeted population comprised of 10 firms underwriting micro insurance businesses since 2009 namely; AIG, APA, Britam, CIC, Heritage, ICEA, Jubilee, Kenya Orient, Kenindia and UAP since 2009. The secondary data collected was used to determine the cause and effect relationship by analyzing the changes in micro insurance; general and life premiums and no of micro insurance policies from the 10 insurance companies and their effect on insurance uptake.

**Limitation of the Study**
The study used historical data which may not be accurate to forecast future trends hence it may limit possibility of generalizing findings to the future periods. However, the researcher used six financial year information which is a longer period and the findings are therefore likely to recur in the future.

**LITERATURE REVIEW**
**Concept of Micro Insurance**
Micro Insurance is the protection of low-income people against specific perils in exchange for regular premium payments proportionate to the likelihood and cost of the risk involved. It is not a specific product or product line. It is also not limited to a specific provider type. It is the provision of cover to a specific market segment, that’s the low-income persons. It is also defined as a mechanism to protect poor people against risk (accident, illness, death in the family, natural disasters, etc.) in exchange for insurance premium payments tailored to their needs, income and level of risk. It is aimed primarily at the developing world’s low-income workers, especially those in the informal sector of the economy who tend to be underserved by mainstream commercial and social insurance schemes (Tomchinsky, 2008).

Micro insurance is defined by the International Association of Insurance Supervisors (IAIS, 2007) as “insurance that is accessible to the low-income population, provided by a variety of different entities, but run in accordance with generally accepted insurance practices. The risk insured under a micro insurance policy is managed based on insurance principles and funded by premiums. This definition excludes social welfare and emergency assistance by governments, as this is not funded by premiums relating to the risk, and benefits are not paid out of a pool of funds that is managed based on insurance and risk principles (Smith, 2010).

Microinsurance recognizes that poor people are remarkable reservoirs of energy and knowledge. And while the lack of financial services is a sign of poverty, today it is also understood as an untapped opportunity to create markets, bring people in from the margins and give them the tools with which to help themselves. (Annan, 2005).

According to the Insurance regulatory authority. Micro insurance aims at enabling low income earners manage risks such as Accident, Illness, theft, death, fire and natural disasters such as flood and drought. Micro insurance cover is provided in exchange for affordable insurance premium tailored to the needs, income and nature of risks faced by buyers. Those targeted by micro insurance include the JuaKali sector, farmers, farm workers and house helps among others. This group lacks appropriate mechanisms to control risks allowing losses to drive them into helpless situations and abject poverty given that they cannot afford conventional insurance products. It is important to note that the majority of the Kenyan population falls within this category. IRA has recognized this need and is keen on facilitating the insurance industry to develop affordable insurance products to serve the needs of this group (IRA 2014).

**Origin and History of Micro Insurance**

Micro insurance is generally, but inaccurately, referred to as a new concept. It first appeared as a new financial service within microfinance and then developed into a sector of its own. However, it is only the term - Micro insurance that is fairly new. The principles of Micro insurance are not new: risk pooling and risk transfer trace back to some of the precursors of insurance, such as the Roman burial guilds Small policies, such as industrial life, and mutual protection schemes were offered in the 19th and early 20th century. Mechanisms of Micro insurance were preceded by cooperatives and credit unions, some of which created their own insurance companies Micro insurance was developed as part of Microfinance in the 90’s when Microfinance Institutions started offering insurance products, primarily credit life, to protect their loan portfolios. Some of these policies were eventually underwritten by commercial insurers thus beginning their involvement in MI since then; MFIs have sought to expand their offerings of financial services, including more complex insurance products. The term "micro insurance" was first published around 1999 and in the development environment, defining it has been a subject of much debate and discussion (Preliminary Donor Guidelines, 1999).

**Traditional Insurance**

Anja, Doubell and Herman (2012) stated that Out of 16 million insurable Kenyans 12 million were stated to be in the micro insurance sector and the other 4 million are in traditional insurance. This signified the potential impact of the micro products in the development of insurance and its penetration within Kenya.
Traditional insurance segment focuses on corporate, middle and high class of Kenyans. The Kenyan insurance industry is small. Total gross insurance premiums generated in 2008 were KSh55 billion (US$ 730 million or 2.6% of GDP), of which gross premiums for general and long-term business consisted of KSh35 billion (US$ 460 million or 1.7% of GDP) and KSh20 billion (US$ 270 million or 0.9% of GDP), respectively. Voluntary insurance serves only 3.6% of the adult population, while 1% of adults have life insurance. Furthermore, the industry has not grown much during last ten years. (IRA Report, 2013).

Currently traditional insurance products In Kenya are expensive and not readily available to the poor Makove (2011) also indicated that the current insurance regulatory framework in Kenya focuses on the traditional insurance with little recognition of micro insurance. According to research carried out by Swiss Re in 2007, most growth in the insurance industry over the past decade has come from the wealthy and middle income markets in emerging economies. Premiums grew by 3.3% globally and by 11.8% in the emerging markets in that year. In part this was due to a growing number of clients moving into the wealthy and middle income brackets in these countries (Swiss Re, 2007).

**Micro-Insurance in Kenya**

Micro insurance is an emerging trend in the Kenyan market and as such its regulation is not provided for in the existing Insurance Law. It is provided by a variety of institutions, and should be delivered in a way appropriate to low-income households with the products being designed as commercial insurance products that are fully funded by the premiums paid (Hougaard et al, 2009).

Those targeted by micro insurance include the Jua Kali sector, farmers, farm workers and house helps among others. This group lacks appropriate mechanisms to control risks allowing losses to drive them into helpless situations and abject poverty given that they cannot afford conventional insurance products. It is important to note that the majority of the Kenyan population falls within this category. IRA has recognized this need and is keen on facilitating the insurance industry to develop affordable insurance products to serve the needs of this group. In addition, for some of those already active in micro insurance; this could already make a significant contribution to policy numbers and even total premiums. In the case of Co-operative Insurance Company (CIC), micro insurance is reported to already contribute 20% of total premiums (Kuria, 2010). CIC collected 5.6% and 3.5% of the total life and general direct premiums collected, respectively (IRA, 2008). In terms of number of policyholders, the contribution would be much more significant. This reflects the commercial potential of micro insurance, particularly given the current small retail life base in the traditional industry (IRA, 2008).

Anja, Doubell & Herman (2012) spelt out the significance of micro insurance in the Kenyan market by stating the development and penetration rate of micro insurance to be 3% of the GDP while life insurance accounted for 1% . Out of 16 million insurable Kenyans 12 million were stated to be in the micro insurance sector. This signified the potential impact of the micro products in the development of insurance and its penetration within Kenya. Already some insurance and non-insurance institutions have welcomed micro insurance by introducing products such as Afya Bora by CIC and Salama Sure by UAP with Faulu Kenya offering Faulu Afya. Most of these products focus on primary risks such as Livestock and Crop, Health, Funeral and Life Insurance. Other financial institutions facilitate the development of micro-insurance through marketing, distribution as well as serving as premium collection and claims payment points e.g. Banks, Microfinance Institutions, Mobile Money Transfer Providers and Sacco’s.

**Insurance Uptake**

Uptake of insurance is the ratio of Gross Direct Premiums to Gross Domestic Product (GDP) (Odemba, 2013) this currently stands at just about 3.44% in Kenya, which is very low. Currently, work is being done by insurance companies in the area of micro insurance. Insurance providers can build customer involvement and loyalty; establish competitive differentiation; and increase referral value by applying various initiatives, (Business Daily, 21st January 2013).
Insurance uptake occurs due to the uncertainties that affect the welfare of the People. Since insurance provides resources that will be available in the future in case of occurrence of adverse shocks, the decision to buy insurance, or to self-insure through savings, is also related to the nature and extent of the uncertainty. Beck and Webb (2003), Browne and Kim (1993), and Outreville (1996). Despite the fact that insurance has been practiced for over a thousand years world over, it is still a fact that insurance uptake is still very low, not only in Kenya but the world over. Insurance penetration is a global problem with developed markets like UK at about 11% and USA at about 8.6% (Swiss Re, Economic Research and Consulting 2007).

Total gross premiums for 2008 stood at KSh55 billion (US$ 730 million or 2.6% of GDP), of which gross premiums for general and long-term business consisted of KSh35 billion (US$ 460 million or 1.7% of GDP) and KSh20 billion (US$ 270 million or 0.9% of GDP), respectively. This compares favorably to insurance penetration in neighboring countries such as Uganda (0.6% of GDP), Ethiopia (0.9% of GDP) and Tanzania (0.9% of GDP) but less favorably to more developed African countries such as South Africa (15.3% of GDP), Namibia (8.1% of GDP), Mauritius (4.9% of GDP) and Botswana (3.9% of GDP). (Swiss Re, Economic Research and Consulting, 2008).

Insurance Penetration
Insurance penetration shows the relationship between insurance consumption and the size of the economy, that is the share of GDP. It represents the average insurance spending per GDP in a given country. It is therefore expressed as the ratio between insurance premium and the GDP. Insurance penetration measures the importance of insurance activity relative to the size of the economy. The penetration rate indicates the level of development of insurance sector in a country. the higher the penetration rate the more developed insurance market is in that particular economy (Onduso, 2014).

According to (2014 Swiss Re) penetration In Africa was: 15.44% in South Africa, 15% in Egypt, 7.7% in Namibia, 5.8% in Mauritius, 3.44% in Kenya and 1.8% in Tunisia. According to the association of Kenya Insurers Annual Report 2013, the overall insurance penetration has increased to 3.44%. AKI chairperson Justus Mutiga in the 2013 insurance annual report observed that microinsurance and bancassurance will be the key drivers for premium growth and penetration in the industry (AKI, 2014).

Growth Ratio
The growth ratio is defined as the ratio of increase in the number of clients it measures how fast the number of clients is increasing or decreasing, how well developed is insurance awareness and how competitive is the product vis-à-vis other products or household risk management alternatives.

To measure growth over more than one period, this formula is used. The formula for Growth over the past three periods including the current period is defined as follows:

\[
\text{Growth ratio } n = \frac{\text{Number of insured } n - \text{Number of insured } n-3}{\text{Number of insured } n-3}.
\]

Micro-Insurance Premiums
Micro-Insurance premium is the amount of money that an individual or business must pay for a micro-insurance policy. The micro insurance premium is considered income by the insurance company once it is earned, and also represents a liability in that the insurer must provide coverage for claims being made against the policy. Because the coverage value for micro insurance is lower than a usual insurance plan the insured people pay considerably smaller premiums, micro insurance premiums are typically regular annual, quarterly, and monthly and are based on age or other specific risk characteristics, and collected regularly. Mostly from bank deductions.

Micro-Insurance Policy
It is a contract of insurance, describing the term, coverage, premiums and deductibles. In insurance, the insurance policy is a contract (generally a standard form contract) between the insurer and the insured, known as the policyholder, which determines the claims which the insurer is legally required to pay. In exchange for an initial payment, known as the premium, the insurer promises to pay for loss caused by perils covered under the policy language. Insurance contracts are designed to meet specific needs and thus have many features not found in many other types of contracts. Since insurance policies are standard forms, they feature boilerplate language which is similar across a wide variety of different types of insurance policies. The insurance policy is generally an integrated contract, meaning that it includes all forms associated with the agreement between the insured and insurer. (Garand, 2010).

METHODOLOGY
Introduction
This chapter introduces the research methods, design, population, sampling and data collection methods to be used and finally the data analysis approach taken.

Research Design
Research Design refers to the structure of an enquiry, or a logical task undertaken to ensure that evidence collected enables one to answer questions as unambiguously as possible (De Vaus, 2001). The study sought to determine the causal effect relationship that exists between micro insurance and insurance uptake in Kenya, This study hence employed a causal research design which involves test of relationships between variables.

Location of the Study
The study took place at the Headquarters of 10 firms underwriting micro medical and property businesses for the past six years namely; AIG, APA, Britam, CIC, Heritage, ICEA, Jubilee, Kenya Orient, Kenindia and UAP, It also took place at the national treasury; all the headquarters of the above are located in Nairobi, Kenya.

Population of the Study
Population is defined as the entire group of individuals, events or objects having common characteristics that conform to a given specification (Mugenda& Mugenda, 2003). The population of the study included the 10 firms underwriting micro insurance businesses namely; AIG, APA, Britam, CIC, Heritage, ICEA, Jubilee, Kenya Orient, Kenindia and UAP since 2009 and the national treasury. Since the population was not large, the study took a census approach.

Sampling Procedure and Sample Size
The sample size was 10 Head of Department of either Underwriting or Finance Department in the insurance companies chosen to obtain the premiums, and number of scores for the years 2009 to 2014. The Population was not large; so the study took a census approach of all the microinsurance premiums and number of policies from the ten companies underwriting microinsurance business, for the period 2009-2014. The period was long enough to help predict future trends.

Research Instruments
A data collection checklist was used to collect data on micro insurance premiums, and number of policies, resulting from micro insurance business for the 10 selected insurance companies between the periods 2009 to 2014 also a data collection checklist was used to collect information on population and GDP estimates. The contents and face validity of the checklist was checked by the supervisor.

Data Collection
According to (Flick, 2009), data collection is the gathering of empirical evidence with the objective of gaining new insights about the situation and to answer the questions that initiated the research.
collection checklists were administered specifically to the Head of Department of either Underwriting or Finance Department in the insurance companies chosen to obtain the premiums, and number of scores for the years 2009 to 2014. Data collection checklist was administered to the officer in charge in the national treasury to collect information on population and GDP estimates.

**Data Analysis and Presentation**

The study used both descriptive and inferential statistics in analyzing the data. Analysis was done with the help of Statistical package for social sciences (SPSS version 23). First, data collected was cleaned, sorted and collated. Descriptive statistics were used to profile the characteristics of the data. The study used multiple linear regression equation and the method of estimation was Ordinary Least Squares (OLS) so as to establish the relationship between the micro insurance and insurance demand variables. The F- ratio was used to test the overall significance of the estimated multiple linear regression model while t-statistic was used to test the hypotheses on the individual regression coefficients at 5% level of significance. The findings were presented in form of frequency tables and graphs to aid in the analysis and ease with which the inferential statistics were drawn.

**Analytical Model**

The multiple linear regression equation used took into consideration three independent variables for the 10 companies from 2009 to 2014 period.

It was presented as follows;

\[ Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon \]

Where;

\( i=1, 2 \)

\( Y_i = \) insurance uptake (1=insurance penetration, 2=growth ratio)

\( X_1 = \) the micro insurance life premiums of the 10 companies for the past 6 years

\( X_2 = \) the micro insurance general premiums of the 10 companies for the past 6 years

\( X_3 = \) number of micro insurance number of policies of the 10 companies for the past 6 years.

\( \beta_1, \beta_2, \beta_3 = \) regression model coefficients.

\( \beta_0 = \) Constant/Y intercept.

\( \varepsilon = \) the values of an unobserved error term.

**Tests for Ordinary Least Square Assumptions**

The tests that were used included homoscedasticity, Multicollinearity and autocorrelation. Homoskedacity was used to determine whether the variance of the error term is constant and same for all observations (Anderson, 2007). Heteroskedacity was detected by use of scatter plots. Variance inflation factor and tolerance levels are used to test for Multicollinearity. The presence of Multicollinearity makes it difficult to isolate the impact of each independent variable on dependent. Durbin Watson test (d) static was used to test for autocorrelation which occurs when regression error are correlated across observations. Autocorrelation is not present when Durbin Watson static takes values between 0 and 4.

**Ethical Consideration**

Ethical consideration in research gives researcher guidelines to ensure that research is carried out in the best interest of the respondents (Cardwell, 1999). Ethical issues include; informed consent, Confidentiality and harm for the respondents (Regis, 2006). Informed consent is an ethical requirement which demands that respondents in a research be allowed a choice to participate or not participate in a research after receiving full information about the possible risks and benefits of their participation (Urombo, 2000). In this study the researcher and the research assistants informed the respondents on the purpose of the study.
Consent to collect data from the insurance companies was sought from the officer in charge. The respondents were given freedom to choose whether to participate or not to participate in this study and also the researcher sought authority from NACOSTI to collect data and permission from 10 selected insurance and the National Treasury who provided the data.

Confidentiality denotes the researcher’s ethical obligation to keep the respondents’ identity and responses private (Neumann, 2001). In this study the respondents were assured of confidentiality of the information they gave. To maintain this confidentiality anonymity of the respondents was maintained by not asking them to write their name in the data collection forms.

Ethics require that researchers carry out a study in a way that does not cause physical or psychological harm to the respondents (Urombo, 2000). Psychological harm may include: irritation, anger, emotional stress, loss of self-esteem, invasion of privacy and damage to personal dignity (Urombo, 2000). This study protected the respondents from psychological harm by not seeking for information that was private and sensitive in order to avoid causing them embarrassment, irritation, anger, emotional stress and lowering their self-esteem.

RESULTS AND DISCUSSION
Introduction
This chapter presents the information processed from the data collected during the Study to establish the effect of micro insurance segment on insurance uptake in Kenya. The sample composed of 10 firms underwriting micro insurance businesses for the past six years namely; AIG, APA, Britam, CIC, Heritage, ICEA, Jubilee, Kenya Orient, Kenindia and UAP and also the national treasury.

Descriptive Statistics and Test for Normality
To test for normality of the data, descriptive statistics was used. In order to make accurate and reliable conclusions normality test was used to determine the normal distribution of the sampled data. The mean was used to determine the average of the data and standard deviation was used to measure dispersion from the mean. This was explained by the table below.

<table>
<thead>
<tr>
<th>Table 2: Descriptive Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Minimum</td>
</tr>
<tr>
<td>Statistic</td>
</tr>
<tr>
<td>Insurance uptake</td>
</tr>
<tr>
<td>Micro insurance life premiums</td>
</tr>
<tr>
<td>Micro insurance general premiums</td>
</tr>
<tr>
<td>Number of Micro Insurance Policies</td>
</tr>
<tr>
<td>Gross direct premiums</td>
</tr>
<tr>
<td>Gross domestic Product</td>
</tr>
</tbody>
</table>

N=24, 6

Table 2 indicates that the skewness statistic is within the range of ± 3 for microinsurance life premiums, microinsurance general premiums and number of microinsurance policies which is an indication that data is normal, unbiased and it can be used reliably to make inferences in this study. The mean represents generalization of data indicating that the data values were average. Micro insurance life premiums had a mean of 10200125 while micro insurance general premiums had a mean of 8958260.04, findings depict that the micro-insurance premiums both life and general and steadily increased over the study period. Gross direct premiums had a mean of 3159 while gross domestic product had a mean of 106503.33 the standard deviations for the variables are not close to zero which depicts that the values not concentrated around the mean. Micro insurance life premiums had the highest deviation this could imply that it would have a higher effect on the independent variables.
**Heteroscedasticity Test**

A residual plot was used to determine whether the dependent variable exhibit equal levels of variance across a range of independent variables (s) the error term is constant and the same for all observations. A residual scatter plot is a figure that shows one axis for predicted scores and one axis for errors of prediction, initial visual examination can isolate any outliers, otherwise known as extreme scores in the data set the residuals and the variance of the residuals should be the same for all predicted scores (homoscedasticity). If this is true, the assumption is met scores will be randomly scattered about a horizontal line. In contrast, any systematic pattern or clustering of scores is considered a violation. (Tabachnick, B. G. & Fidel, L. S. 2007).

![Scatterplot](image)

**Figure 2. Test for Heteroscedasticity**

In figure 2 as the predictive values increases the residuals are neither increasing nor decreasing, they are fairly clustered around the line of total fit around the center. This shows existence of Homoskedacity and absence of heteroscedacity which implies the standard errors are correct and have equal variances thus the results were used for hypothesis testing and ordinary least square method was used.

**Multicollinearity Test**

To test for correlation between the independent variable Multicollinearity was used. Existence of Multicollinearity is evidenced by the standard errors for the regression coefficient estimators becoming inflated which results in t-statistics becoming too small and less powerful in terms of their ability to reject the null hypothesis. Variance inflation factor and tolerance levels are used to test for Multicollinearity VIF of less than 10 and tolerance level of more than 0.1 are preferred (Munga, 2014).

Multicollinearity was eliminated through a stepwise regression technique systematically. Aczel&Sounderpadian(2002) states that stepwise regression is a mixture of backward elimination and forward selection methods which involves eliminating a variable and entering a variable permanently to the regression equation respectively .a summary of eigen values, conditional index and variance proportions is provided in the table below.
Table 3: Collinearity diagnostics

<table>
<thead>
<tr>
<th>Model</th>
<th>Tolerance</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro insurance General premiums</td>
<td>.051</td>
<td>3.68</td>
</tr>
<tr>
<td>Micro Insurance Life Premiums</td>
<td>.033</td>
<td>2.71</td>
</tr>
<tr>
<td>Number of Micro Insurance Policies</td>
<td>.052</td>
<td>1.74</td>
</tr>
</tbody>
</table>

**Dependent Variable: insurance uptake**

In the above table micro insurance life premiums had the lowest tolerance level at 0.33 and number of micro insurance policies had the highest tolerance level at 0.52. Tolerance level for all the independent variables were greater than 0.1 this suggested that there was no Multicollinearity problem. Micro insurance general premiums had the highest VIF of 3.68 while number of micro insurance premiums had the lowest VIF, all the variables had a VIF of less than 10 hence there was an indication that there was no Multicollinearity among the independent variables thus it was possible to isolate the effect of each independent variable on the dependent variables.

**Pairwise Correlations**

To determine the degree or strength of linear relationship among the variables Pearson correlation ($r$) was used. Linearity increases the predictive power of the model and the validity of the estimated coefficients. The study sought to determine the correlation between the variable in order to determine the strength and direction of the relationship at 5% significance level.

A correlation of $r>0.7$ implies that the variable are strongly related negatively or positively.

Table 4: Pearson Correlation Coefficients

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Insurance Uptake</th>
<th>Micro insurance Life Premiums</th>
<th>Micro insurance General Premiums</th>
<th>Number of Micro Insurance Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>1.000</td>
<td>.903</td>
<td>.865</td>
<td>.887</td>
</tr>
<tr>
<td>Insurance Uptake</td>
<td>.903</td>
<td>1.000</td>
<td>.973</td>
<td>.973</td>
</tr>
<tr>
<td>Micro insurance Life Premiums</td>
<td>.865</td>
<td>.973</td>
<td>1.000</td>
<td>.957</td>
</tr>
<tr>
<td>Microinsurance General Premiums</td>
<td>.887</td>
<td>.973</td>
<td>.957</td>
<td>1.000</td>
</tr>
<tr>
<td>Number Of Micro Insurance Policies</td>
<td>.000</td>
<td>.007</td>
<td>.013</td>
<td>.009</td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insurance uptake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microinsurance life premiums</td>
<td>.007</td>
<td>0.00</td>
<td>.013</td>
<td>.001</td>
</tr>
<tr>
<td>Microinsurance General premiums</td>
<td>.013</td>
<td>.001</td>
<td>0.00</td>
<td>.001</td>
</tr>
<tr>
<td>Number of Micro insurance policies</td>
<td>.009</td>
<td>.001</td>
<td>.001</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Person correlation was used to determine the relationship between micro insurance life premiums, micro insurance general premiums, number of micro insurance and insurance uptake. The correlation coefficient for micro insurance life premiums and insurance uptake was 0.903 with $p$-value (0.07) which was found to be significant at 5% significance level this implies that there exists a strong positive relationship between micro insurance life premiums and insurance uptake. An increase in micro insurance life premiums will lead to an increase in insurance uptake.
The correlation coefficient for microinsurance and insurance uptake was 0.865 with p-value (0.13) which was found to be significant at 5% significance level this implies a strong positive relationship between micro insurance general premiums and insurance uptake. An increase in micro insurance general premiums will lead to an increase in insurance uptake.

The correlation coefficient between number of micro insurance policies and insurance uptake was 0.887 with p-value (0.09) which was found to be significant at 5% significance level this implies a strong positive relationship between number of micro insurance policies and insurance uptake. An increase in number of micro insurance policies will lead to an increase in insurance uptake.

**Regression Analysis**

The multiple correlations (R) indicates the correlation between dependent variable and the independent variables jointly predicted by the model. The multiple coefficient of determination (R²) determines the changes of variation in dependent variable as explained by dependent variables jointly. A coefficient of R² > 0.7 is explained by the independent variables and the existence of a strong correlation between variables. The table below shows the values of R and R².

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>Change Statistics</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.790a</td>
<td>.693</td>
<td>.557</td>
<td>.27164</td>
<td>.823</td>
<td>1.892</td>
</tr>
</tbody>
</table>

b. Dependent Variable: insurance uptake

In table 4.6 multiple coefficients of correlation (R) was 0.790 which implies that the degree of association between insurance uptake and micro insurance life premiums, micro insurance general premiums and number of micro insurance policies is strong and positive. The (R²) was 69.3% which implies that 69.3% variations in insurance uptake are explained by micro insurance life premiums, micro insurance general premiums and number of micro insurance policies in the model. While 30.7% of variations in insurance uptake is explained by random error or other factors.

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>.685</td>
<td>3</td>
<td>.228</td>
<td>8.564</td>
<td>.0414b</td>
</tr>
<tr>
<td>1</td>
<td>Residual</td>
<td>.148</td>
<td>2</td>
<td>.074</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>.833</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the ANOVA statistics in the above table, the processed data, which are the population parameters, had a significance level of 0.414 which shows that the data is ideal for making a conclusion on the population’s parameter. The F calculated at 5% Level of significance was 8.564 Since F calculated is greater than the F critical (value = 4.76), this shows that the overall model was significant i.e. there is a significant relationship between insurance uptake and micro insurance in Kenya.

**Regression Coefficients**

In determining the cause effect relationship between the dependent variable and the explanatory variables the regression coefficients were tested at the 5% level of significance using t-test.

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>95.0% Confidence Interval for B</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td>T</td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>2.635</td>
<td>.273</td>
<td>9.669</td>
</tr>
</tbody>
</table>
Proceedings of the Fourth International Research Conference

Microinsurance

General premiums 7.80 .000 325 -.245 .024 .000 .000 .051 19.781
Life premiums 2.77 .000 1.005 .610 .031 .000 .000 .033 30.598
Number of Micro insurance policies 6.87 .000 .221 .168 .016 .000 .000 .052 19.380

a. Dependent Variable: insurance uptake

Regression Equation

The coefficient of regression table above was used in coming up with the model below:

\[ IU = 2.635 + 7.80 \text{MGP} + 2.77 \text{MLP} + 6.87 \text{MP} + \varepsilon \]

Where IU is insurance uptake, MGP is micro-insurance general premiums, MLP is micro-insurance life premiums and MP is number of micro-insurance policies. From the model, taking all factors (micro-insurance general premiums, micro-insurance life premiums and number of microinsurance policies) constant at zero, insurance uptake in Kenya was 2.365.

The data findings analyzed also shows that taking all other independent variables at zero, a unit increase in micro-insurance premiums will lead to a 7.80 increase in insurance uptake in Kenya was 2.635; unit increase in micro-insurance life premiums will lead to a 2.77 increase in insurance uptake in Kenya while a unit increase in number micro insurance policies will lead to a 6.87 increase in insurance uptake in Kenya. According to the model, all the variables were significant as their significance value was less than 0.05, micro-insurance life premiums, microinsurance general premiums and numbers of micro-insurance policies all were positively correlated with insurance uptake in Kenya.

The Effect of Micro Insurance Life Premiums on Insurance Uptake

The study aimed at determining the effect of microinsurance life premiums on insurance uptake in Kenya. In the above table the coefficient obtained from regression was 2.77 with (p-value 0.001<0.05) thus the null hypothesis that there is no significant effect of microinsurance life premiums on insurance uptake in Kenya was rejected. There is a statistically significant positive relationship between microinsurance life premiums and insurance uptake in Kenya unit increase in micro-insurance life premiums will lead to a 2.77 units increase in insurance uptake in Kenya.

The Effect of Micro insurance General Premiums on Insurance Uptake

The study sought to find the effect of microinsurance general premiums on insurance uptake in Kenya. The coefficient obtained from the regression was 7.80 with (p-value 0.001<0.05) thus the null hypothesis that there was no significant effect of microinsurance general premiums on insurance uptake in Kenya was rejected this leads to the conclusion that there exists a statistically significant relationship between microinsurance general premiums and insurance uptake in Kenya. The data findings analyzed also shows that taking all other independent variables at zero, a unit increase in micro-insurance general premiums will lead to a 7.80 units increase in insurance uptake in Kenya.

The Effect of Number of Microinsurance Policies on Insurance Uptake

The study aimed at finding the effect of number of microinsurance policies on insurance uptake in Kenya. The coefficient obtained from the regression was 6.87 with (p-value 0.001<0.05) thus the null hypothesis that there was no significant effect of number of microinsurance policies on insurance uptake in Kenya was rejected this led to the conclusion that there exists a statistically significant relationship between number of microinsurance policies on insurance uptake. A unit increase in number of micro insurance policies will lead to a 6.87 unit increase in insurance uptake in Kenya.

The implication of these results is that microinsurance segment had a significant effect on insurance uptake. This makes the microinsurance segment an important segment for improving insurance uptake in Kenya. This is in line with Laura (2014) who in her paper “Micro-insurance learning” observed that
insurance uptake was largely positively affected by microinsurance insurance premiums and no of insurance policies.

SUMMARY OF FINDINGS
The study sought to establish the effect of micro insurance segment on insurance uptake in Kenya. This study research design was causal research which involved test of relationships between variables. This was achieved by analyzing the changes in insurance uptake arising as a result of changes in microinsurance general premiums, microinsurance life premiums and number of microinsurance policies. The significance of this study was established through the ANOVA tables.

Normality of data was tested by use of Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test showed a test distribution that is normal for all the models. This further confirmed normality of data. The presence of homoscedasticity was determined by use of residual plot diagrams which showed that residuals had equal variances suggesting the presence of homoscedasticity. The Multicollinearity was tested by use of VIF and tolerance levels. Microinsurance life premiums had the lowest tolerance level at 0.33 and number of microinsurance policies had the highest tolerance level at 0.52. Tolerance level for all the independent variables were greater than 0.1 this suggested that there was no Multicollinearity problem. Microinsurance general premiums had the highest VIF of 3.68 while number of microinsurance premiums had the lowest VIF, all the variables had a VIF of less than 10 hence there was an indication that there was no Multicollinearity among the independent variables. The correlation of the errors across the observations was checked by the use of Durbin Watson d statistic which was 1.892 this was greater than 0 and less than 4, thus autocorrelation was absent thus preventing the occurrence of type 1 error.

The processed data, which are the population parameters, had a significance level of 0.254 which shows that the data is ideal for making a conclusion on the population’s parameter. The F calculated at 5% Level of significance was 8.564 Since F calculated is greater than the F critical (value = 4.76), this shows that the overall model was significant i.e. there is a significant relationship between insurance uptake and micro insurance in Kenya. Coefficients of correlation (R) was 0.790 which implies that the degree of association between insurance uptake and microinsurance life premiums, microinsurance general premiums and number of microinsurance policies is strong and positive. The (R²) was 69.3% which implies that 69.3 % variations in insurance uptake are explained by microinsurance life premiums, microinsurance general premiums and number of microinsurance policies in the model. While 30.7% of variations in insurance uptake is explained by random error or other factors.

The data findings analyzed also shows that taking all other independent variables at zero, a unit increase in micro-insurance premiums will lead to a 7.80 increase in insurance uptake in Kenya was 2.635; unit increase in micro-insurance life premiums will lead to a 2.77 increase in insurance uptake in Kenya while a unit increase in number micro insurance policies will lead to a 6.87 increase in insurance uptake in Kenya. According to the model, all the variables were significant as their significance value was less than 0.05, micro-insurance life premiums, microinsurance general premiums and numbers of micro-insurance policies all were positively correlated with insurance uptake in Kenya.

CONCLUSIONS
The study found out that there is a statistically significant positive relationship between microinsurance life premiums and insurance uptake in Kenya. An increase in microinsurance life premiums will lead to an increase in insurance uptake. This is in line with Laura (2014) who in her paper “Micro-insurance learning” observed that insurance uptake was largely positively affected by insurance premiums. In addition the study also concluded there was a positive relationship between microinsurance general premiums and insurance uptake. An increase in microinsurance general premiums will lead to an increase in insurance uptake. The study found a strong positive relationship between number of microinsurance
policies and insurance uptake. An increase in number of microinsurance policies will lead to an increase in insurance uptake.

**RECOMMENDATIONS**

Based on the findings of this study the researcher made the following recommendations:

i. Since microinsurance general premiums had the highest positive and significant effect on insurance uptake insurance companies should capitalize more on microinsurance general products to get a competitive edge.

ii. Insurers should invest more in market analysts to help them research more on favorable microinsurance life products. This would enhance both microinsurance life premiums which were not doing as well like microinsurance general premiums.

iii. The study recommends that the government through the insurance regulatory authority should support the microinsurance segment by coming up with regulations that favor the low income earners this would improve number of micro insurance policies consumed and as a result insurance uptake would improve.

iv. Assess the effects of micro-insurance on the financial performance of insurance companies

v. A similar research can be undertaken on wider scale, for example covering all the insurance companies in East Africa to see whether there is a similarity in findings.

vi. The study targeted firms underwriting micro medical and property businesses, further studies should cover all the firms underwriting any insurance services to have a more general conclusion.

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APPLICATION OF SCIENCE, ENGINEERING AND TECHNOLOGY IN ENVIRONMENTAL CONSERVATION AND RENEWABLE ENERGY DEVELOPMENT

METRIC EQUIVALENCE AS AN ALMOST SIMILARITY PROPERTY

Gitonga, E. M.¹, Musundi, S. W.¹* and Nzimbi, B. M.²
¹Chuka University, P. O. Box 109-60400, Kenya
²School of Mathematics, College of Biological and Physical Sciences University of Nairobi, P. O. Box 30197-00100, Nairobi.
Correspondence: gitongaeric420@gmail.com, 0723613521, sammusundi@yahoo.com, 0720870132
Correspondence: nzimbi@uonbi.ac.ke, 0715925762

ABSTRACT

Various results that relate to almost similarity and other classes of operators such as isometry, normal, unitary and compact operators have been extensively discussed. It has been shown that if operators S and T are unitarily equivalent, then S is almost similar to T. Similarly, it has been shown that if operators A and B are such that A is almost similar to B and if A is Hermitian, then A and B are said to be unitarily equivalent. Metric equivalence property which is a new relation in operator theory has drawn much attention from mathematicians in the recent past. Two operators S and T are unitarily equivalent if they are metrically equivalent projections. It has been shown that if operators S and T are unitarily equivalent, then S is metrically equivalent to T. However, there is no literature that has been shown for the conditions under which metric equivalence and almost similarity coincide. In this paper we will therefore strive to establish the equivalence relation between metric equivalence property and almost similarity relation. To achieve this, properties of invertible operators, normal operators, similar operators, unitarily operators as well as projection and self-adjoint operators will be employed.

Keywords: Unitarily equivalent relations, Metric equivalence property

1. INTRODUCTION

The class of almost similar operators was first introduced by (Jibril, 1996). He defined the class of almost similar operators as follows:

Two operators A and B are said to be almost similar if there exists an invertible operator N such that the following conditions are satisfied:

\[ A^*A = N^{-1}(B^*B)N \]
\[ A^* + A = N^{-1}(B^* + B)N \]

(Jibril, 1996), proved various results that relate almost similarity and other classes of operators. (Musundi et al., 2013) have shown that unitary equivalence of operators implies almost similarity of operators. Linear operators \( T \in B(H) \) and \( S \in B(K) \) are unitarily equivalent if there exist a unitary operator \( U \in B(H, K) \) such that \( UT = SU \) i.e. \( T = U^*SU \). (Campbell & Gellar, 1977). (Nzimbi et al., 2008) further studied the concept of almost similarity where they have shown that similarity implies almost similarity.

(Nzimbi et al., 2013) introduced the concept of metric equivalence. They further proved that metric equivalence is an equivalence relation.

Two operators \( A \in B(H) \) and \( B \in B(K) \) are said to be metrically equivalent if:

\[ ||Ax|| = ||Bx|| \] (equivalently, \( \frac{1}{2} < Ax, Ax > \frac{1}{2} = \frac{1}{2} < Bx, Bx > \frac{1}{2} \) for all \( x \in H \), that is \( A^*A = B^*B \)). Of great interest, (Nzimbi et al., 2013) concretely discussed the spectral picture of metrically equivalent operators. They also gave some conditions under which metric equivalence of operators implies unitary equivalence of operators. Two operators A and B are said to be similar if there exist an invertible operator \( N \in B(H, K) \) such that \( NA = BN \) or \( A = N^{-1}BN \). If \( S \in B(H) \) and \( T \in B(H) \) are similar, then \( S^* \) and \( T^* \) are similar. It has been shown (Nzimbi et al., 2008) that if \( S \in B(H) \) and \( T \in B(H) \) are unitarily equivalent, then \( S \) and \( T \) are similar. If \( S \) and \( T \) are normal operators in a Hilbert space \( H \), then \( S \) is
unitarily equivalent to $T$ if and only if $S$ is similar to $T$. Thus it follows that two similar normal operators $S$ and $T$ are unitarily equivalent. (Musundi et al., 2013) have showed that if operators $S$ and $T$ are unitary equivalent, then $S$ is almost similar to $T$. Efforts towards establishment of the relation between the almost similarity and metric equivalence properties of operators could mark a significant contribution to the existing knowledge.

**RELATED LITERATURE REVIEW**

The review includes literature on some results on almost similarity, characterization of unitary equivalence of operators in terms of almost similarity. We also review metric equivalence relation and closely related relations on some classes of operators. In extension, we review some conditions under metric equivalence of operators implies unitary equivalence of operator.

**Some Results on Almost Similarity**

(Jibril, 1996) has shown that two operators $A$ and $B$ are said to be almost similar if there exist an invertible operator $N$ such that the following two conditions are satisfied:

\[ A^*A = N^{-1}(B^*B)N \]

\[ A^* + A = N^{-1}(B^* + B)N. \]

**Theorem 2.1.1:** (Nzimbi et al., 2008)

*Almost similarity of operators is an equivalence relation.*

**Proof:** (Nzimbi et al., 2008)

(i) Let $A \in B(H)$, then $A^*A = N^{-1}(A^*A)N$, where $N$ is an invertible operator. Also, $A^* + A = N^{-1}(A^* + A)N$. Hence $A^{as}A$.

(ii) Now suppose that $A^{as}B$, there exist an invertible operator $N$ such that

\[ A^*A = N^{-1}(B^*B)N \]

\[ A^* + A = N^{-1}(B^* + B)N \] (1)

And

\[ B^*B = M^{-1}(A^*A)M, \quad B^* + B = M^{-1}(A^* + A)M, \]

where $N = M^{-1}$ which is an invertible operator, since $N^{-1}$ is invertible. Hence $B^{as}A$.

(iii) Let $A, B, C$ be in $B(H)$. Suppose that $A^{as}B$ and $B^{as}C$. Then we have

\[ A^*A = N^{-1}(B^*B)N, \quad A^* + A = N^{-1}(B^* + B)N \] (2)

\[ B^*B = M^{-1}(C^*C)M, \quad B^* + B = M^{-1}(C^* + C)M \] (3)

Where $M$ and $N$ are invertible operators. Using (3) and (4) we have that

\[ A^*A = N^{-1}[M^{-1}(C^*C)M]N = (MN)^{-1}C^*C(MN) = S^{-1}(C^*C)S \]

\[ A^* + A = N^{-1}[M^{-1}(C^* + C)M]N = (MN)^{-1}C^* + C(MN) = S^{-1}(C^* + C)S \]

where $S = MN$, is invertible since $M$ and $N$ are invertible. It then follows that $A^{as}C$.

**Theorem 2.1.2:** (Campbell & Gellar, 1977)

An operator $T \in B(H)$ is Hermitian if and only if $(T + T^*)^2 \geq 4T^*T$.

Theorem 2.2.2 helps us to prove the following results, where we assume the equality sign of this theorem.

**Proposition 2.1.3:** (Nzimbi et al., 2008)

*If $A, B \in B(H)$ such that $A^{as}B$ and $B$ is Hermitian, then $A$ is Hermitian.\)*

**Proof:** (Nzimbi et al., 2008)

Since $A^{as}B$ there exist an invertible operator $N$ such that $A^*A = N^{-1}(B^*B)N$, on multiplying both sides by 4, we have

\[ 4A^*A = N^{-1}(4B^*B)N \] (1)

Also $A^{as}B$, implies $A^* + A = N^{-1}(B^* + B)N$, on squaring both sides, we obtain,
Thus
\[ N^{-1}(B^* + B)^2 N = (A + A^*)^2 \] \hspace{1cm} (2)
Since B is Hermitian, we have that (B + B*)^2 = (2B)^2 = 4B^2 = 4B* B. Substituting this in (2) we get
\[ (A + A^*)^2 = N^{-1}(4B*B)N \] \hspace{1cm} (3)
From (1) and (3) we have 4A*A = (A + A*)^2 which shows that A is Hermitian, by
Theorem 2.1.2.

**Proposition 2.1.4:** (Musundi et al., 2013)
If \( A, B \in B(H) \) such that A and B are unitarily equivalent, then \( A^{a-s} B \).

**Proposition 2.1.5:** (Nzimbi et al., 2008)
If \( A, B \in B(H) \) such that \( A^{a-s} B \), and if A is Hermitian, then A and B are unitarily equivalent.

**Proof:** (Nzimbi et al., 2008)
By assumption, there exists an invertible operator N such that \( A^* + A = N^{-1}(B^* + B)N \). Since A is Hermitian and \( A^{a-s} B \) by proposition 2.1.3, B is Hermitian. Thus we have \( 2A = N^{-1}2BN \) which implies that \( A = N^{-1}BN \). This implies that, A and B are similar and since both operators are normal (both A and B are Hermitian), they are unitarily equivalent.

**Remark 2.1.6:** (Nzimbi et al., 2008)
The above proposition gives a condition under which almost similarity of operators implies similarity.

**Theorem 2.1.7:** Fuglede Commutativity Theorem (Rudin, 1991)
Assume that \( A, B, T \in B(H) \), where A and B are normal, and \( AT=TB \). Then \( A^*T = TB^* \).

**Theorem 2.1.8:** (Nzimbi et al., 2008)
If \( T \in B(H) \) is invertible, then T has a unique polar decomposition \( T = UP \), with U an isometry (which is in fact a unitary) and \( P \geq 0 \). If \( T \in B(H) \) is normal, then T has a polar decomposition \( T = UP \) in which U and P commute with each other and T.

**Theorem 2.1.9:** (Nzimbi et al., 2008)
Suppose \( A, B, T \in B(H) \), and T is invertible, and \( A = TBT^{-1} \). If \( T = UP \) is the polar decomposition of T, then \( A = UBU^{-1} \).

**Remarks 2.1.10:** (Nzimbi et al., 2008)
This theorem asserts that similar normal operators are actually unitarily equivalent .The following results shows that unitary equivalence preserves normality of operators.

**Theorem 2.1.11:** (Sitati et al., 2013)
If \( T \) is a normal operator and \( S \in B(H) \) is unitarily equivalent to T, then S is normal.

**Theorem 2.1.12:** (Nzimbi et al., 2013)
Two similar normal operators S and T are unitarily equivalent.

**Remark 2.1.13:** Having looked at the properties of almost similarity operators, we will employ these properties and from the definition of a metric equivalence relation to establish conditions when almost similarity implies metric equivalence.

**Metric Equivalence of Some Operators**
Recall that two operators \( A \in B(H) \) and \( B \in B(K) \) are said to be metrically equivalent if \( \|Ax\| = \|Bx\| \), (equivalently, \( 1 < Ax, Ax > \geq \frac{1}{2} = 1 < Bx, Bx > \geq \frac{1}{2} \) for all \( x \in H \), that is \( A^*A = B^*B \))
The numerical range \( W(T) \) of an operator \( T \in B(H) \) is defined as \( w(T) = \{ \lambda \in \mathbb{C} : \lambda = < Tx, x >, \| x \| = 1 \} \) and the numerical radius \( r(T) \) of T is defined as \( r(T) = \sup \{ \lambda : \lambda \in W(T) \} \). (Kubrusly, 1997)
An operator $T$ is said to be normaloid if $r(T) = \|T\|$, (equivalently, $\|T^n\| = \|T\|^n$). In complex Hilbert space $H$, every normal operator is normaloid and so is every positive operator.

**Theorem 2.2.1:** (Nzimbi et al., 2013)
If $T$ is a normal operator and $S \in \mathcal{B}(H)$ is unitarily equivalent to $T$, then $S$ is normal.

**Theorem 2.2.2:** (Dragomir, 2007)
A necessary and sufficient condition that an operator $T \in \mathcal{B}(H)$ be normal is that $\|Tx\| = \|T^*x\|$ for every $x \in H$.

**Corollary 2.2.3:** (Nzimbi et al., 2013)
An operator $T \in \mathcal{B}(H)$ is normal if and only if $T$ and $T^*$ are metrically equivalent.

**Theorem 2.2.4:** (Nzimbi et al., 2013)
If $T$ is a normal operator, then there exist a unitary operator $U$ such that $T^* = UT$.

**MAIN RESULTS**

**Relationship between metrically equivalence operator and almost similarity operators.**
To show this relationship we need the following results:

**Theorem 3.1.1:** (Nzimbi et al., 2013)
Two operators $A \in \mathcal{B}(H)$ and $B \in \mathcal{B}(K)$ are said to be **metrically equivalent** if $\|Ax\| = \|Bx\|$, (equivalently, $1 < Ax, Ax > 1^2 = 1 < Bx, Bx > 1^2$ for all $x \in H$, that is $A^*A = B^*B$).

**Corollary 3.1.2:** (Nzimbi et al., 2013)
If $S$ and $T$ are metrically equivalent normal operators, then there exist a unitary operator $U$ such that $S = UT$.

**Theorem 3.1.3:** (Nzimbi et al., 2013)
If $T$ is a normal operator, then there exist a unitary operator $U$ such that $T^* = UT$.

**Corollary 3.1.4:** (Nzimbi et al., 2013)
An operator $T \in \mathcal{B}(H)$ is normal if and only if $T$ and $T^*$ are metrically equivalent.

**Theorem 3.1.5:** (Jibril, 1996),
Two operators $A$ and $B$ are said to be **almost similar** if there exists an invertible operator $N$ such that the following conditions are satisfied:

$A^*A = N^{-1}(B^*B)N$

$A^* + A = N^{-1}(B^* + B)N$

**Proposition 3.1.6:** (Nzimbi et al., 2008)
If $T, S \in \mathcal{B}(H)$ such that $T^{a_2}S$ and $S$ is Hermitian, then $T$ is Hermitian.

**Corollary 3.1.7:** All hermitian operators are normal.

**Corollary 3.1.8:** (Nzimbi et al., 2013)
An operator $T \in \mathcal{B}(H)$ is normal if and only if $T$ and $T^*$ are metrically equivalent.

**Definition 3.1.9:** An operator $P$ is said to be a projection operator if $P = P^*$ and $P = P^2$.

**Theorem 3.1.10:** (Dragomir, 2007)
A necessary and sufficient condition that an operator $S \in B(H)$ be normal is that $\| Sx \| = \| S^*x \|$ for every $x \in H$.

Thus our main results follows:

**Theorem 3.2.1:** If $S, T \in B(H)$ such that $S \sim T$, then $S$ and $T$ are metrically equivalent.

**Proof**
Suppose $S, T \in B(H)$ such that $S \sim T$ and let $S$ be Hermitian. An operator $S$ is said to be Hermitian if $S = S^*$. We note that $S$ and $T$ are said to be *almost similar* if there exists an invertible operator $N$ such that the following conditions are satisfied:

- $S^*S = N^{-1}(T^*T)N$
- $S^* + S = N^{-1}(T^* + T)N$

Assume that there exist an invertible operator $N$ such that $S^* + S = N^{-1}(T^* + T)N$. Since $S$ is Hermitian and $S \sim T$, then by Proposition 4.1.6 $T$ is Hermitian. Thus we have $2S = N^{-1}2TN \Rightarrow S = N^{-1}TN$. So that $S$ and $T$ are similar and being Hermitian operators it means they are also normal, so they are unitarily equivalent. i.e. $S = U^*TU$.

Now if $S = U^*TU$ then $S^* = U^*T^*U$.

Let $x \in H$ and since $S$ is normal then by Theorem 4.1.10, $\| Sx \| = \| S^*x \|$

By the definition of a norm

$\| Sx \|^2 = < Sx, Sx >$

$= < S^*Sx, x >$

$= < U^*T^*UU^*TUX, x >$

$= < U^*T^*TUX, x >$ by theorem 4.1.3 we get

$= < U^*UT^*U^*Ux, x >$

$= < TT^*x, x >$ but since $T$ is normal then $TT^* = T^*T$ then, we have

$= < T^*Tx, x >$

$= < Tx, Tx > = \| Tx \|^2$ so that

$\| Sx \| = \| Tx \|$

Thus $S$ and $T$ are metrically equivalent.

**Theorem 3.2.2:** If $T$ and $S$ are metrically equivalent projections operators, then $T$ and $S$ are almost similar.

**Proof**
Suppose that $T$ and $S$ are metrically equivalent projections operators. We recall that an operator $T$ is said to be a projection operator if $T = T^*$ and $T = T^2$.

Since $T$ and $S$ are projections ($T = T^*$ and $T = T^2$, $S = S^*$ and $S = S^2$) then they are self-adjoint and by Corollary 4.1.7 it implies that they are normal operators.

Since $T$ and $S$ are normal operators then they exist a unitary operator $U$ such that $T^* = UT$.

Thus $S$ being a projection operator, self-adjoint and also metrically equivalent to $T$, we have $S = S^2 = S^*S = T^*T = UTT^*U^* = UT^2U^* = UTU^*$ i.e. $S = UTU^*$, which shows that $S$ and $T$ are unitarily equivalent.

Again since $S = UTU^*$ then $S^* = U^*T^*U$ and thus

$S^*S = U^*T^*UU^*TU = U^*T^*TU = U^{-1}T^*TU$ ........................................(i)

$S^* + S = U^*T^*U + U^*TU = U^*(T^* + T)U = U^{-1}(T^* + T)U$ ...................................(ii)
Equation (i) and (ii) shows that $S^{-a}T$.

**Remark.** For two operators that are metrically equivalent to imply almost similarity, then the two operators must be projection operators. This gives the condition under which metric equivalence implies almost similarity.

**Corollary 3.2.3:** Two metrically equivalent operators implies almost similarity if and only if they are projection operators.

**REFERENCES**


DIVERSITY OF HARMFUL CYANOBACTERIA IN THE ECONOMIC STIMULUS PROGRAMME FISH PONDS IN THARAKA-NITHI COUNTY

Kibaara, D.I., Magana, A.M., Githae, E.W. and Onyango, B.O.
Chuka University, P. O. Box 109-60400, Chuka

ABSTRACT
Cyanobacteria are important primary producers in aquatic ecosystems through the autotrophic pathway. However, bloom forming cyanobacteria pose a danger to fish and human health in artificial fish ponds as a result of cyanotoxins they produce. In Tharaka-Nithi County, the Government of Kenya established the Economic Stimulus Programme (ESP) fish ponds in 2009, although the ponds have since experienced unexplained fish deaths and low annual fish yields. It is still unclear the cause of such deaths and its association with seasons of high cyanobacterial blooms. Determination of cyanobacterial diversity in the ESP fish ponds of Tharaka Nithi County is necessary in order to delineate harmful forms and determine the nature of toxins they produce. Diversity studies based on microscopy may be inconclusive since morphological features are influenced by growth and environmental conditions which preclude it as a valuable taxonomic criterion. A combination of morphological studies and the more accurate molecular markers has the potential to resolve such taxonomic inconsistencies, since the polyphasic framework can provide correspondence between data inferred from genotypes and phenotypes. The objective of this study was to determine the genetic diversity amongst cyanobacteria populations within six ESP fish ponds in Tharaka-Nithi County. Water samples from the study sites were collected, centrifuged, membrane-filtered and the concentrate subjected to DNA extraction. The genomic DNA was subjected to PCR analysis using 16S rRNA primers specific to cyanobacteria. PCR products were sequenced at Segolip Sequencing Unit, BecA-ILRI Hub, and the sequences analyzed on CLC Main Workbench and MEGA Version 6.0 software.

There was marked heterogeneity in the 16S rRNA gene analysis of the cyanobacterial isolates. Individual genera identified included Microcystis (51.8%), Anabaena (24%), Planktothrix (11.5%), Nostoc (7.4%), Oscillatoria (3.2%), Chroococcus (2.1%) and Aphanizomenon. Among the species Microcystis aeruginosa was the most dominant (68.7%), followed by Anabaena circinalis (22.4%). The two species increased in population with increased water pollution, which indicates possible contamination of the ESP ponds with inorganic fertilizers from surface run-offs or leached materials from agricultural lands. This study provides opportunities for controlling harmful cyanobacteria and thereby increasing fish yields which may improve food security in the region.

Keywords: Cyanobacteria, molecular diversity, fish ponds

INTRODUCTION
Blue green algae (Cyanobacteria) are integral to fish production as sources of natural food for fish and other aquatic animals. The presence of cyanobacteria in aquatic systems enhance productivity in artificial fish ponds which require over 13 mg/l in dry biomass for sustainable fisheries (Egna & Boyd, 1997). Cyanobacterial abundance has been used to estimate potential fish yields (Andon et al., 2012). Despite the important nutritional role, some bloom forming cyanobacteria have undesirable effects on fish, the environment and human health (Zimba et al., 2001; Reichwaldt & Ghadouani, 2012), through production of toxic secondary metabolites known as cyanotoxins (Tucker, 2008). Many bloom-forming species produce toxins and the type of toxins produced are dependent on the species composition of the group (Parulekar et al., 2017). Cyanobacterial genera such as Aphanizomenon, Anabaena, Oscillatoria, Microcystis and Cyclindrospermopsis produce harmful algal blooms (HABs) with varying concentrations of cyanotoxins (Carmichael, 1992), with a potential to kill aquatic organisms (Shumway, 1990). In Sri Lanka, fish deaths due to HABs was observed to increase with increased entry of phosphorus and nitrogen from agricultural farms (Svrcek and Smith, 2004). Besides, HABs lead to decreased growth rates of aquatic organisms, result in challenges with human food safety and negatively affect water quality through undesirable odors and tastes (Tucker, 2008). Cyanotoxins may be hepatoxic, neurotoxic or irritants and cause death of fish after intraperitoneal injection (Sivonen and Jones, 1999). Marzouk et al., (2013) showed that ingestion of toxic cyanobacteria causes stress, sluggish movements and reduced...
reflexes accompanied by a reduction in overall health in *Oreochromis niloticus*. Blooms due to cyanobacteria often lead to increased turbidity of the water which greatly reduces the amount of light reaching the bottom of the pond and in turn to lower photosynthesis and in effect, the amount of energy available to the grazers.

Cyanobacteria are a morphologically diverse group of organisms ranging from unicellular to filamentous forms. Their morphology depends on environmental conditions with colours ranging from dark green, blue-green, yellow, brown to black, and rarely red (Konstantinos *et al*., 2011). Traditionally, classification of cyanobacteria has been based on morphological characters. However, diversity studies based on morphology may be inconclusive since such features are influenced by growth and environmental conditions which precludes it as a valuable taxonomic criteria. For instance, cyanobacteria with the same genetic makeup may appear quite different under various physiological conditions as a result of differential gene expression (Jahan *et al*., 2010). Thus, a combination of morphological studies and the more accurate molecular markers has the potential to resolve such taxonomic inconsistencies, since the polyphasic framework can provide correspondence between data inferred from genotypes and phenotypes. Recent studies using 16S rRNA gene sequencing have extended the knowledge of the phylogenies (Lyra *et al*., 2001). The 16S rRNA gene is fairly constant and universal to bacteria making random sequence changes accurate measures of evolution, and the gene is large enough for informatics analyses (Patel, 2001). Furthermore, the comparative analyses of 16S rRNA gene sequences provide a novel approach to investigate the difference between strain collections and natural communities (Ferris *et al*., 1996).

The Government of Kenya through the Economic Stimulus Programme (ESP) established 900 fish ponds in Tharaka-Nithi County in 2009 (Republic of Kenya, 2011). Despite this investment, fish yields from the ponds has been below potential and has not contributed to the envisaged boost in food security. Frequent and sudden fish deaths have occurred in most ponds which, invariably coincide with the acquisition of a green coloration of pond water. It is not clear if such deaths are due to water toxicity due to HABs. The primary objective of this study was to assess cyanobacteria diversity within the ESP fish ponds of Tharaka Nithi County and to identify cyanotoxin producing species in order to help mitigate potential harmful effects to fish and improve overall human health.

MATERIALS AND METHODS
Cyanobacterial strain isolation
A total of 18 isolates were obtained from five ESP fish ponds located between longitudes 37° 18” and 37° 28” East and receives bi-modal rainfall patterns between March to May and October to December (Republic of Kenya, 2007). The isolates were distinguished based on the pond from which they were derived as follows; Itugururu (A1, A2, A3 and G1, G2, G3), Fisheries (F1, F2 and F3), Tunyai (K1, K2, K3) Kiaritha (R1, R2, R3), and Church ponds (C1, C2, C3). Pure cultures were isolated through serial dilution on BG11 medium optimized for cyanobacteria following standard methods (Andersen *et al*., 2005) and maintained in 100 ml test tubes under laboratory conditions; temperature 22 ± 1 °C and light regime of 12h light/12h dark. Growth of selected isolates are as shown in Plate 1.

Plate 1. Pure cultures of cyanobacteria on BG11 media.
DNA extraction and PCR analysis

For DNA extraction, 100 ml pure isolates were centrifuged individually at 10,000 revolutions per minute for 50 min in an Avanti J-26XP (Beckman Coulter, Atlanta, GA, USA) centrifuge. The pellets were collected and the supernatant filtered through 0.22-μm membranes. DNA was extracted from the pellet and filters with a DNA Isolation kit. The concentration and purity of DNA was estimated using a Nanodrop™ Lite Spectrophotometer (Thermo Scientific Inc, USA) at 260-280 nm and by horizontal gel electrophoresis (Thistle Scientific Ltd, USA) on a 0.8% (w/v) agarose gel at 100 V for 30 min and visualized under UV after staining with GelRed™ (Thermo Scientific, USA). About 20 ng of each pooled DNA sample was used as template in PCRs with cyanobacteria forward primers CYA359F (5′-GGGGAAATCTTCCGCAATGGG-3′) along with the reverse primers; CYA781Ra (5′GACTACAGGGGTATCTAATCCCTT-3′) and CYA781Rb (5′GACTACTGGGTATCTAATCCCTT-3′) to amplify the 16S rDNA genes in cyanobacteria and in chloroplasts of eukaryotic phytoplankton. The reaction contained template 2-μl of the DNA, 25-μl of PCR buffer, 0.5-μl of 10 mM each primer, 1-μl of 2 mM dNTPs, 2.5-μl 100×EDTA, 0.5-μl Taq polymerase (TaKaRa Bio Inc, Japan), and 11.5-μl dH₂O. The reaction was run in a Master thermocycler (C1000-BioRad, USA) with an initial 2 min denaturation at 94°C, followed by 30 cycles of 30 sec at 94°C, 30 sec at 55°C, and 30 sec at 72°C. PCR products were separated by horizontal gel electrophoresis on 1.5% (w/v) agarose gel at 100 V for 1 hour and visualized under UV after staining with 2 μl GelRed™ (Thermo Scientific). Capillary sequencing of 10 μl PCR aliquots was conducted with similar PCR primers at Segolip Sequencing Unit, BecA-ILRI Hub, on a 3730xl DNA Analyzer (Thermo Fisher Scientific Inc. USA). Forward and reverse sequences were assembled and trimmed on CLC Main Workbench (CLC Bio, Version 6.8.3). Assembled sequences were transferred to MEGA Version 6.0 software and aligned using CLUSTAL W according to Tamura et al., (2011). Additional sequences for further phylogenetic analysis were obtained from GenBank (http://www.ncbi.nlm.nih.gov/) NCBI BLAST portal using the following criteria: sequences had to be sufficiently long (at least 1400 bp) and were obtained from freshwater species of cyanobacteria with at least 95% similarity index. The 16S rRNA sequence NR_074282 of Gloeobacter violaceus strain PCC7421 was used as outgroup. Evolutionary histories were inferred using the Neighbour-Joining method and distances computed using the Maximum Composite Likelihood (Tamura and Kumar, 2004).

RESULTS

Analysis of 16S rRNA genes

The PCR reactions yielded a partial 16S rRNA gene (size appx. 1400 bp) from every isolate. The DNA profiles for 12 isolates are as indicated on Plate 2.

![Plate 2. Profiles of Cyanobacterial DNA profiles obtained from 12 isolates](image-url)
**Identities of cyanobacterial species**

Results of BLAST analysis revealed marked heterogeneity amongst cyanobacteria from ESP ponds of Tharaka Nithi County compared to sequences deposited in the GeneBank as shown on Table 1. Isolates A2, C2, K1 and K3 were identified as *Microcystis aeruginosa* at 100%, 98%, 100% and 96% similarity values with GenBank sequences. *Microcystis aeruginosa* was the most dominant cyanobacterial species, occurring in all the fish ponds except at Fisheries and Kiaritha. Three species of *Oscillatoria* were identified including *O. nigriviridis* (A1) from Itugururu fish pond, *O. sancta* (F1) from Fisheries pond and *O. lutea* (R2) from Kiaritha fish pond with maximum identity values of 98%, 98% and 100% respectively. *Planktothrix pseudaghardhii* (A3 and K2 detected at 100% and 99% similarity indices) was the only member of the *Planktothrix* genus and were obtained from Itugururu and Tunyai fish ponds respectively. Two *Nostoc* species were identified, including *Nostoc commune* (C1 at 97% similarity) and *Nostoc calcicola* (F2 at 96% similarity), although isolate G3 identified as *Nostoc* sp. was not resolved to the species level. Other cyanobacterial species identified were *Chroococcus* sp. (G1 and G2 at 95% similarity index), *Aphanizomenon flos-aquae* (R1 at 100% similarity index) and *Aphanizomenon* sp. (F3 at 99% similarity index). One *Anabaena inaequalis* (R3) was detected at 97% similarity.

**Table 1.** Identified cyanobacteria from ESP fish ponds in Tharaka Nithi County

<table>
<thead>
<tr>
<th>Pond of origin</th>
<th>Isolate</th>
<th>Species identity</th>
<th>NCBI acc. with maximum identity</th>
<th>Percentage identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itugururu</td>
<td>A1</td>
<td><em>Oscillatoria nigriviridis</em></td>
<td>EU244875.1</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td><em>Microcystis aeruginosa</em></td>
<td>D89031.1</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>A3</td>
<td><em>Planktothrix pseudaghardhii</em></td>
<td>FJ184443.1</td>
<td>100%</td>
</tr>
<tr>
<td>Church ponds</td>
<td>C1</td>
<td><em>Nostoc commune</em></td>
<td>AB088375.2</td>
<td>97%</td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td><em>Microcystis aeruginosa</em></td>
<td>D89031.1</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td><em>Microcystis viridis</em></td>
<td>D89033.1</td>
<td>100%</td>
</tr>
<tr>
<td>Fisheries</td>
<td>F1</td>
<td><em>Oscillatoria sancta</em></td>
<td>NR_114511.1</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>F2</td>
<td><em>Nostoc calcicola</em></td>
<td>HM573461.1</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td>F3</td>
<td><em>Aphanizomenon</em> sp.</td>
<td>FJ234882.1</td>
<td>99%</td>
</tr>
<tr>
<td>Itugururu</td>
<td>G1</td>
<td><em>Chroococcus</em> sp.</td>
<td>KP890780.1</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td><em>Chroococcus</em> sp.</td>
<td>KP890780.1</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>G3</td>
<td><em>Nostoc</em> sp.</td>
<td>LC228974.1</td>
<td>96%</td>
</tr>
<tr>
<td>Tunyai</td>
<td>K1</td>
<td><em>Microcystis aeruginosa</em></td>
<td>D89031.1</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>K2</td>
<td><em>Planktothrix pseudaghardhii</em></td>
<td>FJ184422.1</td>
<td>99%</td>
</tr>
<tr>
<td></td>
<td>K3</td>
<td><em>Microcystis aeruginosa</em></td>
<td>D89031.1</td>
<td>96%</td>
</tr>
<tr>
<td>Kiaritha</td>
<td>R1</td>
<td><em>Aphanizomenon flos-aquae</em></td>
<td>HG917867.1</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>R2</td>
<td><em>Oscillatoria lutea</em></td>
<td>AB115967.1</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>R3</td>
<td><em>Anabaena inaequalis</em></td>
<td>KT290324.1</td>
<td>97%</td>
</tr>
</tbody>
</table>

**Variation in cyanobacteria genera**

The most abundant genera identified was *Microcystis* (27.77%) followed by *Oscillatoria* and *Nostoc* (16.67%), *Planktothrix*, *Aphanizomenon*, and *Chroococcus* (11.1%) while the least abundant group was *Anabaena* (5.55%) as shown in Fig. 1.
Fig. 1. Distribution of Cyanobacterial genera detected in the ESP fish ponds of Tharaka Nithi County

Phylogenetic analysis of cyanobacteria

The phylogenetic tree (Fig. 2) built from 18 cyanobacterial sequences generated from this study and similar sequences retrieved from the NCBI portal with the highest query coverage resulted in four distinct groups A, B, C and D. Group A constituted members of *Aphanizomenon, Nostoc* and *Anabaena* species that diversified into three sub-clades at 100% bootstrap support. In sub-clade AI were isolates from Fisheries and Kiaritha ponds; F3 and R1 identified as *Aphanizomenon flos-aquae* and *Aphanizomenon* sp. respectively. The two isolates clustered with GeneBank sequences FJ234882.1 and HG917867.1 at 83% and 100% bootstrap support values. Isolate R3 from Kiaritha fish pond, identified as *Anabaena inaequalis* occurred in sub-clade AII with sequence KT290324.1 from the GeneBank at 100% bootstrap support. Four isolates were in subclade AIII, including G3, from Itugururu identified as *Nostoc* sp. similar to LC228974.1 at 100% bootstrap support, F2 from Fisheries identified as *Nostoc calcicola* similar to HM573461.1 at 100% bootstrap support and C1 from Church ponds identified as *Nostoc commune* similar to D89031.1 at 100% bootstrap support. In Clade B, there were only two isolates (A3 and K2) from Itugururu and Tunyai both identified as *Planktothrix pseudagardii*, with closest similarity to FJ184443.1 and FJ184422.1 at bootstrap support values of 100%. Clade C had isolates R2, F1, A1 obtained from Kiaritha, fisheries and Kitugururu clustered with AB115967.1, NR_114511.1 and EU244875.1 which belonged to the species *Oscillatoria lutea*, *Oscillatoria sancta* and *Oscillatoria nigriviridis* respectively. Clade D had two subclades DI and DII. Subclade DI consisted of two isolates (G1 and G2 from Itugururu) identified as *Chroococcus* sp. similar to the GeneBank sequence KP890780.1 at 100% bootstrap support. Within subclade DII, only isolate C3 obtained from Church ponds was determined as *Microcystis viridis* while the rest K3, A2, K1 and C2 from Tunyai, Church ponds and Itugururu identified as *Microcystis aeruginosa*. The former isolate had 89% bootstrap support similarity to the sequence D89033.1, while the latter clustered with sequence D89031.1 at 100% and 92% bootstrap support values respectively.
Fig. 1. A Neighbour-joining phylogenetic tree of Cyanobacterial species from ESP ponds of Tharaka-Nithi County.

The optimal tree with the sum of branch length = 0.77044812 is shown. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) are shown above the branches. The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were computed using the Maximum Composite Likelihood method and are in the units of the number of base substitutions per site.

DISCUSSION
Cyanobacteria play a key role in the functioning of many ecosystems and because they produce toxins they are potentially harmful organisms. Despite their importance, however, many aspects of their biodiversity and ecology are poorly understood. Routine species identification, mostly using morphology-based classifications, may not provide sufficient taxonomic resolution as cyanobacteria with similar or identical morphology can differ significantly in their physiology. In recent years, the analysis of 16S rRNA gene sequences has demonstrated that the morphological classification of cyanobacteria in some cases corresponds to phylogenetically coherent taxa (Garcia-Pichel et al. 1996), whereas in other cases the traditional classification greatly underestimates extant diversity (Ferris et al. 1996). According to Komařek & Anagnostidis (1999) until now, seven species of cyanobacterium have been delineated from very different habitats that range from freshwater to saline or thermal places. In this study, 18 isolates from Economic Stimulus Package fish ponds of Tharaka Nithi County were evaluated. There was marked heterogeneity in the 16S rRNA gene analysis of the cyanobacterial isolates. Individual genera identified included Microcystis (27.77%), followed by Oscillatoria and Nostoc (16.67%), Planktothrix, Aphanizomenon and Chroococcus (11.1%) while the least abundant group was Anabaena (5.55%). Amongst the cyanobacteria detected, Microcystis, Oscillatoria and Chroococcus are known toxin producers. Microcystis which was the most abundant species detected produces microcystin, cytotoxic linear lipopeptide (Eric et al., 2007) implicated in fish deaths (Lyra et al., 2001). Microcystins absorbed into cells through membrane transporters which otherwise carry essential biochemicals or nutrients. A study by Luo et al., (2017) observed that the population of Microcystis aeruginosa increases with increased water pollution, which indicates possible contamination of the ESP fish ponds with inorganic fertilizers from surface run-offs or leached materials from agricultural lands. Chroococcus produces the neuro-toxic β-N-methylamino-L-alanine and 2,4 diaminobutyric acid (Paul et al., 2009) which previously caused human poisoning with symptoms of nausea, vomiting and muscle weakness (Azevedo et al., 2002). A neurotoxic compound known as anatoxin-a has been detected in food samples containing Planktothrix and Oscillatoria, which was fed to dogs and led to death due to acute neurotoxicosis (Birgit et al., 2008). It is however useful to further determine cyanobacterial concentration in fish samples in order to correlate fish deaths with the toxins.

ACKNOWLEDGEMENT
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REFERENCES
TOWARDS FUZZY LOGIC IN VIRTUAL ENTERPRISES PROBLEM

Musumba, W. G* and Wario, D. Rb

*Department of Computer Science, Dedan Kimathi University of Technology, P.O. Box 657-10100, Nyeri, Kenya; george.musumba@dkut.ac.ke
bDepartment of Computer Science and Informatics, University of Free State, Private Bag X13 Kestell 9866-South Africa. Email: wariord@ufs.ac.za

Abstract
The trend where enterprises outsource competencies is getting replaced by strategic alliances, where enterprises work together towards a common goal and share responsibilities as well as their profits. This calls for new ways of organizing work and the technological support that allows flexibility. A Virtual Enterprise (VE) is a temporary organization that pools together different member enterprise core competencies. The construction industry is a key sector in any economy. A construction project is implemented by a team of professionals and an alliance of companies. A crucial competitive factor of a VE is its ability to form an end-user focused team which can be jeopardized if the right team is not formed. This can be attributed to poor choice of partners for the tasks due to insufficient information available about partners and lack of facilitation techniques. This study proposed definition of multiple criteria decision making problem for construction projects. A multi criteria decision making technique is designed that can be applied to derive each partner's weight and determine the best partner that is eventually selected for each task. A technique that incorporates fuzzy logic in Analytic Hierarchy Process to be used by construction industry project initiators to effectively evaluate and select right partners for tasks when information available about partners is insufficient. Incorporating fuzzy logic in decision making techniques can address the partners’ evaluation and selection process reliability issue.

Keywords: Multi-criteria decision making, Fuzzy analytical hierarchy process, Partners evaluation, Selection problem.

INTRODUCTION
Recently, large, medium and small sized enterprises are teaming up to enhance their competitiveness in the market-place and adapt to the rapid changes of technological innovation. Organizations enhance their competitive ability in the market-place by creating effective relationships with others. A Virtual Enterprise (VE) is a temporary organization that pools together different member enterprise core competencies (Crispim & de Sousa, 2009). VEs offer new opportunities (for developing products) to companies operating within an environment with a growing number of participants, such as, contractors, service providers, agencies and others.

A typical application area for the VE paradigm is in industrial manufacturing. Nowadays, most manufacturing processes are not carried out on a single line. Companies tend to focus on their core competencies and join efforts with others, in order to fulfill the requirements of new products and associated services demanded by the market. In a VE, every enterprise is just a node that adds some value to the process. Although most classic examples of cooperative networked organizations can be found in some particular business domains such as the automotive industry, this tendency is spreading to many other areas including the food and agribusiness industry (Camarinha-Matos et al., 1997), electronics (Azevedo et al., 1998) and civil engineering (Zarli & Poyet, 1999).

Similar to manufacturing industries, the need to remain competitive in the market also forces service provider companies to seek alliances outside their core competencies when additional skills / resources are needed to fulfill business opportunities. For instance, travel agencies typically offer aggregated or value-added-services composed of components supplied by a number of different organizations. To “book a complete journey plan”, services may include several means of traveling, several hotel bookings, car rentals and leisure tour bookings. A networked cooperation must exist among the many different organizations (Afsarmanesh & Camarinha-Matos, 2000) to enable collaboration.
Building and Construction Industry in Kenya

Kenya has a well-developed building and construction industry with quality engineering, building and architectural design services. The construction industry is a key sector in Kenya economy and has consistently posted high growth (Kenya Economic Survey, 2016; Kenya Economic Report, 2016). The industry also offers direct employment to a significant proportion of the labour force spread throughout the country. The growth in construction in 2016 was 9.2% from an expansion of 13.9% registered in 2015. According to Kenya Economic Survey (2017), there was increased activity in the construction of roads and development of housing that translated to an increase in employment in the sector from 148.6 thousand jobs in 2015 to 163,000 jobs in 2016.

The growth in real estate and the property sector were mainly driven by demand for new office space and urban housing. Among the infrastructure that contributed significantly to this growth were earthworks construction for the Standard Gauge Railway (SGR) between Mombasa and Nairobi, the ongoing construction of roads and energy infrastructure, and expansion of airports. The improvement of the port of Mombasa also contributed to the sector’s growth through the construction work for the second container terminal, infrastructural modifications of berths and construction of a new access road (Kenya Economic Survey, 2016). Reported building plans approved increased in value by 43.3 per cent from KSh 215.2 billion in 2015 to KSh 308.4 billion in 2016. Also reported building works completed decreased in value to 24.7 per cent of the approved building plans in 2016, compared to 32.9 per cent in 2015. There was significant increase in value of public buildings completed from KSh 61.5 million in 2015 to KSh 3.8 billion in 2016. Furthermore, new private buildings in Nairobi City County's value went up by 7.5 per cent from KSh 70.9 billion in 2015 to KSh 76.2 billion in 2016, on account of continued increase in construction of both residential and non-residential buildings. These reports are disseminated in the Kenya Economic Survey (2017).

This sector has attracted a lot of interests from local and foreign investors as seen from the massive projects that have either been completed, are undergoing implementation or are scheduled to take off (World Bank Report [WBR], 2014; Kenya National Bureau of Statistics [KNBS] Report, 2016). Another major beneficiary of the boom in the construction industry was the financial intermediation industry where the commercial banks’ loans and advances to construction and real estate sectors grew by 13.6 and 32.4 per cent, respectively, in 2014. Total government expenditure on transport infrastructure was projected to quadruple from KSh 84.5 billion in 2013/2014 to KSh 250.5 billion in 2014/2015 (Kenya Economic Survey, 2015).

In Table 1 presentation of a detailed analysis of selected key economic indicators in the Building and Construction sector for the period 2012 to 2016 is made. The Government expenditure index on roads increased from 350.3 in 2015 to 461.0 in 2016 following an increase in road construction projects. The reported private building works completed in Nairobi City County index rose from 369.4 in 2015 to 407.1 in 2016. Similarly, an increase in the index was registered in public building works reported to have been completed in major towns. This increase was from 112.6 in 2015 to 138.9 in 2016. A rise was also noted in the consumption of cement, a major input in construction of buildings and civil works. Table 1 shows that the rise was by 10.5 per cent from 5,708.8 thousand tonnes in 2015 to 6,302.0 thousand tonnes in 2016. A decrease of credit to the construction industry was marginal to KSh 104.8 billion in 2016 from KSh 106.3 billion in 2015. Employment in the sector grew by 10.1 per cent from 148.1 thousand persons recorded in 2015 to 163.0 thousand persons in 2016.

Table 1. Selected key economic indicators in building and construction, 2012-2016 (KNBS, 2017) 1982=100

<table>
<thead>
<tr>
<th>Indicator/Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index of reported private building completed in major towns</td>
<td>300.6</td>
<td>321.3</td>
<td>341.4</td>
<td>369.4</td>
<td>407.1</td>
</tr>
<tr>
<td>Index of reported public building completed in major towns</td>
<td>86.9</td>
<td>103.7</td>
<td>106.1</td>
<td>112.6</td>
<td>138.9</td>
</tr>
</tbody>
</table>
A construction project is implemented by a team of professionals and an alliance of companies (Talukhaba, 1999). Alliance of companies is formed by consultants who evaluate contractors for specific project tasks. Consultants are hired by the client to manage the project on their behalf. The needs of the construction industry have been changing from time to time. Talukhaba (1999) while investigating factors causing construction projects delays in Kenya, observed that the factors are associated with the project participants, the process and the environment of project implementation. Factors are poor financial management by clients, inadequate designs and poor management of the construction process by the parties involved in project implementation. These are compounded by poor resource management such as materials and equipment by contractors, inadequate recognition and response to project risks inherent in both the physical and socioeconomic environments of the project, and inadequate regard for the role of project stakeholders by the parties involved in the project implementation process.

**THE PROBLEM**
The trend where enterprises outsource competencies is getting replaced by strategic alliances, where enterprises work together towards a common goal and share responsibilities as well as their profits. This calls for new ways of organizing work and the technological support that allows flexibility. A crucial competitive factor of a VE, is its ability to form an end-user focused team which can be jeopardized if the right team is not formed.

The construction sector’s potential contribution to growth of the economy can be enhanced given recent increased expenditure on infrastructure development, if the challenges facing the sector are effectively addressed. Delayed completion of projects (Patroba, 2012), frequent collapse of buildings (Charagu, 2013), lack of ethics (Githui, 2012), use of inappropriate specifications and manuals, incompetent design, poor supervision, use of inappropriate materials, poor coordination and management of contractors (Mambo, 2010), poor construction procedures (Kenya Engineers Report on Projects [KERP], 2006) are among the challenges facing the sector. These can be attributed to poor choice of partners for the tasks due to insufficient information available about partners and lack of facilitation techniques.

This lack of information can be attributed to the sources of information. Project initiators normally use company profiles to evaluate partners (Charagu, 2013). Information from company profiles is often insufficient and decisions made out of insufficient information are subjective. Furthermore, the choices made by project initiators do not take into account that human judgements during partner evaluation and selection are imprecise. This can lead to selection of undeserving partners because partner attributes can change during and / or after the evaluation and selection process, with the possibility of having the qualified partners being unqualified.

Evaluation and selection of a candidate among many alternative contestants is a multi-criteria decision-making (MCDM) process (Chena et al., 2009). MCDM process has been widely used in various fields such as location selection, information project selection, material selection, management decisions,
strategy selection, and problems relating to decision-making (Chiou et al., 2005). Selection of best partner among many partners for construction project is an MCDM process.

The study proposes that multiple criteria should be well defined for construction projects so that each prospective partner can be evaluated against each criterion. A multi criteria decision making technique should be designed that can be applied to derive each partner's weight and determine the best partner that is eventually selected for each project task.

Partners' evaluation and selection process reliability for construction projects can be enhanced if decision making techniques that are able to deal with subjective information (Mikhailov, 2003; Covella & Olsina, 2006) are employed. Analytic Hierarchy Process (Saaty & Kearn, 2014), Elimination EtChoix Traduisant la REalite’ (Roy, 1991), Technique for Order Preference by Similarity to Ideal Solution (Lai et al., 1994), Data Envelopment Analysis (Cook et al., 2014), Neural Networks, Weighted Linear Models, Linear Programming, Mathematical Programming (Aruldoss et al., 2013) are among multi criteria decision making techniques. However, they cannot be used to select right partners for construction projects given that company profiles used as sources of information used to evaluate potential partners have subjective information.

Incorporating fuzzy logic (Yager & Zadeh, 2012) in decision making techniques can address the partners’ evaluation and selection process reliability issue. This study proposes a framework that incorporates fuzzy logic in Analytic Hierarchy Process (AHP - a multi-criteria decision making technique) to be used by construction industry project initiators to effectively evaluate and select right partners for tasks and evaluate / predict partners' performance, even when information available about them is insufficient.

Construction Project as a Virtual Enterprise
Projects in the construction sector are implemented by multiple partners. A client hires an architect / consultant who makes designs for the project and engages other consultants to carry out the various tasks. For example, in a building construction project, the main consultant who is normally the architect, contracts civil/structural, electrical, mechanical, plumbing, interior design and landscaping engineers. They work as a team to accomplish the tasks. The main consultant selects the best engineer / engineering firm among many firms who have similar qualifications. These companies coordinate among each other.

Electrical engineering firm carries out connections to power supply, wiring, fittings and conduits. Mechanical engineering firm carries out fixing sleeves, fittings among others. Plumbing firm does pipe works, connections to external works among others. Land-scaping firm carries out earth works, planting, constructing fountain among others. Interior design firm does partitioning, paint works, furnishing and decorations.

METHODOLOGY
Multi-criteria decision making technique is designed and applied to the values assigned to selection criteria and sub criteria by evaluators to select the best partners for each task. This approach is sequential multi-level technique. While selecting the best partners for a particular task in the construction project, the partners' attributes are analyzed and weights assigned. Multi criteria decision making algorithms are used to derive relative weights of partners and checking consistency of evaluators' judgements. Analytical Hierarchy Process (AHP) is an analytical algorithm for data in hierarchical structure. It can be used as an analysis as well as a multi-criteria decision making technique. Multi-level partners’ evaluation and selection process is implemented in three cycles (Musumba, 2017; Nyongesa et al., 2017).

First Cycle: Use of AHP - The objective of this cycle is to evaluate the importance of selection criteria, sub-criteria and partners using crisp numerical values. AHP is useful in determining evaluation
preferences by a group of evaluators, however, its weakness include giving unreliable results when evaluator judgement is uncertain. Thus, in order to deal with uncertainty during evaluation there is a need for an algorithm, which can cope with this reality.

Second Cycle: Use of Fuzzy AHP (FAHP) - The objective of this cycle is to extend AHP (using fuzzy logic) which is applicable for managing “certain” evaluation judgements, and to imitate the way humans’ reason and judge. Human reasoning and judgement during the partner evaluation and selection is subjective and can be said to be “uncertain”. Thus, algorithms that can deal with the uncertainty of human judgements will be an improvement on AHP. Fuzzy logic combined with the AHP algorithm can compensate for the weakness of AHP. The algorithm is implemented and the outcomes of the FAHP and AHP are compared. FAHP does not discard priority weights with low numerical values.

Third cycle: Use of industrial case studies to show the applicability of FAHP.

THE ANALYTICAL HIERARCHY PROCESS
The Analytical Hierarchy Process (AHP) (Saaty, 1980, 1990; Saaty & Kea, 2014) is a method for modelling unstructured decision-making problems. Unstructured decision making problems are those in which there is not a clear arrangement of the components of the problems. In the construction industry, the partner evaluation and selection problem is unstructured. AHP is a theory of measurement for dealing with quantifiable and intangible criteria that has been applied to numerous areas, such as decision theory and conflict resolution (Vaidya & Kumar, 2006). More and more researchers are realizing that AHP is an important generic method and are applying it to various manufacturing areas (Chan et al., 2000). In addition to the wide application of AHP in manufacturing areas, research and industrial activities of applying AHP on other selection problems are also quite active (Tam & Tummala, 2001).

AHP being a multi-criteria decision-making (MCDM) method, uses pairwise comparisons of alternatives to derive weights of importance from a multi-level hierarchical structure of objectives, criteria, sub-criteria and partners. In cases where the comparisons are not perfectly consistent, AHP provides an uncomplicated method for improving the consistency of the comparisons, by using the eigenvalue method and consistency checking method. The hierarchical structure fits well with the hierarchical structure of a partner evaluation and selection problem.

AHP algorithm has the following steps: i) define the unstructured problem and state clearly the goal/objectives and outcomes; ii) decompose the complex problem into a hierarchical structure of alternatives; iii) employ pairwise comparisons of alternatives and form pair-wise comparison matrices; iv) use the eigenvalue method to estimate the relative weights; v) check the consistency of decision judgements; vi) aggregate the relative weights to obtain the overall rating for alternatives.

These steps of the algorithm can be summarized into three (Vila & Beccue, 1995). Firstly, the problem is decomposed into a number of hierarchical levels. Secondly, data is collected from evaluators, arithmetic mean computed on the values and pairwise comparison matrices are formed. This step reduces the complexity of the multi-criteria multi-decision to a simple set of pairwise comparisons. A rating scale is used to indicate the level of importance / preference of one alternative over another, instead of comparing all alternatives simultaneously. The third step is called synthesization. It is where the overall weights of alternatives in all levels of the hierarchy are obtained.

To summarize, assume you have a hierarchical structure of m alternatives with respect to a specific objective, which must be evaluated using n criteria, denoted Ci(i=1, 2, ...n). Let the weight of criterion Ci with respect to the objective be Wc. Let the relative weight of alternative k (1≤ k≤ m) with respect to criterion Ci be WkCi. The overall weights, denoted P; (1≤ i≤ m) of m alternatives with respect to the objective are given by equation 1.
It is important to note that $W_{Ci} (1 \leq i \leq n)$ are the relative (local) weights of criteria $Ci$ while $W_{KCI}$ are relative weights of alternatives, in this case, the partners. These relative weights are computed for elements at level 1 of the hierarchical structure, then at levels 2, 3 to the last level.

Cheng et al. (1999) identified the following shortcomings of AHP; (i) it is used in nearly crisp decision applications; (ii) deals with unbalanced scale of judgements (1 up to 9); (iii) does not take into account any uncertainty associated when mapping human judgement to a number scale; (iv) the ranking of AHP is imprecise or inexact; (v) the subjective assessment of decision makers, and change of scale have great influence on the AHP outcome. Furthermore, Wang and Chin (2008) found that the increase in the number of attributes geometrically increases the number of pairwise comparisons by $O(n^2/2)$ which can lead to inconsistency or failure of the algorithm. Also, AHP cannot solve non-linear models (Cheng et al., 1999). In view of these AHP weaknesses, Fuzzy AHP that addresses these challenges is discussed in the following sections.

**FUZZY ANALYTICAL HIERARCHY PROCESS**

Fuzzy theory has proven advantages for dealing with imprecise and uncertain decision situations and models human reasoning in its use of approximate information (Yager & Zadeh, 2012). Fuzzy set theory implements grouping of data with boundaries that are not distinctly defined. In conventional AHP, the pairwise comparison is established using a nine-point scale which indicates the human preferences between alternatives (Cheng et al., 1999). The discrete scale of AHP has the advantage of ease of use but, it cannot handle the uncertainty associated with the mapping of evaluators' preferences to a number (Kwong & Bai, 2002). The evaluators' judgements are normally vague and difficult to represent in terms of exact numbers but could best be given as interval judgements than fixed value judgements.

Different types of fuzzy numbers (triangular or trapezoidal) are used to decide the priority of one decision variable over other (Buckely, 1985; Dubois et al., 2000). A triangular fuzzy number (TFN), $\tilde{N}$ is given by $a \leq b \leq c$ where $b$, $a$, and $c$ are the most likely, the lower bounds and upper bounds decision values, respectively (Buckely, 1985; Dubois et al., 2000). Figure 1 shows a fuzzy number, which is characterized by a membership function. It differs from traditional set which defines an element as either belongs or does not belong to a set (i.e. 0 and 1). The fuzzy triangular membership function gives the foundation for defining other types of membership functions such as general triangular function, right-angled triangular function and trapezoidal function. For example when $a=b$ for a right-angled triangular membership function such as $(I, J, 3)$ (Buckley, 1985).

When Saaty's nine scale values are converted into fuzzy numbers and the values used in AHP, the resulting algorithm is Fuzzy AHP (FAHP). There are many types of FAHP algorithms such as: FAHP (with extent analysis) (Chang, 1996; Zhu et al., 1999; Mikhailov, 2003), Fuzzy goal programming (Wang & Fu, 1997; Wang & Chin, 2008) and fuzzy preference programming (Bozdag et al., 2003). This study adopts the FAHP (with extent analysis) algorithm.
**Design of Fuzzy AHP algorithm for virtual enterprise**

This study proposes an algorithm specifically for partner evaluation and selection in the construction sector that incorporates the concept of fuzzy extent analysis in AHP. The proposed FAHP (with extent analysis) algorithm has three steps, which is similar to conventional AHP except that in each step, fuzzy theory is introduced. Fuzzy extent analysis is used to obtain partners’ selection criteria relative importance and partner performance preferences (Zhu et al., 1999). Thus, the computation of fuzzy extent analysis results in fuzzy weights.

**Steps of the proposed Fuzzy AHP algorithm for this study are as follows:**

Step 1. Obtain preference values / level of importance of alternatives. This is done by choosing the linguistic attributes e.g. the statement “Indicate how important each of the following criterion is when your company is selecting partners for structural engineering works in a building construction project” needs an evaluator to choose one answer from (extremely important, very important, important, weakly important and not at all important) to answer.

Step 2. The chosen linguistic attributes are converted into numerical crisp values using Table 2. In the partner evaluation tool, alphabetical symbols (A, B, C, D, E) with matching nominal scales (extremely important, very important, important, weakly important and not at all important) are provided. These are converted to Saaty scale.

<table>
<thead>
<tr>
<th>Alphabetical symbol</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
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<td></td>
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<tr>
<td>Ordinal important</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Very important</td>
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<td>6</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Important</td>
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<td>8</td>
<td>7</td>
<td>5</td>
<td>3</td>
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<tr>
<td>Weakly important</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Not at all important</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
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</tbody>
</table>

Step 3. Once the linguistic opinions are converted to numerical values, computation of the arithmetic mean is done and the averages of crisp values are converted to fuzzy scale using Table 3.

<table>
<thead>
<tr>
<th>Alphabetical Symbol</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tr>
<td>Nominal scale</td>
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<tr>
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<tr>
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<td>5</td>
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<tr>
<td>Weakly important</td>
<td>7</td>
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<td>7</td>
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<tr>
<td>Not at all important</td>
<td>9</td>
<td>9</td>
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</tbody>
</table>

Step 2. The chosen linguistic attributes are converted into numerical crisp values using Table 2. In the partner evaluation tool, alphabetical symbols (A, B, C, D, E) with matching nominal scales (extremely important, very important, important, weakly important and not at all important) are provided. These are converted to Saaty scale.

<table>
<thead>
<tr>
<th>Alphabetical Symbol</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tr>
<td>Important</td>
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</tbody>
</table>

The linguistic symbols obtained from evaluators can be converted directly to TFNs and their arithmetic mean computed. The use of weight mean operator helps to get the collective opinion of all participants.
This is done to all lower bound, middle and upper bound triangular fuzzy values. The outcomes of this step are comprehensive fuzzy opinions.

Step 4. Compute the pairwise comparisons matrices of the values of alternatives. This step gives the fuzzy pairwise comparison matrix in form of triangular fuzzy number \((l, m, u)\). The pairwise comparison judgement matrix gives the preference of one alternative \((A_i)\) over the other \((A_j)\), and is given by

\[
A_{ij} = \frac{A_i}{A_j} \quad \text{for } i, j = 1, 2, 3, \ldots, n. 
\]  

(2)

Step 5. Apply the fuzzy extent analysis to the pairwise comparison matrix. The basic procedures for fuzzy extent are adopted from Zhu et al. (1999) thus,

Let \(X = \{x_1, x_2, x_3, \ldots, x_n\}\) be an object set (for this study object set is either the objective, criteria, or sub-criteria) and

\(G = \{g_1, g_2, g_3, \ldots, g_n\}\) be a goal defined for each level in the hierarchical structure. Thus, \(G\) can change depending on the level of the hierarchy.

M extent analysis on each object is taken

\[
\tilde{M}_{gl_i}^1, \tilde{M}_{gl_i}^2, \tilde{M}_{gl_i}^3, \ldots, \tilde{M}_{gl_i}^m, \quad i = 1, 2, 3, \ldots, n
\]  

(3)

where \(\tilde{M}_{gl_i}^j\) \((j=1, 2, 3, \ldots, m)\) are triangular fuzzy numbers (TFNs).

There are three procedures as explained in the following section for finding extent analysis of objects.

Step 6.1 First procedure: The fuzzy synthetic extent value \((S)\) with respect to the \(i^{th}\) object is defined as,

\[
S_i = \sum_{j=1}^{m} \tilde{M}_{gl_i}^j * \left[ \sum_{j=1}^{m} \tilde{m}_{gl_i}^j \right]^{-1}
\]  

(4)

The symbol * in equation 5.14 is a multiplication operator

To obtain \(\sum_{j=1}^{m} \tilde{M}_{gl_i}^j\), perform the normalized fuzzy addition operation of \(m\) extent analysis values for a particular matrix such that:

\[
\sum_{j=1}^{m} \tilde{M}_{gl_i}^j = \left( \sum_{j=1}^{m} l_j \right) \left( \sum_{j=1}^{m} m_j \right) \left( \sum_{j=1}^{m} u_j \right)
\]  

(5)

where \(l\) is the lower limit (bound) value, \(m\) is the most promising value and \(u\) is the upper limit (bound) value. Table 7 is an example of a fuzzy pairwise comparison matrix.

Let \(Ob1\) represent object 1, \(Ob2\) represent object 2 to \(Obn\) representing object \(n\). Additionally, let \(Obil\) denote the lower TFN value, \(Obim\) denote the middle TFN value while \(Obiu\) denote the upper TFN value of the \(i^{th}\) object. Therefore for \(Ob1\) in column 1, \(\sum_{j=1}^{n} l1\) is found by getting the sum of \((Ob1l, Ob2l, \ldots, Obnl)\), \(\sum_{j=1}^{n} m1\) is found by getting the sum of \((Ob1m, Ob2m, \ldots, Obnm)\) while \(\sum_{i=1}^{n} u1\) is found by getting the sum of \((Ob1u, Ob2u, \ldots, Obnu)\). The same process is repeated for columns 2, 3 to \(n\) for objects 2, 3 to \(n\).

Table 4 is normalized in the same way it is done in conventional AH by dividing each fuzzy number in a column with its respective sum of the column. That is lower bound elements are divided by the sum of lower bound elements. Likewise the same is done to middle and upper bound elements.

Table 4. Fuzzy Pairwise Comparison Matrix

<table>
<thead>
<tr>
<th>Objective</th>
<th>Object 1 (Ob1)</th>
<th>Object 2 (Ob2)</th>
<th>...</th>
<th>Object n (Obn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object 1</td>
<td>Ob1l Ob1m Ob1u</td>
<td>Ob2l Ob2m Ob2u</td>
<td>...</td>
<td>Obnl Obnm Obnu</td>
</tr>
<tr>
<td>Object 2</td>
<td>Ob1l Ob1m Ob1u</td>
<td>Ob2l Ob2m Ob2u</td>
<td>...</td>
<td>Obnl Obnm Obnu</td>
</tr>
<tr>
<td>...</td>
<td>Ob1l Ob1m Ob1u</td>
<td>Ob2l Ob2m Ob2u</td>
<td>...</td>
<td>Obnl Obnm Obnu</td>
</tr>
<tr>
<td>Object n</td>
<td>Ob1l Ob1m Ob1u</td>
<td>Ob2l Ob2m Ob2u</td>
<td>...</td>
<td>Obnl Obnm Obnu</td>
</tr>
</tbody>
</table>
Let us use $nl_{1,1}$, $nm_{1,1}$, and $nu_{1,1}$ to denote normalized values for column 1 in row 1, $nl_{1,1}$, $nm_{1,1}$, and $nu_{1,1}$ for column 2 in row 1 and $nl_{1,1}$, $nm_{1,1}$, and $nu_{1,1}$ for column 3 in row 1. If similar notations are applied to other rows and fuzzy addition of the rows of the normalized values is done, results are shown in Table 5.

Table 5. Fuzzy Addition of Normalized Pairwise Comparison Matrix

<table>
<thead>
<tr>
<th>Object 1 (Ob1)</th>
<th>Object 2 (Ob2)</th>
<th>...</th>
<th>Object n (Obn)</th>
<th>Fuzzy Addition to obtain $\sum_{j=1}^{m} M_{gi}^j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$nl_{1,1}$, $nm_{1,1}$, $nu_{1,1}$</td>
<td>$nl_{1,2}$, $nm_{1,2}$, $nu_{1,2}$</td>
<td>...</td>
<td>$nl_{1,n}$, $nm_{1,n}$, $nu_{1,n}$</td>
<td>$\sum_{j=1}^{m} l1$</td>
</tr>
<tr>
<td>$nl_{2,1}$, $nm_{2,1}$, $nu_{2,1}$</td>
<td>$nl_{2,2}$, $nm_{2,2}$, $nu_{2,2}$</td>
<td>...</td>
<td>$nl_{2,n}$, $nm_{2,n}$, $nu_{2,n}$</td>
<td>$\sum_{j=1}^{m} m1$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>$\sum_{j=1}^{m} u1$</td>
</tr>
<tr>
<td>$nl_{n,1}$, $nm_{n,1}$, $nu_{n,1}$</td>
<td>$nl_{n,2}$, $nm_{n,2}$, $nu_{n,2}$</td>
<td>...</td>
<td>$nl_{n,n}$, $nm_{n,n}$, $nu_{n,n}$</td>
<td>$\sum_{j=1}^{m} ln$</td>
</tr>
</tbody>
</table>

Values in the fourth column of the first row are obtained as follows:

$\sum_{j=1}^{m} l1 = nl_{1,1} + nl_{1,2} + ... + nl_{1,m}$

$\sum_{j=1}^{m} m1 = nm_{1,1} + nm_{1,2} + ... + nm_{1,n}$

$\sum_{j=1}^{m} u1 = nu_{1,1} + nu_{1,2} + ... + nu_{1,n}$

Similarly, values in the second row are obtained as:

$\sum_{j=1}^{m} l2 = nl_{2,1} + nl_{2,2} + ... + nl_{2,n}$

$\sum_{j=1}^{m} m2 = nm_{2,1} + nm_{2,2} + ... + nm_{2,n}$

$\sum_{j=1}^{m} u2 = nu_{2,1} + nu_{2,2} + ... + nu_{2,n}$

while values in the last row are obtained as:

$\sum_{j=1}^{m} ln = nl_{n,1} + nl_{n,2} + ... + nl_{n,m}$

$\sum_{j=1}^{m} mn = nm_{n,1} + nm_{n,2} + ... + nm_{n,n}$

$\sum_{j=1}^{m} un = nu_{n,1} + nu_{n,2} + ... + nu_{n,n}$

To obtain $[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j]$ perform the fuzzy addition operation of

$M_{gi}^j$ ($j=1, 2, ..., m$) values such that;

$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j = (\sum_{i=1}^{n} li, \sum_{i=1}^{n} mi, \sum_{i=1}^{n} ui)$

(6)
where:
\[
\begin{align*}
\sigma_i^n l_i & = \sum_{j=1}^m l_1 + \sum_{j=1}^m l_2 + \ldots + \sum_{j=1}^m l_n \\
\sigma_i^n m_i & = \sum_{j=1}^m m_1 + \sum_{j=1}^m m_2 + \sum_{j=1}^m m_n \\
\sigma_i^n u_i & = \sum_{j=1}^m u_1 + \sum_{j=1}^m u_2 + \ldots + \sum_{j=1}^m u_n
\end{align*}
\]

The inverse of this vector is then computed, such that:
\[
\left[ \frac{1}{\sigma_i^n u_i} \frac{1}{\sum_{j=1}^m m_j} \frac{1}{\sum_{j=1}^m l_j} \right]^{-1}
\]

Note: Inverse of a fuzzy number \( N (l, m, u) = N^{-1} (1/l, 1/m, 1/u) \)

Thus equation 7 then becomes:
\[
(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j) \times \left( \frac{1}{\sum_{j=1}^m u_i} \frac{1}{\sum_{j=1}^m m_j} \frac{1}{\sum_{j=1}^m l_i} \right)
\]

Recall that if an inverse of a fuzzy number \( N^{-1} (1/l, 1/m, 1/u) \), the value to be multiplied is given in reversed order thus \((1/u, 1/m, 1/l)\).

The outcome of the first procedure extent values of each alternative which are still fuzzy in nature. These are referred to as blocks of fuzzy extent values. Block 1 is for alternative 1, block 2 for alternative 2 and so on.

Step 6.2 Second procedure: Layer simple sequencing (Defuzzification of extent analysis values)
There are two alternatives that can be used to implement this procedure. The first procedure is the original Fuzzy AHP technique. The second procedure is a proposed modification to the Fuzzy AHP.

**Step 6.2.1 Alternative one-Fuzzy Synthetic Method.**
Fuzzy synthetic method (Mikhailov, 2003) compares each block (alternative) pair by pair towards the overall goal. This gives the sequencing weight vector, \( V_i \), for each block. The same procedure is done when finding the local weights for all levels in the hierarchy. Bozdag et al. (2003) stated that given two triangular fuzzy numbers \( \tilde{F}_1 (l_1, m_1, u_1) \) and \( \tilde{F}_2 (l_2, m_2, u_2) \), the degree (D) of possibility that \( \tilde{F}_1 (l_1, m_1, u_1) \geq \tilde{F}_2 (l_2, m_2, u_2) \) is defined as,
\[
D (\tilde{F}_1 \geq \tilde{F}_2) = \begin{cases} 
1, & \text{if } m_1 \geq m_2 \\
0, & \text{if } u_1 \leq l_2 \\
\frac{m_1 - u_2}{(u_2 - u_2) - (m_1 - l_1)}, & \text{otherwises }
\end{cases}
\]

To explain equation 8, we consider two fuzzy numbers \( \tilde{F}_1 = (l_1, m_1, u_1) \) and \( \tilde{F}_2 = (l_2, m_2, u_2) \). For a sensible comparison between these two fuzzy numbers, it should be investigated both the degree of possibility that \( \tilde{F}_1 \) is bigger than or equal to \( \tilde{F}_2 \) and the degree of possibility that \( \tilde{F}_1 \) is smaller than or equal to \( \tilde{F}_2 \). Let \( D (\tilde{F}_1 \geq \tilde{F}_2) \) denote the degree of possibility that \( \tilde{F}_1 \) is bigger than or equal to \( \tilde{F}_2 \). We have three possible cases for \( D (\tilde{F}_1 \geq \tilde{F}_2) \):

**Case 1:** If \( m \geq m \), then we have \( D (\tilde{F}_1 \geq \tilde{F}_2) = 1 \).

**Case 2:** If \( u \leq l \), then we have \( D (\tilde{F}_1 \geq \tilde{F}_2) = 0 \).

**Case 3:** For all other possible cases the corresponding degree of possibility is given by \( D (\tilde{F}_1 \geq \tilde{F}_2) = \frac{l_1 - u_2}{(m_2 - u_2) - (l_1 - l_1)} \).

For a logical comparison, Chang (1996) uses the degree of possibility that a fuzzy number \( \tilde{F}_1 \) is to be greater than \( k \) fuzzy numbers. This term can be written as follows:
\[ D(\tilde{F}_i \geq \tilde{F}_1, ..., \tilde{F}_n) = D(\tilde{F}_i \geq \tilde{F}_1) \land D(\tilde{F}_i \geq \tilde{F}_2, ..., D(\tilde{F}_i \geq \tilde{F}_n)) \] (9)

The principle of fuzzy number comparison (Chang, 1996) states that the degree of possibility that a fuzzy number \( F_i \) is greater than or equal to a set of fuzzy numbers is equal to the minimum degree of possibility among these values. This is stated as:

\[ D(\tilde{F}_i \geq \tilde{F}_1, ..., \tilde{F}_n) = \min_{} (D(\tilde{F}_i \geq \tilde{F}_j | j=1,2,3,., n)) \] (10)

Consider the synthetic extent values \( S_i \) found from matrix of \((n \times n)\), then the degree of possibility of the \( i^{th} \) alternative is given by:

\[ \min (D(S_i \geq S_j | j=1,\ldots,n; j \neq i) \]

**Step 6.2.2 Alternative two: Geometric Mean Method (Modified Fuzzy AHP)**

For each block, a geometric mean of the fuzzy extent values is computed. This gives the priority vector, \( V_i \), for each block. The same procedure is done when finding the local weights for all levels in the hierarchy. For both alternatives, the non-normalized priority vector for \( n \) elements becomes:

\[ P_{V_i}' = (h_1', h_2', \ldots, h_n')^T \]

where \( h_i' \) is the priority vector value for each of the \( n \) alternatives.

\[ P_{V_i} = h_i' / \sum_{i=1}^{n} h_i' \; : \; P_{V} = (h_1, h_2, \ldots, h_n)^T \].

This becomes the local weight of alternatives in each level of the hierarchy. Global weights for partners are derived by multiplying local weights in lower hierarchy to local weights in the parent elements in the hierarchy. The partner with the highest weight is selected. This method however, is time consuming.

Wang et.al. (2006) criticized FAHP with (Extent Analysis) technique and through an example showed that this method cannot estimate true weights from fuzzy comparison matrix. The main criticism revolves around the fact that this method may assign a zero as criterion weight which disturbs the whole decision making hierarchy. The basis of extent analysis theory is that it provides a degree to which one fuzzy number is greater than another fuzzy number, and this degree of greatness is considered as criterion weights. Therefore, if two fuzzy numbers do not intersect then the degree of greatness of one fuzzy number to the other is 100 percent and therefore it will assign 1 as weight to that criterion while the other criteria will be assigned as zero weight. In light of the above discussion, Wang et.al (2006) summarized the main problems with this method as follows;

i) Once a criteria is assigned a zero weight, it will not be considered in the decision making process.

ii) This method may lose some useful information in the form of judgment ratios in the fuzzy comparison matrices as some of the criterion are assigned zero weight.

iii) It was shown that weights calculated through this method may not represents the true relative importance of that criteria.

iv) This method might select the worst decision alternative as the best one and thus leads to wrong decision making.

Future research should propose techniques that can handle weaknesses of FAHP.

**Application of the proposed Fuzzy AHP for virtual enterprise**

This algorithm addresses the problem of using crisp values during evaluation and selection of partners. For example, borrowing partners' selection criteria proposed in (Nyongesa et al., 2017), an evaluator might feel that technical skills of a partner are more important than management skills but cannot tell exactly by how much. This data can be represented a range of values (fuzzy/continuous). Suppose averages of evaluators' opinions for business criterion (CN₁), technical criterion (CN₂) and management
criterion (CN₃) as presented in (Nyongesa et al., 2017) are 9, 7 and 7 respectively. These crisp values are fuzzified using triangular fuzzy numbers resulting into (7, 9, 9) for CN₁, (5, 7, 9) for CN₂ and (5, 7, 9) for CN₂ respectively. A fuzzy pairwise comparison matrix was formed as shown in the Table 6.

Table 6. Fuzzy PCM for Partner Evaluation and Selection Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>CN₁</th>
<th>CN₂</th>
<th>CN₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN₁</td>
<td>1, 1, 1</td>
<td>7/5, 9/7, 9/9</td>
<td>7/5, 9/7, 9/9</td>
</tr>
<tr>
<td>CN₂</td>
<td>9/9, 7/9, 5/7</td>
<td>1, 1, 1</td>
<td>1, 1, 1</td>
</tr>
<tr>
<td>CN₃</td>
<td>9/9, 7/9, 5/7</td>
<td>1, 1, 1</td>
<td>1, 1, 1</td>
</tr>
<tr>
<td>Sum</td>
<td>3, 2.556, 2.428</td>
<td>3.4, 3.286, 3</td>
<td>3.4, 3.286, 3</td>
</tr>
</tbody>
</table>

Values in field 1, column 1 for business against itself is (1,1,1) which is found by dividing lower bound value by lower bound value, middle value by middle value and upper bound value by upper bound value (7/7, 9/9, 9/9). Values in field 3, column 1, is found by dividing (7, 9, 9) by (5, 7, 9). Other field values are derived in the same manner. The sum of each column is found by adding lower bound values together, middle values together and upper bound values together. That is sum of column 1 is (1+1+1=3), (1+7/9+7/9=2.556) and (1+5/7+5/7=2.428). The sums of columns 2 and 3 are found in the same manner.

To calculate the extent analysis on the Fuzzy PCM, the following steps were followed. The Fuzzy PCM is normalized. Table 7 shows the normalized fuzzy pairwise comparison matrix of the selection criteria.

Table 7. Normalized Fuzzy Pairwise Comparison Matrix for Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>CN₁</th>
<th>CN₂</th>
<th>CN₃</th>
<th>Fuzzy Addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN₁</td>
<td>0.333, 0.391, 0.412</td>
<td>0.412, 0.391, 0.333</td>
<td>0.412, 0.391, 0.333</td>
<td>1.157, 1.173, 1.078</td>
</tr>
<tr>
<td>CN₂</td>
<td>0.333, 0.304, 0.294</td>
<td>0.294, 0.304, 0.333</td>
<td>0.294, 0.304, 0.333</td>
<td>0.921, 0.912, 0.960</td>
</tr>
<tr>
<td>CN₃</td>
<td>0.333, 0.304, 0.294</td>
<td>0.294, 0.304, 0.333</td>
<td>0.294, 0.304, 0.333</td>
<td>0.921, 0.912, 0.960</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>2.999, 2.997, 2.998</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inverse of sum</td>
<td></td>
<td>0.333, 0.334, 0.334</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fuzzy addition in the last column of the first row is achieved as follows:

\[
0.333+0.412+0.412=1.157; 0.391+0.391+0.391=1.173; 0.412+0.333+0.333=1.078
\]

Other rows were determined using the same procedure.

Sum of the fuzzy additions in the second last row is found as

\[
1.157+0.921+0.921=2.999; 1.173+0.912+0.912=2.997; 1.078+0.960+0.960=2.998
\]

The inverse of the sums of fuzzy additions in last row was found by dividing one (1) by the sum of the fuzzy additions. In this case inverses are:

\[
\frac{1}{2.999} = 0.333, \frac{1}{2.997} = 0.334, \frac{1}{2.998} = 0.334
\]

Extent analysis values are found by multiplying the normalized fuzzy addition of each criterion by the inverse of the sums of the normalized fuzzy addition.

\[
1.157\times0.334, 1.173\times0.334, 1.078\times0.333 = 0.386, 0.392, 0.359
\]

The local weights of each criterion are derived by finding the geometric mean of the fuzzy extent values as shown in Table 8.

Table 8. Fuzzy Local Weight for the Selection Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Fuzzy Local Weight</th>
<th>Defuzzified Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN₁</td>
<td>0.386, 0.392, 0.359</td>
<td>0.379</td>
</tr>
<tr>
<td>CN₂</td>
<td>0.308, 0.305, 0.320</td>
<td>0.311</td>
</tr>
<tr>
<td>CN₃</td>
<td>0.308, 0.305, 0.320</td>
<td>0.311</td>
</tr>
</tbody>
</table>
The last column of the matrix is determined by finding geometric mean of the fuzzy weights. Thus, for the first row: \((0.386 \times 0.392 \times 0.359)^{1/3} = 0.379\). The same procedure was done to find the local weights for second and third levels of the hierarchy. Table 9 shows the local weights for \(C_{N1}\) sub criteria (i.e., \(SCN_{1,1}\), \(SCN_{1,2}\) and \(SCN_{1,3}\)). It should be noted business criterion sub-criteria were denoted as \(SCN_{1,1}\) to \(SCN_{1,3}\) for FS, Sp and BS respectively. Likewise, technical criterion sub-criteria were denoted as \(SCN_{2,1}\) to \(SCN_{2,4}\) for TC, DS, CD and IT respectively. Finally, management criterion sub-criteria were denoted as \(SCN_{3,1}\) to \(SCN_{3,3}\) for CR, CC and MA respectively.

Table 9. Local Weight for \(C_{N1}\) Subcriteria

<table>
<thead>
<tr>
<th>Sub criteria</th>
<th>Local Weight</th>
<th>Defuzzified weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>(C_{N1})</td>
<td>0.436</td>
<td>0.382</td>
</tr>
<tr>
<td>(C_{N2})</td>
<td>0.290</td>
<td>0.315</td>
</tr>
<tr>
<td>(C_{N3})</td>
<td>0.240</td>
<td>0.302</td>
</tr>
</tbody>
</table>

The same procedure is done when finding the priority vectors and local weights for all levels in the hierarchy. The global weights are derived like in AHP. Table 10 shows the outcome when these sample data are subjected to Fuzzy AHP. To calculate the PW of partners, the global weights for each sub-criterion in each criterion is multiplied by the local weights of each partner according to a sub-criterion. After this, the sum of the products (partner local weights multiplied by sub-criterion global weights) of each partner is computed. This is illustrated in the following section.

Table 10. Results of Evaluation using FAHP

<table>
<thead>
<tr>
<th>Criteria</th>
<th>(C_{N1})</th>
<th>(C_{N2})</th>
<th>(C_{N3})</th>
<th>Priority Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN LW</td>
<td>0.379</td>
<td>0.311</td>
<td>0.311</td>
<td></td>
</tr>
<tr>
<td>SCN</td>
<td>SCN_{1,1}</td>
<td>SCN_{1,2}</td>
<td>SCN_{1,3}</td>
<td></td>
</tr>
<tr>
<td>SCN LW</td>
<td>0.413</td>
<td>0.303</td>
<td>0.282</td>
<td></td>
</tr>
<tr>
<td>GW</td>
<td>0.157</td>
<td>0.115</td>
<td>0.107</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.090</td>
<td>0.062</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.044</td>
<td>0.115</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.152</td>
<td>0.087</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.072</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>0.233</td>
<td>0.433</td>
<td>0.285</td>
<td>0.188</td>
</tr>
<tr>
<td>P2</td>
<td>0.167</td>
<td>0.167</td>
<td>0.143</td>
<td>0.250</td>
</tr>
<tr>
<td>P3</td>
<td>0.233</td>
<td>0.111</td>
<td>0.333</td>
<td>0.167</td>
</tr>
<tr>
<td>P4</td>
<td>0.112</td>
<td>0.101</td>
<td>0.154</td>
<td>0.274</td>
</tr>
<tr>
<td>P5</td>
<td>0.155</td>
<td>0.188</td>
<td>0.085</td>
<td>0.121</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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</tbody>
</table>

Note: CN LW denotes criterion local weight
SCN denotes sub criterion
SCN LW denotes sub criterion local weight
GW denotes global weight

\[
\begin{bmatrix}
  0.333 & \cdots & 0.155 \\
  \vdots & \ddots & \vdots \\
  0.100 & \cdots & 0.006
\end{bmatrix}
\times
\begin{bmatrix}
  0.157 \\
  \vdots \\
  0.072
\end{bmatrix}
= 
\begin{bmatrix}
  0.264 \\
  \vdots \\
  0.140
\end{bmatrix}
\]

The global weight (GW) for \(C_{N1,2}\) (SP) is derived by multiplying local weight of business criterion by local weight of \(C_{N1,2}\), which is \(0.379 \times 0.303 = 0.115\). GW for \(C_{N2,3}\) (CD) is \(0.311 \times 0.140=0.044\). Likewise GW for \(C_{N3,3}\) (MA) is \(0.311 \times 0.231=0.072\). Finally PW for partners is derived by finding the sum of products of global weights of each sub criterion and the local weight of the partner in the sub criterion. For instance PW for partner 2 is \(0.157 \times 0.167 + 0.115 \times 0.167 + 0.107 \times 0.143 + 0.090 \times 0.250\).
+ 0.062 x 0.375 + 0.044 x 0.150 + 0.115 x 0.267 + 0.152 x 0.333 + 0.087 x 0.100 + 0.072 x 0.400 = 0.231. PWs for partners 1, 3 to 5 are derived in the same way. If all was perfect the sum of the weights for partners should be 1. From Table 6.15, the sum is 1.0 with an error of 0. The PWs of partners 1 through 5 are 0.264, 0.231, 0.214, 0.151 and 0.140 respectively. Partner 1 has the highest weight and is consequently selected.

Ideally, in any algorithm that ranks alternatives, the sum of the PWs of alternatives should be 1. If this is not the case, then the algorithm has not performed optimally therefore resulting in errors. The higher the error the worse the algorithm’s performance becomes. Since the consistency ratio correlate to the judgmental errors in pairwise comparisons (Karlsson et al., 1998; Ahmed & Kilic, 2015), it can be concluded that these mean errors correspond to the consistency ratio (Saaty, 1980).

To determine the efficiency of this technique, the same data was applied to AHP technique specialized for virtual enterprise as discussed by both Sanga (2010) and Nyongesa et al. (2017) and the as depicted in Table 11 were found.

Table 11. Results of Evaluation using AHP

<table>
<thead>
<tr>
<th>Criteria</th>
<th>CN1</th>
<th>CN2</th>
<th>CN3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN LW</td>
<td>0.391</td>
<td>0.304</td>
<td>0.304</td>
</tr>
<tr>
<td>SCN</td>
<td>SCN1,1</td>
<td>SCN1,2</td>
<td>SCN1,3</td>
</tr>
<tr>
<td>SCN LW</td>
<td>0.527</td>
<td>0.170</td>
<td>0.303</td>
</tr>
<tr>
<td>GW</td>
<td>0.206</td>
<td>0.066</td>
<td>0.118</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>CN1,2</th>
<th>SCN2,2</th>
<th>SCN2,3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCN</td>
<td>0.379</td>
<td>0.214</td>
<td>0.286</td>
</tr>
<tr>
<td>SCN LW</td>
<td>0.496</td>
<td>0.188</td>
<td>0.316</td>
</tr>
<tr>
<td>GW</td>
<td>0.211</td>
<td>0.066</td>
<td>0.315</td>
</tr>
<tr>
<td></td>
<td>0.333</td>
<td>0.115</td>
<td>0.368</td>
</tr>
<tr>
<td></td>
<td>0.167</td>
<td>0.143</td>
<td>0.250</td>
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<tr>
<td></td>
<td>0.274</td>
<td>0.122</td>
<td>0.211</td>
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<td></td>
<td>0.121</td>
<td>0.259</td>
<td>0.021</td>
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<tr>
<td></td>
<td>0.122</td>
<td>0.211</td>
<td>0.194</td>
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<tr>
<td></td>
<td>0.333</td>
<td>0.010</td>
<td>0.400</td>
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<tr>
<td></td>
<td>0.229</td>
<td>0.315</td>
<td>0.299</td>
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<tr>
<td></td>
<td>0.188</td>
<td>0.085</td>
<td>0.021</td>
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<tr>
<td></td>
<td>0.250</td>
<td>0.333</td>
<td>0.154</td>
</tr>
<tr>
<td></td>
<td>0.400</td>
<td>0.233</td>
<td>0.085</td>
</tr>
<tr>
<td>Priority</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weights</td>
<td>0.367</td>
<td>0.200</td>
<td>0.100</td>
</tr>
<tr>
<td></td>
<td>0.333</td>
<td>0.100</td>
<td>0.400</td>
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<tr>
<td></td>
<td>0.211</td>
<td>0.066</td>
<td>0.315</td>
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<td></td>
<td>0.167</td>
<td>0.143</td>
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<td>0.274</td>
<td>0.122</td>
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<td>0.259</td>
<td>0.021</td>
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<td></td>
<td>0.122</td>
<td>0.211</td>
<td>0.194</td>
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<td>0.400</td>
<td>0.233</td>
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<td>0.229</td>
<td>0.315</td>
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<td>0.021</td>
<td>0.085</td>
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<td>0.211</td>
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<td>0.274</td>
<td>0.122</td>
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<td>0.121</td>
<td>0.259</td>
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<td>0.122</td>
<td>0.211</td>
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<td>0.400</td>
<td>0.233</td>
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<td>0.229</td>
<td>0.315</td>
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<td></td>
<td>0.121</td>
<td>0.021</td>
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<tr>
<td>Priority</td>
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<tr>
<td>Weights</td>
<td>0.367</td>
<td>0.200</td>
<td>0.100</td>
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<td></td>
<td>0.333</td>
<td>0.100</td>
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<td></td>
<td>0.211</td>
<td>0.066</td>
<td>0.315</td>
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<tr>
<td></td>
<td>0.167</td>
<td>0.143</td>
<td>0.250</td>
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<td>0.274</td>
<td>0.122</td>
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<td>0.259</td>
<td>0.021</td>
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<tr>
<td></td>
<td>0.122</td>
<td>0.211</td>
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<td></td>
<td>0.400</td>
<td>0.233</td>
<td>0.085</td>
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<td></td>
<td>0.229</td>
<td>0.315</td>
<td>0.299</td>
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<tr>
<td></td>
<td>0.121</td>
<td>0.021</td>
<td>0.021</td>
</tr>
<tr>
<td>Total</td>
<td>0.998</td>
<td>0.998</td>
<td>0.998</td>
</tr>
<tr>
<td>Error</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
</tbody>
</table>

All the computations and symbols are as used in Table 11. Both techniques ranked all the partners in the following order, P1, P2, P3, P4 and P5 with P1 with the highest weight and P5 having the lowest weight. FAHP (with extent analysis) has the least error of zero (0) while the conventional AHP has an error of 0.002. In order to verify the results of FAHP and as compared to AHP, sources of data is varied from additional five cases of evaluators and projects. Table 12 shows the results of case one (1).

Table 12. Case 1: Results of Algorithms

<table>
<thead>
<tr>
<th>Method</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>Total</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHP</td>
<td>0.261</td>
<td>0.231</td>
<td>0.229</td>
<td>0.153</td>
<td>0.123</td>
<td>0.997</td>
<td>0.003</td>
</tr>
<tr>
<td>FAHP</td>
<td>0.266</td>
<td>0.232</td>
<td>0.214</td>
<td>0.141</td>
<td>0.143</td>
<td>0.996</td>
<td>0.004</td>
</tr>
</tbody>
</table>

For case 1, P1, P2, P3, P5 and P4 have priority weights in that order with P1 with the highest and P4 with the least. However, this slightly differs from AHP where P4 has a higher weight than P5. AHP has the least error of 0.003 while FAHP has an error of 0.004. Table 13 shows the results of case two (2).

Table 13. Case 2: Results of Algorithms
For case 2, P1, P2, P3, P5 and P4 have priority weights in that order with P1 with the highest and P4 with the least. However, this slightly differs from AHP where P4 has a higher weight than P5. FAHP is the more accurate than AHP with the lesser error of 0.005. Table 14 shows the results of case three (3).

<table>
<thead>
<tr>
<th>Method</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>Total</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHP</td>
<td>0.256</td>
<td>0.229</td>
<td>0.229</td>
<td>0.153</td>
<td>0.122</td>
<td>0.989</td>
<td>0.011</td>
</tr>
<tr>
<td>FAHP</td>
<td>0.261</td>
<td>0.236</td>
<td>0.214</td>
<td>0.131</td>
<td>0.153</td>
<td>0.995</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Table 14. Case 3: Results of Algorithms

For case 3, P1, P2, P3, P4 and P5 have priority weights in that order with P1 with the highest and P5 with the least. However, this slightly differs from FAHP where P5 has a higher weight than P4. AHP is the more accurate than FAHP with the lesser error of 0.002. Table 15 shows the results of case four (4).

<table>
<thead>
<tr>
<th>Method</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>Total</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHP</td>
<td>0.263</td>
<td>0.244</td>
<td>0.229</td>
<td>0.143</td>
<td>0.119</td>
<td>0.998</td>
<td>0.002</td>
</tr>
<tr>
<td>FAHP</td>
<td>0.262</td>
<td>0.232</td>
<td>0.214</td>
<td>0.141</td>
<td>0.148</td>
<td>0.997</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Table 15. Case 4: Results of Algorithms

For case 4, P1, P2, P3, P4 and P5 have priority weights in that order with P1 with the highest and P4 with the least. However, P4 and P5 have similar weights in FAHP. FAHP is the more accurate than AHP with an error of 0. Table 16 shows the results of case five (5).

<table>
<thead>
<tr>
<th>Method</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>Total</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHP</td>
<td>0.228</td>
<td>0.258</td>
<td>0.226</td>
<td>0.150</td>
<td>0.126</td>
<td>0.988</td>
<td>0.012</td>
</tr>
<tr>
<td>FAHP</td>
<td>0.224</td>
<td>0.256</td>
<td>0.222</td>
<td>0.161</td>
<td>0.133</td>
<td>0.996</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Table 16. Case 5: Results of Algorithms

For case 5, P2, P1, P3, P4 and P5 have priority weights in that order with P2 with the highest and P5 with the least. FAHP is the more accurate than AHP with a lesser error of 0.004 while AHP has an error of 0.012. The arithmetic mean total and errors of the algorithms are shown in Table 17.

<table>
<thead>
<tr>
<th>Method</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Total</th>
<th>Mean Total</th>
<th>Mean Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHP</td>
<td>0.997</td>
<td>0.989</td>
<td>0.998</td>
<td>0.996</td>
<td>0.988</td>
<td>4.968</td>
<td>0.9936</td>
<td>0.0064</td>
</tr>
<tr>
<td>FAHP</td>
<td>0.996</td>
<td>0.995</td>
<td>0.997</td>
<td>1</td>
<td>0.996</td>
<td>4.984</td>
<td>0.9968</td>
<td>0.0032</td>
</tr>
</tbody>
</table>

Table 17. Arithmetic Mean Total and Error

From these comparisons, it can be stated that FAHP has average accuracy of 99.68% with a mean error of 0.0032 which is better than AHP which 99.36 % accurate with a mean error of 0.0064. The two techniques are effective but FAHP (with extent analysis) outweigh conventional AHP in terms of generality. This is because FAHP (with extent analysis) can be used when evaluators' judgements are either exact or fuzzy. Apart from the correctness, simplicity and generality of the algorithm, other aspects which can be used to differentiate between the algorithms are time and space complexities.
Time complexity refers to time in which the algorithm runs. It is determined by finding the upper bound on the execution time (Chang, 1996). Chang (1996) found FAHP (for n criteria) has the time complexity of \( n(n+6) \) and AHP has a time complexity equal to \( \frac{n(n-1)}{2} \). AHP algorithm can be extended to be used in a situation where the evaluators have imprecise information about evaluation judgements. Fuzzy logic can be incorporated in AHP to address the uncertainty of users' judgements during the evaluation of partners. These algorithms gave approximately similar results in all the cases.

**CONCLUSION**

Although Sanga (2010), demonstrated the suitability of AHP in evaluation of alternatives that considers multiple criteria because of its accuracy and flexibility in making a logical, consistent and informed decision, it still cannot deal with subjectivity of human evaluations. AHP deals with crisp values of evaluation and selection judgements. However, human judgements are imprecise, uncertain and fuzzy. Furthermore, when the number of evaluation and selection criteria considered increases, the number of pairwise comparisons increases geometrically. This can lead to inconsistencies or even that the AHP algorithm fails completely. FAHP can address this problem and is proposed as an alternative method for imprecise problems or problems with more criteria. Using AHP in the VE partner evaluation and selection is suitable because it simplifies a complex problem by breaking it up into smaller steps that help in visualizing the problem.

Using FAHP (with extent analysis), it has been shown how preferences can be attained for decision-making process, in the partner evaluation and selection problem. It differs from the traditional AHP method, which uses preferences generated from crisp values to evaluate and select partners. The level of accuracy of the prioritization outcome when FAHP (with extent analysis) was used was averagely 99.34% while AHP was 99.68%. It can be stated that FAHP (with extent analysis) can be incorporated in the design and development of new techniques for the VE partner evaluation and selection.

This research proposes that techniques which mimic the way evaluation judgements are done by humans, showing how the use of multi-criteria decision making algorithm and fuzzy models can be developed. The traditional solutions using classical set theory have proved not to be conforming to reality, the way human beings rate partner during evaluation. Instead of having only two choices of instances (for example, 0 or 1, true or false, yes or no), human beings rate events or phenomena in many ways (for example, yes, may be, no). The use of fuzzy logic can address the uncertainty, incompleteness of information, randomness of ideas and imprecision of phenomena. This study examined multi-criteria decision-making (MCDM) “under uncertainties”, in particular the linguistic uncertainties and proposes the incorporation of fuzzy logic in AHP algorithm thus addressing issues of partner evaluation and selection while information available about partners is subjective.

There is a great need for the development of techniques for solving evaluation and selection problems (Chou et al., 2008). The computer societies of academics, scholars and researchers have come up with new approaches to address this problem. These new approaches were published in the IEEE computational intelligence journal and IEEE computational intelligence magazine (Bonissone et al., 2009). In a recent publication in IEEE’s computational magazine the MCDM and fuzzy modelling have been identified by researchers as methods to solve hard science problems (if it can well be incorporated into decision support system).

**RECOMMENDATIONS**

An avenue for future study is to consider the design and development of techniques that could be used for partner evaluation and selection problems in general. That research should be carried out to determine the applicability of this proposal to other industries and other research fields. Simulations should done in...
varying scenarios to determine its weaknesses and recommendations of the proposal for its improvement. In this regard, views of all professionals in the construction industry should be considered to develop a model. This will increase acceptability of the technique in the industry.

REFERENCES


EFFECT OF 2, 4-D AND HEXAZINONE APPLICATION ON SOIL DEHYDROGENASE ACTIVITY ON SUGARCANE CULTIVATED SOILS IN NZOIA SUGARCANE PLANTATIONS

Njue, Reuben1, Silas Kiruki2, Anastasia Muia3 and Anastasia Ngigi4

1Department of Biochemistry & Molecular Biology, Egerton University, P. O. Box 536-20115, Egerton
2Biochemistry Department, Chuka University, P. O. Box 109-60400, Chuka, Kenya
3Biological Science Department, Egerton University, P. O. Box 536-20115, Egerton
4Chemistry Department-Multimedia University of Kenya, P. O. Box 15653-00503, Nairobi Kenya.

Correspondence: rnjue30@gmail.com, Tel: +254711 407780

ABSTRACT
Herbicides have been used extensively all over the world and have become indispensable pact of high and cost effective agricultural production. The adverse effect of these herbicides is not only to their targets but also extend to non-targeted organisms. These effects may have detrimental impacts such as disruption of ecosystems, reduced soil health and fertility among other environmental hazardous. Dehydrogenase enzymes, which are intracellular enzyme in microflora of soil, play a key role in redox processes, especially in decomposition of organic matters. The aim of this experiments was to study the effects of 2,4-D and Hexazinone; commonly used herbicides to control weeds in sugarcane plantations in Nzoia sugar company nuclear estates, on the variation of dehydrogenase activity as an indicator of microbial activities on such soils. The soil for experiment were collected 0-10 cm depth using soil auger by random sampling method from three sites on each farm and a composite sample was prepared from the three sub-samples. Soil parameters such as pH, temperature, moisture content, N, P, K, Mg and Ca were analyzed. The experiments were conducted under the field conditions of soil samples collected from two farms which had history of application of the herbicides for five years and an out-grower farm as a control farm. The soils were spiked with the two xenobiotics at the field application rate and analyzed for the dehydrogenase activity for a period of seven days using TTC method and bacterial colony forming units using nutrient agar methods. The experiment showed that Hexazinone and a boosting activity to the microbial activity as indicated by overall DHA activity of 16.375±1.822 in farm F139, 21.970±3.448 in farm F212, 113.45±15.453 in farm OGF. On the other hand, 2, 4-D had suppressing effect on microbial activity as shown by DHA activity of 0.532±0.120 in farm F139, 0.541±0.139 in farm F212 and 6.594±1.175 in farm OGF. The noted results of DHA activity were in reference to untreated soils from the three farms which were 4.529±0.408 in farm F139, 6.103±0.341 in farm F212 and 21.578±3.234 in farm OGF. The two herbicides effects on the total microbial activity was also backed with bacterial density results which showed there was low bacterial count upon 2,4-D application 2.463±3.693*10^5 in untreated soil 2.487±5.607*10^5 in Hexazinone treated soil and 2.007±4.194*10^4 in 2,4-D treated soil. All the farms had acidic soils, but other parameters were within the normal ranges.

Keywords: Herbicides, enzyme activities, dehydrogenase, colony forming unit.

INTRODUCTION
Microbial communities are vital for the normal operation of the ecosystem both in relation to direct interaction with fauna and in nutrients and organic matter cycling (Mandal et al., 2007). Soil enzymes, which are part of the microbial, are important in the life processes, similarly in the soil they play significant role in maintaining the soil health and its environment (Das and Varma, 2010). The enzymatic activities in the soil are majorly of microbial community origin being derived from intracellular, cell-associated or free enzymes. Soil enzymes are a group of enzymes, which are found on soil microbial community and play a crucial role in maintaining soil ecology, physical and chemical properties, fertility and soil health (Adak et al., 2014; Das and Varma, 2011). The enzymes act as mediators and catalysts of important soil functions that include: decomposition of organic inputs; transformation of native soil organic matter; release of inorganic nutrients for plant growth; N2 fixation; nitrification; denitrification; and detoxification of xenobiotics. In addition, soil enzymes have a crucial role in C (β-glucosidase and β-galactosidase), N (urease), P (phosphatase), and S (sulphatase) cycle (Martinez et al., 2010).
The amounts of the enzymes in soils vary, due to the fact that, soil may contain varying amount of organic matter content, composition and activity of the living organisms and intensity of biological processes (Makoi and Ndakidemi, 2008). Analysis of enzymes in soil provides essential information on biological processes taking place. Enzymes in the soil are sensitive to both anthropogenic and natural interferences and they can be used to elucidate any induced changes in soil ecosystem (Kizilkaya and Aşkin, 2007). For instance some researches have revealed high dehydrogenase activities in soils collected from forests where there are less anthropogenic disturbances compared to areas like farms where there are frequent management activities (Kumar et al., 2013). Examples of the enzymes found in the soil include; amylase, arylsulphatases, b-glucosidase, cellulose, chitinase, dehydrogenase, phosphatase, protease, and urease released from plants (Das and Varma, 2011). Soil dehydrogenase enzymes are among the key enzymes involved in soil biochemical processes and maintaining soil biogeochemical cycles. Dehydrogenase enzymes belong to the oxidoreductases (EC 1.1.1) class of enzymes and catalyze the oxidation of organic compounds by separating two -H atoms. The separated H atom is mostly transferred to nicotinamide adenine dinucleotide (NAD) or nicotinamide adenine dinucleotide phosphate (NADHP) (Wolińska and Stępniewska., 2012: Kumar et al., 2013). Measurement of soil DHA was initiated by (Lenhard, 1956). Dehydrogenase enzymes activity measurement on soil has been used for decades and can be considered as the most important and sensitive indicator of soil microbial activity (Järvan et al., 2014). This is owing to the fact that, unlike other enzymes in soil, dehydrogenases are intracellular enzymes and occur in all viable microbial cells. The intracellular nature of the enzymes makes it a good parameter for the analysis of the viable cells in the soil. In addition, dehydrogenase enzymes are immediately degraded following cell death and therefore their detection is only in the living cells (Kizilkaya and Aşkin., 2007). Its analysis gives a good correlation between biological activity in the soil and the microbial population at time of analysis (Kumar et al., 2013). Measurement of dehydrogenase enzymes is based on the redox reaction process in which 2, 3, 5- triphenyltetrazolium chloride (TTC) is reduced to the creams red-colored triphenylformazan (TPF). 2, 3, 5- triphenyltetrazolium chloride (TTC) act as an electron acceptor in anaerobic soil environment condition during the electron transfer process in ETC chains of Microbial. Subsequently TTC which is colorless water soluble is reduced by microbial dehydrogenase enzymes to TPF which is a red color water insoluble dye and can be quantify calorimetrically by visible light at 485 nm (Wolińska and Stępniewska., 2012: Mambu., 2014).

The purpose of this study was to analyze the spatial variation of application of two herbicides 2,4-D and hexazinone on soil microbial community using dehydrogenase as the indicator tool. Microbial biomass as mentioned earlier plays a critical role in biochemical transformation occurring in the soil (Masto et al., 2011). Several studies have been conducted on the effects of these two herbicides on other diversity of life. 2,4-D for example, has been linked with human health menaces such as non-Hodgkin’s lymphoma (NHL) among farmers (Zahm, 1997; McDuffie et al., 2001), teratogenic, neurotoxic, immunosuppressive, cytotoxic and hepatoxic effects (Tuschl and Schwab, 2003). Hexazinone on the other hand, has been linked with adverse effects on aquatic lives (Baillie et al., 2015). However, there is limited information on the impacts these two herbicides have on the soil microbial community.

**METHODS AND MATERIALS**

**Study Site**

Soil samples for this study were collected from three selected farms, 212 (ELEV1458M N00o34'06.2"E034o39'41.8"), 139 (ELEV1420M N00o31'59.4"E034o40'45.2") and OGF farm (ELEV1454M N00o31'51.1"E034o42'04.4") from Nzoia sugar company nuclear estate farms (which lies between 34o50'49"E-35o35'41"E longitudes and 0o4'55"N-0o20'11"S latitudes) in Western Kenya–Bungoma County. These farms have many water canals, which drain, into Kuywa river, which traverses through the farm and is one of the Nzoia river tributary (Onywere, 2012). Nzoia river originates from Cherangani hills at a mean elevation of 2,300 m above sea level (asl) and drains into Lake Victoria at an altitude of 1000 m asl. Nzoia river basin lies between latitudes 1° 30’N and 0° 05’S and longitudes 34° and 35° 45’E. It runs approximately south-west and measures about 334 km with a catchment area of about 12,900 km², and a
mean annual discharge of 1777 x 106 m3/year. River Nzoia basin host more than 3 million people. The river is of international importance as it contributes enormously to the shared waters of Lake Victoria. Many other rivers feed the Nzoia river before it discharges into Lake Victoria (NRBMI 2006).

Figure 1: Geographical location of Nzoia Sugar Company farms in Bungoma County (Courtesy of Mr. Geoffrey Maina, Cartographer, Department of Environmental Science, Egerton University, 2016).

**Soil sampling and preparation**
The soil samples were collected from a depth of 0-10 cm using soil auger after removing the surface litters. Soils were collected in three sub-samples from each farm. The three sub-samples were used to
make a composite sample for each farm. The composite samples were dried in clear and sterile aluminium foils at room temperature. After recommended drying, the samples were crushed using motor and thimble to obtain sievable texture. The soils were sieved through 2 mm sieve to remove stones and other debris which were not required. The homogenized soils were kept at 4 oC for the subsequent experiments.

**Determination of physicochemical characteristics of soils**

Soil temperature was measured and recorded in the field, during sampling, using a laser thermometer, Raytek® Model – RAYRPM30L2G (USA). The pH of the soil was measured in a soil water suspension (soil: water ratio of 1:2), by standard method described by Geotechnical Engineering Bureau (2007). 30 Grams of soil was weighed and put in a glass beaker and 30 mL of distilled water added to the sample and stirred. The sample was let to stand for one hour with stirring every 10 -15 minutes to allow pH of the soil slurry to stabilize. The temperature reading of the pH meter was adjusted to that of the sample, before testing. The pH meter was standardized by means of buffers of pH 4.0, 7.0 and 10.

Soil moisture content was measured using the method described by Black (1965). 10 Grams of soil was weighed in aluminium tin and dried overnight in an oven at 105 oC. The weight of the dry soil sample was then recorded. The soil sample was returned in the oven, and dried further at the same temperature until no difference between any two consecutive weight measurements was recorded. The moisture content was calculated as the difference in the soil weight after drying and expressed in percentage.

The amount of Nitrogen (%) was analyzed using Kjeldahl methods (Anderson and Ingram, 1994) and measured using FOSS TECATOR digester machine (2200 Kjeltec Auto Distillation, Sweden). The soil sample was air dried at room temperature (25 oC), ground and sieved using 2 mm sieve. A sample of 0.3 Grams of air dried soil was weighed into a test tube and 4.3 mL of digesting solution (selenium powder, hydrogen peroxide, H2SO4 and lithium sulphate) added. The test tubes were put in digestion block for 3 hours set at 360 oC to obtain clear solution (indicate complete digestion). The samples were allowed to cool at 25 oC for 30 minutes after which they were diluted to 100 mL using 46% NaOH into a conical flask. 10 mL aliquots of the samples and NaOH were taken and distilled. A recipient (1% boric) was prepared. 5 mL of the recipient was mixed with the sample and titrated against standardized acid (0.01 normal HCL) until the pink colour was noted. The volume of the titres were recorded and the calculation done using the formula below.

\[
\%\text{Nitrogen} = \frac{(a-b)N \times 0.014 \times 100 \times 100'}{(a' \times 0.3)}
\]

Where a is volume of sample titre, b is black titre, N is normality of the acid used = 0.01 N HCL, 0.014 is molecular weight of N in a litre (1000 mL), 100 is the dilution factor, 100’ is conversion factor into percentage and a’ is mL of aliquot taken for analysis.

In order to analyze potassium, calcium and magnesium, the samples were prepared similar to those for nitrogen but no distillation was done. The amounts were determined using atomic absorption spectroscopy (AAS) (210 VGF AAS, USA). The quantification was done using calibration curves prepared using known amounts of standards compounds for K, Ca and Mg.

Phosphorous was analyzed using Mehlich method (Horneck et al., 2011). Thus, 5 g of air dried soil was weighed into 250 mL conical flasks. 50 mL of extracting solution (H2SO4 and HCl) was added into the samples. Free activated charcoal was then added and the samples put in an electric shaker for 30 minutes. After shaking, the samples were allowed to settle for 10 minutes and then filtered and the filtrate collected. 5 mL of the filtrate was sampled for colour development using colour developer (vanadium and molybdate in the ratio 1:1). The colour was allowed to develop for 30 minutes and the readings were taken from spectrophotometer (UV-200-RS, USA) at 430 nm wavelength. The quantification was done using calibration curves prepared using known amounts of P standard compound.
Assessment of inhibition of 2,4-D and hexazinone to soil microorganisms

To confirm whether there was any toxicity of the two xenobiotics to the soil microorganism, colony forming unit (CFU) experiments were determined according to the method described by Curtis et al. (2000). To this end, fresh soil from a farm which had never received the two herbicides (OGF) for the control of weeds was used. Soil samples were randomly collected from three sites and mixed together to make a composite sample. The samples were sieved through a 2 mm sieve to remove any unwanted debris and to homogenize the soil. The samples were then put on an aluminum foil at room temperature in three sub-sets. Two of the sub-sets were treated with 2,4-D and hexazinone at the field recommended rate and one of the sub-sets was used as the control. The samples were treated with water to appropriate moisture content (60% water holding capacity). The number of colony forming units in the soil samples was determined using serial dilution technique and the pour plate method. For enumeration of the bacteria, 1 g of soil sample was put in 9 mL distilled water and serially diluted to ×10⁻³. In order to enumerate the bacteria, 1 mL of the ×10⁻³ was then poured on sterile petri dish in which 15 mL of sterile molten nutrient agar was poured and the plates incubated at 30 ±1 oC. The effects of the pesticides on viable bacteria counts were monitored in the soils each day for seven days.

Determination of dehydrogenase activity

The dehydrogenase activity was determined according to the method described by Lenhard (1956) based on the reduction of 2,3,5-triphenyltetrazoliumchloride (TTC) to the creaming red colored formazan (TPF). In this study 6 grams of homogenized soil sample from each farm was weighed in test tubes in triplicates. 1 ml of 50 µg/ml (field recommended application rate) hexazinone and 2,4-D was prepared and used to treat the samples in triplicates. 1 ml of 3% TTC solution was added to each sample and an addition 2 ml of deionized distilled water. The test tubes were caped tightly to exclude the air since the activity of TTC is greatly affected by oxygen. The samples were incubated in dark at 30 (±1) oC for seven days with analysis of the triphenylformazan (TPF) at each day. To the control replicates, 1 ml of 3% TTC was added with no addition of the two herbicides and subjected to the same conditions. The hydrolytic products of the TTC; triphenylformazan (TPF), was extracted by passing 50 ml analytical methanol through 4 µm cellulose glass microfilter paper on a vacuum pump until all the red color was completely collected. The collected red color formazan was analyzed spectrophotometrically at 485 nm using Genesys 10-S 10uv scanning model and the amount of the TPF expressed as µg TPF/g soil sample. The concentration of the TPF is a direct representation of the dehydrogenase activity (redox processes) taking place in that respective soil samples. The data are presented as means of triplicates samples and ±Std.Dev for each farm.

Quantification of the red colour formazan from samples

In order to quantify the amount TPF present in the samples, a standard curve was prepared using standard formazan dye purchased from Kobian chemicals Kenya ltd. The varying concentration of 0 µg/ml, 5 µg/ml, 10 µg/ml, 15 µg/ml, 20 µg/ml, 25 µg/ml and 30 µg/ml were prepared in analytical grade methanol (Hurst et al., 2007). From these concentrations an aliquot of 1 ml was used to analyze the absorbance at 485 nm using UV-scanning spectrophotometer (Genesys 10-S 10uv scanning model (Austria); the same model used for sample analysis. The absorbance (A) readings versus the concentrations of the standards formazan were used to plot a standard curve (fig. 2) from which the formazan concentrations in samples were quantified.
RESULTS
The values of TPF concentration obtained as well as bacterial colony forming units were subjected to analysis of variance (ANOVA) using SAS version 9.1 portable for windows and the means separated using the LSD. Microsoft Excel 2010.Ink was used to draw curves. The results are presented as a mean of triplicates samples and ± standard deviation. The soil physicochemical parameters which includes nitrogen content, phosphorous, potassium, calcium, magnesium, pH, temperature and moisture content for the three farms where soil samples were collected were analyzed. Table 1 shows physicochemical parameters obtained from the two-selected pesticide treated farms and from one out grower farm (OGF).

Table 9: Physical-chemical parameters of soil samples from the three farms

<table>
<thead>
<tr>
<th>Farms</th>
<th>% N</th>
<th>P ppm</th>
<th>K ppm</th>
<th>Ca ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>F212</td>
<td>0.38±0.02</td>
<td>24.75±1.23</td>
<td>153±0.41</td>
<td>602±0.23</td>
</tr>
<tr>
<td>F139</td>
<td>0.34±0.04</td>
<td>21.5±1.34</td>
<td>141±0.12</td>
<td>560±0.25</td>
</tr>
<tr>
<td>OGF</td>
<td>0.40±0.12</td>
<td>31±0.34</td>
<td>144±2.34</td>
<td>678.2±1.57</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Farms</th>
<th>Mg ppm</th>
<th>pH</th>
<th>Temp</th>
<th>Moisture Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>F212</td>
<td>116.8±1.37</td>
<td>4.94±0.53</td>
<td>21.67±0.23</td>
<td>20.41±1.23</td>
</tr>
<tr>
<td>F139</td>
<td>115.7±3.01</td>
<td>5.04±0.61</td>
<td>23.67±1.23</td>
<td>22.36±1.32</td>
</tr>
<tr>
<td>OGF</td>
<td>135±2.47</td>
<td>4.16±0.73</td>
<td>22.33±1.20</td>
<td>22.49±2.12</td>
</tr>
</tbody>
</table>

Significance difference is at P<0.05, different letter assigned in the same column shows significance difference and same letter in the same column denote no significance difference.

Soils from all farms had medium range of soil N% ranging from 0.34±0.04 to 0.40±0.12, there was no significance difference (p<0.05) in the nitrogen percentage in the three farms. The phosphorous level was within the medium range within all farms. Farm OGF had higher level of P (31±0.34) compared to F212 and F139 which had 24.75±1.23 and 21.5±1.34 respectively. The level of P in OGF was statistically significant compared to farm 212 and 139, but there was no significance different in P level between farm F212 and F139. Though the potassium level was within the normal range among all the farms, these levels differed greatly within the three farms, with farm F212 recording the highest level and farm F139 the lowest level. The calcium levels were below the normal range in all farms, with highest recorded in farm OGF and lowest in F139. There was significance difference in calcium levels across all farms. Magnesium level was also within the medium range in all the farms with the highest being recorded in OGF and lowest in F139. These levels statistically differed between OGF and the two farms; F212 and
139, but there was no difference in farm F212 and F139. All the farms had acid soils with pH ranging from 4.16±0.73, 4.94±0.53 and 5.04±0.61 in OGF, F212 and F139 respectively (Marx et al., 1996).

**Toxicity effects of hexazinone and 2,4-D on viable bacterial density**

Colon forming units (CFUs) were enumerated after treating soil with hexazinone and 2,4-D. The results showed that there was gradual decrease in bacterial density as the days increased for 2,4-D treated soil samples. For the control soil samples (without treatment with either hexazinone nor 2,4-D) there was no significant difference (ρ < 0.05) in CFUs for five subsequent days of incubation (2.49±5.03×10^5 g-1 soil to 2.41±3.18×10^5 g-1 soil). The suppression of the bacterial growth was observed in both hexazinone and 2,4-D with significantly higher suppression being noted in 2,4-D treated soils. In hexazinone amended soils, significant suppression was noted within the first and the next three days but there after bacteria continued to grow recording a significant increase between day 4 and day 7. There was significance (ρ < 0.05) decrease in CFUs in day one (2.53±5.13×10^5 g-1 soil) in hexazinone treated soils. The growth suppression effects lasted for a period of three days with a decline in CFUs reading of 1.22±2.89×10^5 g-1 soil. The suppression effect of hexazinone to bacterial growth was overcome on day four (1.89±8.29×10^5 ± g-1 soil), with an observed increased bacterial growth indicated by very high CFUs by day seven (3.51±6.69×10^5 g-1 soil), which was a significant (ρ < 0.05) compared to the rest of the days. There was suppression of bacteria growth by 2,4-D as noted in hexazinone. However, the adverse effects of 2,4-D were severe by 10 log units compared to hexazinone with the first day treatment recording being 1.88±7.45×10^5 CFUs g-1 soil. The suppression lasted for three days, with a decline to 1.33±1.33×10^4 g-1 soil. This was preceded with a recovery from suppression with highest recording of CFU noted in day seven (2.00±5.13×10^4 g-1 soil). Though, there was recovery of the microorganisms from day four up to day seven, there was no significance difference (ρ > 0.05) in the recorded means for this period. Table 2 shows mean variation in colony forming units (CFUs) for soil samples treated with hexazinone and 2,4-D and a control soil sample with no treatment.

**Table 10**: Densities of viable bacteria (CFUs g⁻¹) in soil recorded for seven consecutive days following herbicide treatment in an out grower farm (OGF)

<table>
<thead>
<tr>
<th>Days</th>
<th>Untreated soil CFUs*10^5 g⁻¹ soil</th>
<th>Hexazinone treated soil CFUs*10^5 g⁻¹ soil</th>
<th>2,4-D treated soil CFUs*10^5 g⁻¹ soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.49±5.03abc</td>
<td>2.53±5.13c</td>
<td>1.88±7.45a</td>
</tr>
<tr>
<td>2</td>
<td>2.54±4.67ab</td>
<td>2.09±3.84d</td>
<td>3.50±8.15*10^4b</td>
</tr>
<tr>
<td>3</td>
<td>2.56±0.88ab</td>
<td>1.67±51.97e</td>
<td>1.97±2.96*10^4b</td>
</tr>
<tr>
<td>4</td>
<td>2.63±6.64a</td>
<td>1.89±8.29d</td>
<td>1.33±1.33*10^4b</td>
</tr>
<tr>
<td>5</td>
<td>2.41±3.18abc</td>
<td>2.61±6.00c</td>
<td>1.67±2.03*10^4b</td>
</tr>
<tr>
<td>6</td>
<td>2.28±2.72c</td>
<td>3.11±4.10b</td>
<td>1.70±2.31*10^4b</td>
</tr>
<tr>
<td>7</td>
<td>2.33±2.73bc</td>
<td>3.51±6.69a</td>
<td>2.00±5.13*10^4b</td>
</tr>
</tbody>
</table>

Values are means ±SD, n = 3, Means followed by the same letter in the same column are not significantly different at 5% LSD.

**Dehydrogenase activity results**

Dehydrogenases are soil microbial enzymes involved in catalyzing degradation of organic matter in what is basically a redox process. Soil dehydrogenases are predominantly microbiological in origin and their activities depend on the conditions within the soil ecosystem. Therefore, a higher enzyme activity indicates a greater intensity of mineralization of the organic matter. Figure 3 shows comparison of TPF mean concentrations across incubation period (seven days) for the three farms 139, 212 and OGF without treatment with hexazinone or 2,4-D and upon treatment with the two herbicides.
Figure 3. TPF concentration in soils with and without the addition of herbicides in the farms OGF, 212 and 139. Data points represent means for three replicates.

The overall analysis of the TPF concentration showed that hexazinone treated soils had higher DHA activity across all farms compared to the other two treatments. Soil treated with 2,4-D recorded the least DHA activity in all farms. Table 4 shows the overall mean concentrations and the standard deviations for the TPF concentrations across the three farms 139, 212 and OGF without treatment with hexazinone and 2,4-D and after the treatment.

Table 3. The overall mean concentrations and standard deviation of TPF in soils from the farms for the seven days treatments period

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Replicates</th>
<th>Mean µg/g Soil</th>
<th>Std. Dev</th>
<th>Mean µg/g Soil</th>
<th>Std. Dev</th>
<th>Mean µg/g Soil</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td>21</td>
<td>0.532±0.120</td>
<td></td>
<td>0.541±0.139</td>
<td></td>
<td>6.594±1.175</td>
<td></td>
</tr>
<tr>
<td>Hexazinone</td>
<td>21</td>
<td>16.375±1.822</td>
<td></td>
<td>21.970±3.448</td>
<td></td>
<td>113.45±15.45</td>
<td></td>
</tr>
<tr>
<td>Untreated</td>
<td>21</td>
<td>4.529±0.408</td>
<td></td>
<td>6.103±0.341</td>
<td></td>
<td>21.578±3.234</td>
<td></td>
</tr>
</tbody>
</table>

Means followed by the same letter in the same column are not significantly different at 5% LSD

In farm 139 there was a significant difference in enzyme activity for the two treatments and the control. Hexazinone treated soils performed best with 57% (16.38±1.82 µg/g soil) higher DHA activity as compared to the control which had 4.53±0.41µg/g soil. On the contrary, the soil sample treated with 2,4-D in farm 139 had higher inhibition of DHA in reference to the control samples, recording 78.98% (0.53±0.12 µg/g soil) decrease in DHA activity. In farm 212, there was also significant difference in DHA activity within all the treatments with soil sample treated with hexazinone having higher activity of DHA by 56.52% (6.10±0.34 µg/g soil) with reference to the untreated soil. On the other hand, 2,4-D had suppressing effects on DHA activity with a decrease of 83.71% (0.54±0.14 µg/g soil) with reference to the untreated soil sample. For the OGF farm, which had no history of herbicide treatment, DHA was significantly different for all the treatments. Hexazinone recorded the highest positive activity by 67.53% (113.45±15.45 µg/g soil) with reference to untreated soil sample, while 2,4-D had negative effects on DHA activity by 53.37% (6.59±1.18 µg/g soil) with reference to the untreated soil sample. From the experiment, there was clear evidence, of the negative effects on enzyme activity in all farms upon application of 2,4-D, while hexazinone had boosting effects on the enzyme activity in all farms.
DISCUSSION

Soil physicochemical parameters.

Soil physical-chemical parameters are important tools in biodegradation experiments since they can be used as inferences for the outcomes of such experiments. As the mineralization of the pesticides depends on microorganisms, their activity largely depends on these environmental factors (Shahgholi, and Ahangar, 2014). These soil properties can also be used to explain some soil anomalies that may be observed during analysis. The soil pH ranged from 4.16 to 5.05 indicating all the farms had acidic soil. Biodegradation of some of the pesticides have been found to be slow at pH above 6 and optimum at pH below 5 (Schoenholtz et al., 2000). However, the pH impact is relative to the individual compound being degraded and the potential organism which degrade it. The soil phosphorous for five farms were within the medium range (20-40 ppm) with only one field with excess of 144 ppm (>100) (Horneck et al., 2011). The nitrogen content was also very low (<5%) (Galloway, 2010). Similarly, the K content was extremely low for all the farms (<150 ppm) and magnesium being with the medium range (60–300 ppm) (Horneck et al., 2011). Low level of phosphorous, potassium, calcium and nitrogen may be attributed to acidity of soil (Locascio, 2000; Schoenholtz et al., 2000). Other factors that may lead to low nutrient content in soil are vegetation cover, agricultural activities such as application of fertilizer and clearing of vegetation by burning which are common practice in Nzoia sugar company nuclear estates (Ezeigbo et al., 2013). Total nitrogen may also be low in acidic soils since in acid condition there is unavailability of NH4+ (Medinski, 2007). The soil temperature ranged between 21-27 oC. The major factor that affect the soil temperature is the weather condition such as sun heating which also affect the moisture content (the moisture content ranged between 16 and 22 %) as well (Ezeigbo et al., 2013). The temperatures of soil play a major role in the degradation of the pesticides. It has been reported that most of the degradation of pesticides tends to increase with increase in temperature between 10 to 45 oC (Rani and Sud, 2015). Soil physicochemical properties such as temperature, humidity, and moisture content affect the rate of decomposition of herbicides in soil (Milosevica and Govedarica, 2000). According to Shahgholi and Ahangar (2014), soil moisture content is very crucial to the degradation process. Water acts as the solvent for the pesticides and determines its availability for the microorganism. Dry soil tends to have slow biodegradation compared to wet soil. In water logged soil, anaerobic degradation has been found to take place as opposed to aerobic degradation since there is limitation of oxygen entry to the soil. However, high moisture content may accelerate or hinder the degradation depending on the subject pesticide. On other hand, long term application of pesticides may have adverse effects on some of the soil physical chemical constituents. For instance, application of some of pesticides may lead to alteration of nitrogen (N2) fixing organisms such as Rhizobium, Azotobacteria and Azospirillum (Omakor, Onyido and Buncel, 2001). It may also affect cellulolytic and phosphate solubilizing microorganisms (Gulhane, Gomashe and Sunderkar, 2015).

DHA activity and viable bacterial counts

Soil enzymes have been for long used as sensitive indicator of soil ecological disturbances in natural and agricultural ecosystems (Badiane et al., 2001; Sannino and Gianfreda, 2001). DHAs are key enzymes in the soil microbial respiratory processes and hence a good tool to assess microbial activity upon subjection of soil to pesticides (Cycon et al., 2010). According to Mambu (2014), DHA activity is higher in low doses application of pesticides and lower in high doses pesticides applied areas. In the case of current study, this could be one of the major reasons for the low overall DHA activity recorded in farm 139 and 212 untreated soil samples, which were on frequent application of the two herbicides compared to the higher activity recorded in farm OGF which had never been applied with two herbicides. Secondly, it has been found that inorganically fertilized soils have low level of DHA activity compared to soils fertilized organically using animal manure or compost (Monkiedje, 2006). The results from this study showed drastic decrease in DHA activity across all farms upon treatment with 2,4-D as compared with untreated (control) soil samples. Hexazinone application boosted DHA activity in all the farms. The activity of the DHA enzymes was highly recorded in OGF farm in all experimental treatments. Initially upon the application of the two herbicides, 2,4-D and hexazinone, there was a lag phase in both pesticides, which took approximately two and half days. This could be attributed to the toxicity of the two herbicides.
towards the soil microorganisms. Pesticides cause respiration inhibition in their initial application stages. The effects are then recovered depending on whether the microorganisms are able to metabolize the respective compounds for their physiological needs (Radivojević et al., 2008). Thereafter there was exponential increase in activity of DHA especially in hexazinone treated soils. This could have been due to recovery of microbial population and enzymes activity after initial inhibition due to microbial adaptation to these chemicals or due to their degradation thus being used by microorganisms as the source of carbon or nitrogen. Secondly this can also be due to microbial multiplication on increased supply of nutrients available in form of microorganisms initially killed by herbicides as evidenced in other studies (Vandana et al., 2012; Latha and Gopal., 2010). According to Milosevia and Govedarica (2000), some microorganisms are able to metabolize herbicides immediately they are applied to the soil; however, there is secondary population of microbial community which may take a number of days before they can adapt to metabolize xenobiotics since enzymes responsible are inducible enzymes. The DHA activity increase upon treatment of the soil sample with hexazinone was also supported by viable bacterial enumeration which showed that there was increased CFU compared to untreated soil sample. Study by Rahman et al. (2005) on impact of herbicide oxadiazon on microbial activity showed the herbicide was able to increase the enzyme activity in soil. Other studies that have shown the boosting ability of herbicides to soil microbial activity is that of Haney et al. (2000) and Araujo et al. (2003) that showed glyphosate was able to increase soil microbial activity.

For 2,4-D treatments, the detracting affect was prolonged to approximately four days after which the activity was increased but at very low intensity as compared to the hexazinone treatment. The low DHA activity in 2,4-D treated soil samples was also supported by low viable bacterial density. These effects of 2,4-D to the DHA activity are similar with the findings by Mohiuddin and Mohammed (2014), who found that 2,4-D had inhibitory role on enzymes activity in soil for a period of 20 days and a decrease in inhibition of DHA was noted in 21st day following pesticide application. These findings also reported negative effects of 2,4-D on DHA activity in the initial application to control weeds in agricultural soils particularly in groundnuts cultivated soil (Hussain et al., 2009). The DHA activities recorded initially before the application of the two herbicides in this study were extremely high in OGF farm than in 212 and 139. This difference in DHA activity could be ascribed to the fact that soil enzymes activities are very sensitive to both natural and anthropogenic disturbances (Kumar et al., 2013). For instance, in this study, OGF farm was used as a control farm in which there was no history of herbicides application. Moreover, another factor which may contribute to the low DHA activity in 212 and 139 compared to the high activity in the untreated OGF farm is the regular use of tractor ploughing. This being one of the common anthropogenic disturbances experienced in farm 212 and 139, it may cause reduction in organic matter content in soil due to interference with the accumulation of crop residues in soil top layer and this may cause a reduction in microbial activity (Roldan et al., 2005). Soil microbial activity is more vigorous on soil rich in organic matter, and this could explain why there was high activity of DHA activity in OGF as compared to 212 and 139. Besides, herbicides decomposition also depends on the organic matter in the soil, this is apparently because of vigorous microbial activities (Baboo et al., 2013). This factor can also explain why there was high activity of DHA in OGF farm when treated with hexazinone and 2,4-D. However, the amount of the applied herbicides may also have a great effect on the amount degraded per a given time and also the residue effect of the herbicide detectable in soil (Ngigi et al., 2014).

CONCLUSION
The indiscriminate use of herbicides to control weeds has become a matter of environmental concern due to their adverse effects on the soil microbial diversity which consequently alter the soil fertility. This study was conducted to study the effects of 2,4-D and Hexazinone on soil dehydrogenase enzyme. The study confirmed that 2,4-D has great negative impact on the soil microbial activity at its recommended field rate while Hexazinone had boosting effects on the enzyme activity at the recommended field rate. This therefore, raises an alarm on the appropriate field rate at which the 2,4-D should be applied. In
conclusion, although the use of herbicides is important as it offer cheap and effective way of weed control, their application should be considered due to the detrimental effects to the untargeted organisms.

ACKNOWLEDGEMENT
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REFERENCES
Mohiuddin, M., and Mohammed, M. K. (2014). Research article fungicide (carbendazim) and herbicides (2, 4-d and atrazine) influence on soil microorganisms and soil enzymes of rhizospheric soil of groundnut crop.
ANTIMICROBIAL ACTIVITY OF A STREPTOMYCETE ISOLATE FROM WHEAT FARM SOIL IN MAU FOREST COMPLEX, KENYA

Njoroge, H. W.,*1, Muia A. W.,1, Otaye D.,1 and H. I. Boga2

1Department of Biological Sciences, Egerton University, P. O. Box 536-20115, Egerton, Kenya.
2Institute of Biotechnology Research, Jomo Kenyatta University of Agriculture and Technology, P.O Box 62, 000-00200, Nairobi

ABSTRACT
The study involved isolation of Streptomyces spp. from the soil of various sites in the Mau Forest Complex in Kenya. The isolates were screened for antimicrobial activity against selected bacterial and fungal plant pathogens including; Fusarium moniliforme, Ascochyta rabiei, Erwinia carotovora, Xanthomonas campestris pv. campestris, Pseudomonas savastanoi pv. phaseolicola and reference cultures which were; Staphylococcus aureus ATCC 25923; Escherichia coli ATCC 25922; Pseudomonas aeruginosa ATCC 27853 and Bacillus subtilis ATCC 6633. One isolate from a wheat farm designated as WHF2B16 tested positive as a Streptomyces species through cultural, morphological, biochemical and molecular characterization. It was found to have antimicrobial activity against the fungal pathogens with a zone of inhibition >20mm; one plant bacterial pathogen i.e. Pseudomonas savastanoi pv. phaseolicola with an inhibition zone of 15.5 ± 1.2 mm and was active against the Gram positive bacteria i.e. Bacillus subtilis and Staphylococcus aureus. Ethyl acetate extracts compared to culture filtrates of the isolate were found to produce significantly higher growth inhibitory effects in the test microorganisms in a t test (t-value = , P > 0.05). The isolate was further subjected to 16S RNA analysis and confirmed to be a Streptomyces species assigned as Streptomyces mau 3 (Accession No. KR780774) from the NCBI database. This study has revealed that a streptomycete from Mau Complex in Kenya has the potential to be used as an antifungal and antibacterial agent.

Keywords: Antimicrobial activity, Plant pathogens, Streptomyces

INTRODUCTION
Streptomyces is a genus of Gram positive bacteria belonging to the order Actinomycetales in the Actinobacteria phylum (Kampfer, 2006). Members of this genus are ubiquitous in nature and are mostly soil inhabitants (Madigan and Martinko, 2007). Members of the genus Streptomyces are involved in the biodegradation of various polymers abundant in soil, this is because they are able to produce extracellular enzymes (Keith et al., 2010). This genus is known to produce antibiotics, anti-tumor agents, immunosuppressive agents and enzymes (Hamid et al., 2012; Changhyun and Chan-Kyu, 2014; Laishram et al., 2014). Many antibiotics from streptomycetes today have found practical application in human and veterinary medicine, agriculture and industry (Madigan and Martinko, 2007; de Lima Procopio et al., 2012). Plant diseases have caused epidemics, famines, and hunger. In Kenya, for example, rice blast disease caused by the fungus Magnaporthe oryzae has caused great losses in rice farms (Kihoro et al., 2013). There is a need to look for an alternative means to manage plant diseases other than the classical known chemical pesticides which have a negative effect on the environment, humans and animals too. This necessitates investigating alternative strategies to control fungal and bacterial plant pathogens. The Mau Forest Complex is found in the western side of Mau Escarpment in Kenya. It is an important water tower in Kenya with many rivers originating here. It is the home of different indigenous flora and fauna (Kanyinke, 2005). The microbial diversity of the Mau complex today remains un-investigated. Like other natural environments, it may serve as a repertoire of many useful microbial resources. Due to increasing population pressure, the Mau Complex has encountered many anthropogenic activities in the recent past that have greatly affected this ecosystem (Gichuhi, 2013). The Government of Kenya is making efforts to protect and conserve the biodiversity of this area. To support these efforts there is need to carry out research geared towards conservation and bio-prospecting of useful microbial resources. This study was interested in isolating and studying antibiotic producing Streptomyces that are potentially useful for biological control of plant pathogens affecting food crops in Kenya.

MATERIALS AND METHODS
**Study area**
The Mau Forest Complex is the largest closed-canopy forest ecosystem in Kenya and the largest indigenous forest in East Africa, stretching across 400,000 hectares (1,544 square miles) (Kanyike, 2005). The latitude is between 0° 20’ 60”S and the longitude is between 35° 27’ 32”E. It lies between 2,000 m and 2,600 m above the sea level, on the Western slope of the Mau Escarpment. The soil for the current study was collected in a wheat farm (35°89’ 21.37E, 0° 36’ 21.48N) near a place called Mwisho wa Lami on the Eastern side of the Mau complex.

**Soil Sampling and isolation of *Streptomyces***
Soil samples from the wheat farm were collected randomly using a sterile Soil Auger (20 cm in depth, 2.5 cm in diameter). Soil samples were taken from a depth of 10-20 cm below the soil surface. The samples were air-dried at room temperature for 7-10 days and then passed through a 0.8 mm mesh sieve and preserved in sterile polyethylene bags at room temperature before isolation of the bacteria. Ten grams of the samples of air-dried soil was then mixed with sterile distilled water (90 ml). The mixtures were shaken for 1 hour on a rotary shaker and allowed to settle for another 1 hour. Portions of 1ml of soil suspensions (diluted 10⁻¹) were transferred to 9 ml of sterile water and subsequently decimal serially diluted up to 10⁻⁶. Inoculates consisted of adding 0.1 ml aliquots of 10⁻³, 10⁻⁴ soil dilutions to solid sterile starch-casein agar (Kuster and Williams, 1964; Williams and Davies, 1965), supplemented with filter (0.2 µm pore diameter) sterilized antibiotic solution containing cycloheximide, and nystatin (0.005% final concentration), polymixin-β sulphate (0.0005% final concentration) and sodium penicillin (0.0001% final concentration) to inhibit non-actinomycete bacteria and fungi (Baltz, 2006). The samples were spread plated on the test media in triplicates for each dilution. After incubation for 4 – 7 days at 28°C, the colonies that had developed on the plates were enumerated and expressed in colony forming units (CFU’s) per gram of soil. The isolated colonies of streptomycetes were transferred from the isolation media to a sterile growth media consisting of glucose (10g), yeast extract (1g), potassium nitrate (1g), potassium mono-hydrogen phosphate (0.1g) and agar (15g) per liter. The plates were incubated at 28°C for 6 days. Individual pure colonies of the cultures were isolated and sub-cultured into freshly prepared yeast malt extract agar at 4°C (Demain and Davies, 1999). For ease of identification, isolates were appropriately coded for later use in the antimicrobial activity assay. Thus one isolate coded as WHF2B16 was subjected to antimicrobial bio-assay as described in the following sections. The isolate was obtained from the second sample of soil from the wheat farm and was from a depth of 10-20cm.

**Antifungal bioassay**
Two plant pathogenic fungi were used for screening of antimicrobial effect. These fungi are *Fusarium moniliforme* which cause blights and ear rots in maize and *Ascochyta rabiei* which causes *Ascochyta* blight in chick peas. The fungal test pathogens were grown in PDA (potato dextrose agar) for three days; 8 mm disc plug of the fungi was picked using a sterile cork-borer and placed in at 8 mm hole bored in the middle of a PDA plate. A disc of *Streptomyces* colony grown on agar for five days was obtained using 8 mm diameter cork-borer and placed in the PDA media containing fungal test pathogens. Antifungal activity around the *Streptomyces* agar discs was evaluated as described in (Table 1.) below and the ratings used were modified from those of (Lee and Hwang, 2002).

<table>
<thead>
<tr>
<th>Inhibition diameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>No inhibition</td>
<td>(-) mycelia growth not different from control</td>
</tr>
<tr>
<td>5-9 mm (weak inhibition)</td>
<td>(+) partial inhibition of mycelia growth</td>
</tr>
<tr>
<td>10-19 mm (moderate inhibition)</td>
<td>(++) almost complete inhibition of mycelia growth</td>
</tr>
<tr>
<td>&gt;20 mm (strong inhibition)</td>
<td>(+++) complete inhibition, most mycelia will not grow</td>
</tr>
</tbody>
</table>

Controls were plain agar blocks
Antibacterial bioassay
Antibacterial activity of the isolates was tested against three plant pathogenic bacteria *Xanthomonas campestris pv, campestris, Pseudomonas savastanoi pv, phaseolicola* and *Erwinia carotovora* which causes black rot of cruciferous plants, halo blight disease in beans and soft rot of vegetables respectively. Other standard reference bacterial cultures were also used for the bioassay. These are *Staphylococcus aureus* ATCC 25923; *Escherichia coli* ATCC 25922; *Pseudomonas aeruginosa* ATCC 27853 and *Bacillus subtilis* ATCC 6633. The isolated *Streptomyces* were grown in a broth of the growth media for 72 hours then streaked perpendicularly on plates containing Mueller Hinton agar (Valgas et al., 2007; Balouiri et al., 2016). The plates were incubated for five days at 28°C. A single streak of the test bacteria was done at an angle of 90°C to the *Streptomyces* streak (Sanders, 2012). Incubation was done for 24-48 hours and the distance of inhibition was measured.

Submerged cultures and antimicrobial activity of the culture filtrate
Isolates which showed antimicrobial activity were cultivated on casein glycerol agar at 28°C for 7 days. A 0.6 cm diameter disk of the agar culture was transferred aseptically to 250 ml Erlenmeyer flasks containing 100 ml casein glycerol broth. The inoculated flasks were kept on a rotary shaker at 130 rpm at 28-30°C for 7 days. Cells were removed by centrifugation of the broth at 5000 rpm for 20 minutes. Cell free supernatant was separated using 0.2μm pore size membrane filter (Millipore) and the filtrate collected as the antibiotic sample (Grammer, 1976). The well-diffusion method was used to assay for antifungal and antibacterial activity. For estimation of the antifungal activity, a 10⁶ spore suspension of the fungi was prepared and spread plated on PDA plates using a sterile swab. The plates were allowed to dry for 15 minutes before 4 wells per plate were made using an 8mm sterile cork-borer. Each well was filled with 30 µl of the filtrate (Delahaye et al., 2009). The plates were then incubated at 27°C and observed at day 3, 5 and 7. The test bacteria were grown in Nutrient Broth and compared to a Macfarland standard of 0.5 which is equivalent to an inoculum of 1 × 10⁸ CFU mL⁻¹. Mueller Hinton Agar (MHA) plates were used. The surface of the plates was inoculated using a swab which had been dipped in the inoculum. The swab was streaked three times and each time the plate was rotated at 60°. Using a sterile 8 mm cork-borer, three wells were dug on the seeded agar plates and each well was filled with 30 µl of the filtrate collected as the antibiotic sample (Elleuch et al., 2010). The plates were incubated at 30°C and the diameter of inhibition was measured round the well.

Extraction of the antimicrobial compound
The culture filtrate was transferred aseptically into conical flasks. Ethyl acetate was added to the culture filtrate in the ratio of 1:1. The mixture was then centrifuged at 5000 rpm for 20 minutes for complete extraction. The ethyl acetate phase that contained the antibiotic was separated from the aqueous phase. It was dried at a water bath at 80-90°C and the obtained residue used for antimicrobial bioassay (Ilč et al., 2005). 6 mm filter paper disks were seeded with the antimicrobial compound and placed on PDA and MHA plates previously inoculated with the test pathogens (CLSI, 2012; Acar and Goldstein, 1996). The zone of inhibition was measured.

Cell morphology, cultural and biochemical characteristics
The cell morphology was done by examining spore hyphae under a microscope. The colour of the colonies was determined by cultivating the isolates on yeast-extract malt extract agar (YME), starch casein agar (SCA), nutrient agar (NA) and inorganic salt and starch agar (ISSA) (Shirling and Gottlieb, 1966). Observation was done after 7, 14 and 21 days. The aerial mass color, presence of soluble pigment and the reverse color was also observed. Microscopic observation was done by cover slip method (Shirling and Gottlieb, 1966). The arrangement of spores on mycelium was observed under high power objective in the light microscope. Biochemical tests for the identification of *Streptomyces* species were done using the method described by (Korn-Wendisch and Kutzner, 1992). These included carbon utilization, catalase test, gelatin liquefaction, Simon citrate and Gram reaction tests.
Identification using molecular procedures
The DNA of the isolate was extracted using the phenol/chloroform/isoamyl method (Kieser et al., 2000). The DNA was semi quantified on a 1% agarose gel in 1x TAE buffer and visualized under UV by staining with ethidium bromide (Sambrook et al., 1989). Amplification using universal primers of 8f (5'-AGA GTT TGA TCC TGG CTC AG-3') and 1492r (5'-TACTTGTGTA CGACTT-3') under the following condition: 94°C for 5 min, 30 cycles of 94°C for 45 sec, 48°C for 2 min, 72°C for 90 sec and final extension at 72°C for 10 min. The PCR reaction mixture (50 µl) contained PCR beads 1 µl from each primer 8f and 1492r, 2.5 µl of CdNTPS, 5 µl of the buffer, 0.2 µl of Taq polymerase, 2 µl of BSA and 1 µl of template DNA up to final volume 50 µl which was reached by adding distilled water. Electrophoresis of the PCR products was carried out on 1% agarose gel in 1xTAE buffer containing ethidium bromide (0.5 µg mL\(^{-1}\)), to ensure that a fragment of the correct size was amplified and detected by visualizing under UV light. PCR products were purified using High Pure PCR Product Purification Kiton kit (Roche, Germany) and outsourced for sequencing in Macrogen, South Korea. The 16S rRNA gene sequences were compared to sequences in the public database using Basic Local Alignment Search Tool (BLAST) on the National Center for Biotechnology Information (NCBI), in order to determine the similarity between sequences in the GenBank database (Al-Zahrani, 2007). The phylogenetic tree was drawn using MEGA 6.0 (Tamura et al., 2013).

RESULTS
Cultural and morphological characteristics of the isolate
Cultural and morphological examination of the isolate WHF2B16 showed that this bacterium was a streptomycete. The aerial mycelium of the isolate on inorganic salt and starch agar (ISSA) was white (Plate 1.), the substrate mycelium on the same media was cream and had a pale yellow soluble pigment. The colonies grew with a white aerial mycelium on YME agar and had a cream substrate mycelium with no soluble pigment. The color of the aerial mycelium on SCA was grey with yellow substrate mycelium and pale yellow soluble pigment as shown in Table 2. The colonies were hard to pick, butryous and formed chalky aerial spores. These are common characteristics of members of the genus Streptomyces as listed in the Bergey’s Manual of Systematic Bacteriology (Whitman et al., 2012). The spores were observed under a compound microscope at ×250. The spores were flexuous in shape (Fig 1).

Table 12: Color of isolate WHF2B16 on different media

<table>
<thead>
<tr>
<th>Medium</th>
<th>Aerial mycelium</th>
<th>Substrate mycelium</th>
<th>Soluble pigment</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCA</td>
<td>Grey</td>
<td>yellow</td>
<td>pale yellow</td>
</tr>
<tr>
<td>YME</td>
<td>white</td>
<td>cream</td>
<td>none</td>
</tr>
<tr>
<td>NA</td>
<td>cream</td>
<td>cream</td>
<td>none</td>
</tr>
<tr>
<td>ISSA</td>
<td>white</td>
<td>cream</td>
<td>pale yellow</td>
</tr>
</tbody>
</table>

SCA represents starch casein agar; YME is yeast malt extract; NA is nutrient agar and ISSA represents inorganic salts and starch agar.
Biochemical characteristics
The biochemical tests (Table 3) showed that the isolate belonged to the genus *Streptomyces* as compared to other isolates in the Bergey’s manual (Whitman *et al.*, 2012). The isolate was able to utilize a wide range of carbon sources and had abundant to fair growth. There was doubtful growth in gelatin after fourteen days after inoculation. The isolate was Gram positive, it had a negative catalase test and did not grow on MacConkey and Simon citrate agar (Table 3).

Table 13: Biochemical tests of isolate WHF2B16

<table>
<thead>
<tr>
<th>Biochemical test</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-Glucose</td>
<td>+++</td>
</tr>
<tr>
<td>D-Xylose</td>
<td>+</td>
</tr>
<tr>
<td>D-Mannitol</td>
<td>+</td>
</tr>
<tr>
<td>L-Inositol</td>
<td>+</td>
</tr>
<tr>
<td>L-Arabinose</td>
<td>+++</td>
</tr>
<tr>
<td>Sucrose</td>
<td>++</td>
</tr>
<tr>
<td>L-Rhamnose</td>
<td>++</td>
</tr>
<tr>
<td>Starch</td>
<td>+++</td>
</tr>
<tr>
<td>Gelatin</td>
<td>±</td>
</tr>
<tr>
<td>Catalase</td>
<td>-ve</td>
</tr>
<tr>
<td>Simon Citrate</td>
<td>-</td>
</tr>
<tr>
<td>Milk Agar</td>
<td>++</td>
</tr>
<tr>
<td>MacConkey</td>
<td>-</td>
</tr>
<tr>
<td>Casein Hydrolysis</td>
<td>+ve</td>
</tr>
</tbody>
</table>

+++ = Abundant growth, ++ = moderate growth, + = fair growth, ± = Doubtful, - = no growth.

Antifungal and antibacterial activity
Isolate WHF2B16 showed inhibitory activity against the fungal pathogens in the initial screening method. A photograph of the isolates of *Streptomyces* from wheat field showing inhibitory effect on *Ascochyta rabiei* is shown in Plate 2.
Plate 2. Two isolates with antifungal activity against Ascochyta rabiei. Right is WHF2B16 top and bottom is blank agar block which is control and in the center is Ascochyta rabiei.

The isolate inhibited the growth of both fungal isolates with distances that were above 20mm in diameter as shown in Table 4. This shows that the isolate has potential to inhibit control of fungal pathogens of agricultural importance. The results from initial screening for antibacterial activity using the perpendicular streaking method against bacterial pathogens showed that isolate WHF2B16 was active against one bacterial phytopathogen i.e. Pseudomonas savastanoi pv. phaseolicola. It also had inhibitory activity on reference bacterial cultures such as B. subtilis, P. aeruginosa, E. coli, and S. aureus (Table 4.) indicating its potential inhibition of bacteria in general.

Table 14: Antimicrobial activity of the isolate from the initial screening method

<table>
<thead>
<tr>
<th></th>
<th>X. c</th>
<th>P.s.p</th>
<th>E.car</th>
<th>P.a</th>
<th>E.coli</th>
<th>S.a</th>
<th>B.s</th>
<th>F.m</th>
<th>A. r</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHF2B16</td>
<td>0</td>
<td>15.5±1.2</td>
<td>0</td>
<td>20±0.5</td>
<td>5.3±0.5</td>
<td>19±0.8</td>
<td>20.7±0.9</td>
<td>23±1.2</td>
<td>20±1.2</td>
</tr>
</tbody>
</table>

Values are inhibition zones expressed as mean diameters (mm ± SD). X.c is Xanthomonas campestris, P.s.p is Pseudomonas savastanoi pv. phaseolicola, E. car is Erwinia carotovora, P.a represents Pseudomonas aeruginosa, E. coli is Escherichia coli, S.a represents Staphylococcus aureus, B. s Bacillus subtilis, F. m represents Fusarium moniliforme and A. r represents Ascochyta rabiei.

Further tests with culture filtrates and ethyl acetate extract using the disc diffusion method showed higher antimicrobial activities against the test microorganisms Bacillus subtilis, Staphylococcus aureus, Fusarium moniliforme, and Ascochyta rabiei as shown in Table 5. The culture filtrate and the ethyl acetate extract had no effect on the Gram negative bacteria both in the well and disc diffusion methods even for Pseudomonas aeruginosa that had shown a positive response in the primary screening test. However, a positive inhibitory effect was found in the Gram positive test organisms.

Table 5: Antimicrobial activity of the culture filtrate (C F) and the Ethyl acetate extract (EAE) of isolate WHF2B16.

<table>
<thead>
<tr>
<th>Isolate</th>
<th>B.s</th>
<th>P.s.p</th>
<th>E.car</th>
<th>E.coli</th>
<th>P.a</th>
<th>S.a</th>
<th>F.m</th>
<th>A. r</th>
</tr>
</thead>
<tbody>
<tr>
<td>C F</td>
<td>WHF2B16</td>
<td>10.3±0.6</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>5.7±1.2</td>
<td>25.7±1.2</td>
<td>22±0.5</td>
</tr>
<tr>
<td>EAE</td>
<td>WHF2B16</td>
<td>20±2</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>18±0.5</td>
<td>25±2</td>
<td>23±1</td>
</tr>
</tbody>
</table>

Values are inhibition zones expressed as mean diameters (mm ± SD). Means followed by the same letters in a row do not differ significantly from one another (p>0.05). B.s represents Bacillus subtilis, P.s.p is Pseudomonas savastanoi pv. phaseolicola, E. car is Erwinia carotovora, E. coli is Escherichia coli, P. a is Pseudomonas aeruginosa, S.a is Staphylococcus aureus, F.m is Fusarium moniliforme and A. r is Ascochyta rabiei respectively. NA mean no activity detected.
Molecular analysis
Blast analysis positively identified the test isolate as *Streptomyces* sp. which clustered closely to *Streptomyces badius*, *Streptomyces* sp. E5N135 and *Streptomyces* sp. 514F. The isolate had a gene homology of 99% with the above named members of the *Streptomyces* genus. The isolate was identified as *Streptomyces* Mau 3 ACC. No. KR780774 (Fig. 2).

**Figure 2:** A maximum likelihood tree based on 16S rRNA gene sequences showing the phylogenetic relationships between WHF2B16 and known *Streptomyces* isolates from the NCBI/BLAST database.

**DISCUSSION**
This study has reported the first case of *Streptomyces* isolates with antibacterial and antifungal activity from the Mau Forest Complex in Kenya. Isolate WHF2B16 isolated from a wheat farm in the Mau Forest complex showed antifungal and antibacterial activity against selected plant pathogens and standard reference bacteria test pathogens. WHF2B16 significantly inhibited the growth of Gram positive bacteria and fungi as compared to the Gram negative bacteria. These results agree with the findings of Panwar and Saini, 2012 who observed that 10.76% of their isolates had antibacterial activity against *B. subtilis* as compared to 6.45% isolates which showed antibacterial activity against *E. coli*. Actinomycetes isolates showed more inhibitory activity against Gram positive bacteria than in Gram negative bacteria (Silambarasan et al., 2012). Studies by Laishram et al., 2014 observed that *Streptomyces* isolates inhibited the growth of Gram positive *Staphylococcus aureus* but not Gram negative bacteria, these findings are similar to the current study. This can be attributed to structural differences in cell walls of Gram positive and Gram negative bacteria. The outer membrane layer in the latter group may be an effective permeability barrier due to the presence of structural lipopolysaccharide components which make the cell wall impermeable to lipophillic solutes (Scherrer and Gerhardt, 1971). It may also mean that the antibiotics have an effect on the peptidoglycan development in Gram positive bacteria as is the case with some antibiotics (Kohanski et al., 2012).

The antimicrobial effect of the isolate decreased when the culture filtrate was used as compared to when the isolate was interacting with test pathogens in the solid media. Such findings have been observed by
other researchers who noted that antibacterial activity of actinobacteria was higher in solid media than in culture filtrates (Kumar and Kokati, 2012). *Streptomyces* isolates from Jazan showed decreased to negative antimicrobial activity when grown in liquid media as compared in solid media (Al-Zahrani, 2007). These results agree with the findings of the current study. The isolate was characterized using biochemical, microscopical and morphological characteristics and was identified as a member of the genus *Streptomyces*. It was further characterized using 16S rRNA analysis and BLASTN analysis. The isolate was identified as a *Streptomyces* once more and it was placed in the same clade as *Streptomyces badius* which produces hydroxyl marilone C which has potential anti-tumor and anti-viral properties (Osama *et al*., 2016).

**CONCLUSION**

Mau Forest Complex provides a site with unexploited microbial resources in Kenya. *Streptomyces Mau 1* (Acc. No. KR780774) was isolated from the Complex. This isolate showed antimicrobial activity against Gram positive bacteria and plant pathogenic fungi. 16S rRNA analysis showed the isolate clustered with *Streptomyces badius* and *Streptomyces griseus* which are antibiotic producing *Streptomyces* that have been exploited by the pharmaceuticals. Hence this isolate can be investigated further for antibiotics production and possibly other beneficial secondary metabolites.

**ACKNOWLEDGEMENT**

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**CONFLICT OF INTEREST**

There is no conflict between the authors either financial/commercial or any other form of interest. This paper has not been published elsewhere and is devoid of plagiarism.

**REFERENCES**


SELECTIVE CONVERSION OF FRUCTOSE TO METHYL LEVULINATE USING SULFATED ZIRCONIA-ALUMINA BINARY OXIDES

Njagi, Eric C.*, and Suib, Steven L. b
aDepartment of Physical Sciences, Chuka University, P.O Box 109-60400, Chuka, Kenya
bDepartment of Chemical, Materials and Biomolecular Engineering, University of Connecticut, Storrs, USA
*Corresponding Author. Email: echomba@chuka.ac.ke. Telephone: (+254) 706 459 315

ABSTRACT
Sulfated ZrO$_2$-Al$_2$O$_3$ binary oxides synthesized by a modified co-precipitation method are highly active and selective for direct conversion of fructose to methyl levulinate. The synthesized oxides are amorphous with large mesopores ($\geq$ 3.4 nm) and high pore volumes (0.121-0.315 cm$^3$g$^{-1}$). The most active catalyst (ZA20), containing 20% alumina, selectively converted fructose to methyl levulinate with a high yield of 65% after 1 h at 200°C. The optimal catalyst loading, reaction time, and temperature were 40 mg, 30 min and 200°C, respectively. The catalysts were gradually deactivated with successive reuse due to surface deposition of humins but were easily regenerated by calcination in static air at 500°C for 3 h. However, activity was not fully recovered after regeneration, may due to leaching of sulfate species in the polar solvent media. The formation of ethers during conversion was negligible suggesting that methanol can be recycled after distillation.

Keywords: Sulfated binary oxides, mixed-metal oxides, solid superacids, biochemicals, biomass conversion, levulinate esters

INTRODUCTION
The bulk of global chemicals and fuels demands are currently being met with non-renewable fossil fuels. However, diminishing fossil fuel resources as demand increases, uncertainties of future supplies due to geopolitical factors, and adverse environmental effects due to emission of CO$_2$ into the atmosphere call for urgent development of alternative technologies for sustainable production of fuels and chemicals (Serrano-Ruiz et al., 2010). Lignocellulosic biomass (e.g. agricultural and forest residues, cellulosic municipal and industrial wastes, and energy crops) constitutes a huge reservoir of renewable organic carbon that can be used for sustainable production of biofuels, chemicals, and resins with minimal environmental effects (Chhedu et al., 2007). Lignocellulosic biomass can be converted to several platform chemicals that can be derivatized further to produce high-value bio-based specialty chemicals and polymeric materials (Werpy and Petersen, 2004).

Levulinate esters are among biomass-derived platform chemicals that are increasingly being explored for use as specialty chemicals, green solvents, and oxygenated fuel additives (Christensen et al., 2011; Démolis et al., 2014). Levulinate esters can also be derivatized to produce herbicides, cancer therapeutics (Brunner et al., 2003, Dabrowski et al., 2003), surfactants, lubricants, and polymeric materials (Selifonov et al., 2014).

Several studies have reported the synthesis of levulinate esters from biomass resources through acid-catalyzed alcoholysis of sugars, esterification of levulinic acid, and conversion of furfural and its derivatives (Démolis et al., 2014). Homogeneous acids have high catalytic activities but have several disadvantages including excessive generation of liquid wastes, corrosion of equipment, and difficulties of product purification and catalyst recyclability (Rackemann and Doherty, 2011). Solid acids can overcome these challenges but their usage is limited by their low activity and selectivity due to diffusional limitations and the difficulties of optimizing the acidity required for a specific product (Peng et al., 2011; Saravanamurugan and Riisager, 2012; Rinaldi and Schüth, 2009; Tong et al., 2010; Qi et al., 2009). There is therefore a need to develop solid superacids with high activity and selectivity to enable commercial conversion of biomass to levulinate esters.
Mesoporous metal oxides are well suited for conversion of monosaccharides to biochemicals because the mesopores allow for unhindered access of catalytic sites in their pore system (Rinaldi and Schüth, 2009). The acidity of metal oxides can be enhanced by chemical combination of dissimilar oxides to form homogeneous binary oxides (Miller and Ko, 1997). The acidity can be increased further through incorporation of sulfate species (Yang et al., 2003; Matsuhashi et al., 1999; Brei, 2005).

Sulfated metal oxides are usually synthesized through incipient wetness impregnation of metal hydroxides with H2SO4 or (NH4)2SO4 solutions (Fa et al., 1997). However, materials synthesized using the aforementioned method under similar preparation conditions often have different sulfur loadings and catalytic activity (Fa et al., 1997). In this study, sulfated metal oxides were synthesized using a modified co-precipitation method that led to direct incorporation of sulfate ions in the amorphous hydroxides. The synthesized materials were highly active and selective for conversion of fructose to methyl levulinate.

MATERIALS AND METHODS

Preparation of Sulfated ZrO2-Al2O3 catalysts

Sulfated ZrO2-Al2O3 catalysts were prepared by a modified co-precipitation method. 3 mL of concentrated sulfuric acid (H2SO4, J.T Baker) was dissolved in 50 mL of distilled deionized water (DDW). Then, 5.781 g (0.0250 moles) of zirconyl nitrate (ZrO(NO3)2. xH2O, 99.9%, Alfa Aesar) was added and the solution vigorously stirred. In another beaker, the desired amount of aluminum nitrate (Al(NO3)3. 9H2O, >98%, Sigma-Aldrich) was dissolved in 50 mL of DDW. The two solutions were mixed and vigorously stirred to form a homogeneous solution.

Ammonium hydroxide (28.0-30.0%, Mallinckrodt Baker) was added dropwise, with continuous vigorous stirring, until the pH of solution was between 9 and 10. The resultant precipitate was aged for 24 h at room temperature in the mother liquor with stirring. The precipitate was then filtered, washed with DDW, oven dried at 110°C overnight, and crushed into powder. The powder samples were then calcined in air at 500°C for 3 h. The sulfated ZrO2-TiO2 samples were designated ZA10-ZA90 with numerals indicating the percent of alumina in each bimetallic oxide. Sulfated ZrO2 and sulfated Al2O3 were prepared using the same method without the addition of aluminum nitrate and zirconyl nitrate, respectively.

Characterization of Catalysts

The structural properties of the samples were studied by powder x-ray diffraction (XRD). The XRD patterns were obtained using a Scintag Model PDS-2000 X-ray powder diffractometer. The wavelength of Cu-Kα x-ray radiation used was 1.5418 Å while the beam voltage and current were 45 kV and 40 mA, respectively. Scans were done in continuous mode at a rate of 2º per minute in the 2θ range of 0-90º.

The textural properties of the samples were studied through nitrogen sorption measurements using Quantachrome Autosorb-1-C high performance surface area and pore size analyzer (Quantachrome Instruments, FL, USA). The adsorption and desorption experiments were done at 77 K after initial pretreatment of the samples by degassing at 300°C for 12 h. Surface areas and pore size distributions were determined by the Brunauer-Emmett-Teller (BET) and the Barrett-Joyner-Halenda (BJH) methods, respectively.

Conversion of Fructose to Methyl Levulinate

The conversion of fructose to methyl levulinate was performed in a continuously stirred pressurized reactor (Parr Instrument Company, USA). In a typical reaction, 90 mg of fructose, 50 mg of the catalyst, and 10 mL of absolute methanol (J.T Baker) were loaded into the reactor. The reactor was tightly sealed, purged and then pressurized to 20 bars with nitrogen gas. The temperature of the reactor was then raised to 200°C and held for 1 h. The reactor was then submerged in ice-cold water to quench the reaction. The reactor contents were collected, centrifuged, and the supernatant filtered with a 0.45 µm filter. Stability studies were performed by catalyst recovery and reuse under the same reaction conditions without any
pretreatment. The catalyst was regenerated after the 5\textsuperscript{th} reuse by calcination in static air at 500°C for 3 h and then reused under the same reaction conditions.

**Qualitative and Quantitative Analysis of Products**

The qualitative identification of the products was done using a HP 5890 Series II gas chromatograph equipped with a BD-17MS capillary column (20.0 m x 180 μm x 0.18 μm) coupled with an HP 5971 mass selective detector. Quantitative analysis of the methyl levulinate was done using a HP 5890 series II GC system equipped with a MTX®-biodiesel TG w/Integra-Gap™ capillary column (14.0 m x 530 μm x 0.16 μm) and a flame ionization detector. The calibration curve was obtained using commercial methyl levulinate (Sigma-Aldrich) and 1-Octanol (Sigma-Aldrich) as an internal standard.

**RESULTS**

**Structural Analysis**

Figure 1 shows the XRD patterns of sulfated ZrO\textsubscript{2}, ZrO\textsubscript{2}-Al\textsubscript{2}O\textsubscript{3} binary oxides and Al\textsubscript{2}O\textsubscript{3} samples. Sulfated ZrO\textsubscript{2} was highly crystalline with diffraction peaks corresponding to the monoclinic phase of zirconia. Sulfated Al\textsubscript{2}O\textsubscript{3} was poorly crystalline with broad diffraction peaks corresponding to α-alumina. The synthesized sulfated ZrO\textsubscript{2}-Al\textsubscript{2}O\textsubscript{3} binary oxides were essentially amorphous.

![Figure 1. The XRD patterns of the synthesized materials](image)

**Textural Analysis**

The textural properties of the synthesized samples are summarized in Table 1. Generally, incorporation of alumina into zirconia caused a gradual increase in the surface areas of the resultant binary oxides. Sulfated ZrO\textsubscript{2} and samples with low (≤40%) alumina loading had low surface areas compared to samples with high (>40%) alumina content. Sulfated Al\textsubscript{2}O\textsubscript{3} had the highest surface area. The synthesized materials were porous with pore diameters in the mesoporous range. The size of the pores in the ZA60 sample were significantly larger compared to the rest of the synthesized materials. The pore volumes ranged from 0.121 to 0.315 cm\textsuperscript{3}/g\textsuperscript{1} for ZA80 and Al\textsubscript{2}O\textsubscript{3} samples, respectively.
Table 1. Textural properties of the synthesized sulfated samples

<table>
<thead>
<tr>
<th>Samples</th>
<th>BET surface area (m²/g)</th>
<th>Pore diameter (nm)</th>
<th>Pore volume (cm³/g)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZrO₂</td>
<td>58</td>
<td>3.4</td>
<td>0.182</td>
</tr>
<tr>
<td>ZA20</td>
<td>34</td>
<td>3.4</td>
<td>0.174</td>
</tr>
<tr>
<td>ZA40</td>
<td>76</td>
<td>3.8</td>
<td>0.242</td>
</tr>
<tr>
<td>ZA60</td>
<td>111</td>
<td>12.4</td>
<td>0.233</td>
</tr>
<tr>
<td>ZA80</td>
<td>175</td>
<td>3.4</td>
<td>0.121</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>268</td>
<td>4.3</td>
<td>0.315</td>
</tr>
</tbody>
</table>

²BJH desorption cumulative pore volume

**Conversion of Fructose to Methyl Levulinate**

The yields of methyl levulinate obtained from fructose using the synthesized materials are tabulated in Table 2. These materials selectively converted fructose to methyl levulinate with no other byproducts, except insoluble humins. Intermediate products (e.g. 5-hydroxymethylfurfural) were not obtained. Sulfated ZrO₂ gave a yield of 44.1%. The highest yield (65%) was obtained using sulfated ZrO₂-Al₂O₃ sample with a 20% alumina (ZA20). The other binary oxides gave lower yields than sulfated ZrO₂. No methyl levulinate was obtained using sulfated Al₂O₃. On the basis of its high conversion of fructose to methyl levulinate, the ZA20 sample was chosen for further catalytic tests.

Table 2. Yield of methyl levulinate from fructose using the synthesized materials

<table>
<thead>
<tr>
<th>Sample</th>
<th>Yield (%)</th>
<th>Sample</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZrO₂</td>
<td>44.1</td>
<td>ZA60</td>
<td>19.4</td>
</tr>
<tr>
<td>ZA10</td>
<td>40.8</td>
<td>ZA70</td>
<td>31.8</td>
</tr>
<tr>
<td>ZA20</td>
<td>65.1</td>
<td>ZA80</td>
<td>22.4</td>
</tr>
<tr>
<td>ZA30</td>
<td>31.5</td>
<td>ZA90</td>
<td>9.3</td>
</tr>
<tr>
<td>ZA40</td>
<td>31.0</td>
<td>Al₂O₃</td>
<td>0</td>
</tr>
<tr>
<td>ZA50</td>
<td>23.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conversion conditions: 50 mg catalyst, 90 mg fructose, 10 mL methanol, 200°C, 1 h.

**Effects of Reaction Time**

Figure 2 shows the effect of reaction time on the conversion of fructose to methyl levulinate using the ZA20 sample. The reactor was heated from room temperature to 200°C, held for different times, and then quenched with ice-cold water. The zero time (0 h) was defined as the time required to raise the reactor temperature to 200°C. The yield of methyl levulinate obtained at 0 h was 55%. The yield increased to ca. 64% when the reactor temperature was held constant for 30 min. There was no further significant increase in yield when the reactor temperature was held at 200°C for more than 30 min.

Figure 2. Effect of reaction time on the yield of methyl levulinate from fructose (50 mg catalyst, 90 mg fructose, 10 mL methanol, 200°C).
Effects of Reaction Temperature
Figure 3 shows the effect of reaction temperature on the yield of methyl levulinate from fructose. Conversion of fructose to methyl levulinate was not observed at 100°C. Methyl levulinate yields of ca. 15, 54, and 68% were obtained at 150, 180 and 200°C, respectively.

Figure 3. Effects of reaction temperature on conversion of fructose to methyl levulinate (50 mg catalyst, 90 mg fructose, 10 mL methanol, 1 h)

Effects of Catalyst Loading
Figure 4 shows the effects of catalyst loading on the yield of methyl levulinate from fructose. The yield of methyl levulinate obtained using 10 mg of the catalyst was ca. 10%. The yield increased to ca. 65% with 40 mg of catalyst. There was no significant difference in the yield obtained with a catalyst loading of 40 mg and 50 mg.

Figure 4. Effects of catalyst loading on conversion of fructose to methyl levulinate (ZA20 catalyst, 90 mg fructose, 10 mL methanol, 200°C, 1 h)

Reusability of the Catalyst
Figure 5 shows the yield of methyl levulinate from fructose after successive reuse of the ZA20 sample. The yield of methyl levulinate decreased gradually with successive reuse with the catalyst being completely deactivated after the 4th reuse. The deactivated catalyst was regenerated by calcination in static air for 3 h. The yield of methyl levulinate with the regenerated catalyst was ca. 40%.
DISCUSSION
Sulfated ZrO$_2$-Al$_2$O$_3$ binary oxides were synthesized using a modified co-precipitation method that led to direct incorporation of sulfate species in the precipitated hydroxides. The precipitates were then aged in the mother liquor with continuous stirring to allow for homogeneous incorporation of sulfate ions in the resultant hydroxides. The synthesized binary oxides are therefore expected to have high acidities due to the presence of sulfate species and the creation of new acidic sites through generation of excess charge (Brei, 2005, Miller and Ko, 1997).

Sulfated ZrO$_2$ was highly crystalline with diffraction peaks corresponding to the monoclinic phase of zirconia. However, incorporation of alumina inhibited the crystallization of zirconia producing amorphous binary oxides. The surface areas of the synthesized samples increased gradually with addition of alumina to zirconia, which has been attributed to the corresponding change in structural properties from crystalline to amorphous (Reddy and Khan, 2005). However, the yields of methyl levulinate obtained from fructose suggest that activities of the synthesized materials are independent of surface area.

The synthesized materials have large (≥ 3.4 nm) mesopores and significant pore volumes (≥ 0.121 cm$^3$/g) allowing reactants to access sites in the pores, and unhindered diffusion of methyl levulinate out of the pores before taking part in secondary reactions (Zeng et al., 2010). Sulfated ZrO$_2$-Al$_2$O$_3$ oxides of different compositions gave different yield of methyl levulinate presumably due to differences in the densities of acid sites. However, intermediate hydrolysis products were not obtained suggesting that these materials have the high acidity required for conversion of fructose to methyl levulinate. The high selectivity of these materials can therefore be attributed to the presence of strong acid sites and large mesopores (Lourvanij et al., 1993; Zeng et al., 2010).

The rate of conversion of fructose to methyl levulinate increased with temperature. However, the color of the products and spent catalysts increasingly turned dark brown with increase in reaction temperature. This suggests that the formation and deposition of insoluble humins on the surface of the catalysts increased with increase in reaction temperature. The formation of insoluble humins also increased as the loading of the catalysts increased. Consequently, high reaction temperatures and catalyst loadings did not increase the yields of methyl levulinate but led to conversion of fructose to humins, due to higher rates of polymerization (Antal et al., 1990; Peng et al., 2011).

The gradual decrease in conversion of fructose to methyl levulinate on successive reuse of the catalyst is attributed to the blockage of the active sites due to deposition of solid humins on the surface of the catalyst.
catalyst (Peng et al., 2011). Calcination in static air regenerated deactivated catalysts by removal of humins through combustion. However, the activity was not fully recovered presumably due to reduction of acidity through leaching of sulfate species in the polar solvent (Suwannakarn et al., 2008).

CONCLUSION
Sulfated ZrO$_2$-Al$_2$O$_3$ binary oxides were successfully synthesized using a facile co-precipitation method. The binary oxide with alumina loading of 20% was highly active and selective for conversion of fructose to methyl levulinate. The high activity is attributed to the high density of acidic sites in the binary oxide. The high selectivity is attributed to the presence of high strength acidic sites and large mesopores in the synthesized materials. The catalysts were easily separated from the reaction mixture and reused after thermal treatment. Formation of dimethyl ether was negligible suggesting that the solvent can be distilled and recycled.

RECOMMENDATION
Sulfated ZrO$_2$-Al$_2$O$_3$ binary oxides are promising materials for conversion of fructose to methyl levulinate. Further studies should be undertaken to quantify and optimize the acidities, the chemical stability and the catalytic performance of these materials for conversion of lignocellulosic biomass.

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SYNTHESIS, CHARACTERIZATION AND ANTIMICROBIAL ACTIVITIES OF SOME HYDROXYTRIAZENES AND THEIR COPPER (II) COMPLEXES

A. F. Kariuki and E. C. Njagi

“Department of Physical Sciences, Chuka University, Box 109-60400, Chuka, Kenya.
*Corresponding Author. Email: echomba@chuka.ac.ke Telephone: (+254) 706 459 315

ABSTRACT

Several hydroxytriazene ligands and their copper (II) complexes were synthesized in high yields by the coupling of aryl hydroxylamines and diazonium salts of aromatic amines. The synthesized compounds were characterized by micro-elemental analysis, Fourier Transform Infrared (FT-IR) spectroscopy, Ultraviolet-Visible (UV-Vis) spectroscopy, Proton-Nuclear Magnetic Resonance (1H-NMR) spectroscopy and molar conductivity measurements. Elemental and spectroscopic results indicate that the target compounds were synthesized in high purity. Results of elemental analysis revealed a 1:2 metal to ligand stoichiometry in the complexes. The FT-IR data suggested the coordination of the metal ion with the ligands in a bidentate manner through the O,N donor system. Electronic spectra of the ligands exhibited intra-ligand transition bands indicating π-conjugation in the ligands. The data from molar conductivity measurements indicated that the complexes were non-electrolytes. Antibacterial evaluation of the synthesized compounds was done by disk diffusion and tube dilution methods. Bacterial strains used for antibacterial screening included enteropathogenic Escherichia coli (EPEC), enterohemorrhagic Escherichia coli (EHEC), enteroaggregative Escherichia coli (EAEC), Klebsiella pneumoniae, Proteus mirabilis, Pseudomonas putida, Salmonella enteritidis, Shigella dysenteriae, Staphylococcus aureus and Vibrio cholerae. MIC values of 12.5-50 μg/ml were observed with some of the screened compounds.

INTRODUCTION

Bacterial pathogens are increasingly becoming resistant to antibacterial drugs currently in use. Clinical cases of methicillin-resistant Staphylococcus aureus, vancomycin-resistant enterococci and multidrug resistant Pseudomonas aeruginosa have been reported worldwide (Nordmann et al., 2007; El’Garch et al., 2007). Klebsiella pneumoniae, the causative agent of several diseases (e.g. pneumonia, urinary tract infections, and bacteremia), has developed resistance to many classes of antibacterial drugs including aminoglycosides, cephalosporins, fluoroquinolones, tetracyclines, chloramphenicol and co-trimoxazole (Sikarwar and Batra, 2011; Nathisuwan et al., 2001). Antimicrobial resistance by strains of Escherichia coli to first-line drugs such as fluoroquinolones and β-lactam antibiotics is causing huge clinical challenges (Fanning et al., 2011; Shaikh et al., 2014). Vibrio cholerae, the causative agent of cholera, is increasingly becoming resistant to common antibiotics including sulfamethoxazole, co-trimoxazole, trimethoprim, chloramphenicol, ampicillin, tetracycline, nalidixic acid and gentamicin (Rahmani et al., 2012; Okoh and Igbinsosa, 2010). Antibiotic resistance by Shigella spp. has been reported across several classes of antibacterial agents including ampicillin, nalidixic acid, tetracycline, co-trimoxazole (Mardanesh et al., 2013; Singhania et al., 2012). Moreover, antimicrobial resistance to cephalosporins and fluoroquinolones by Proteus mirabilis is increasingly being reported worldwide (Wu et al., 2008; Saito et al., 2007).

The emergence of multidrug resistant bacterial pathogens is creating serious clinical challenges including diagnostic uncertainties, increased treatment costs and high rates of morbidities and mortalities (Santajit and Indrawattana, 2016). Medical operations (e.g. surgeries) which are dependent on antibiotics for treatment of opportunistic infections are threatened by emergence of multi-drug resistant bacterial pathogens. Moreover, multidrug resistant bacterial strains are complicating treatment of opportunistic infections in immunocompromised patients. There is therefore an urgent need to develop novel antibiotics to counter threats posed by multidrug resistant bacterial pathogens (Penchovsky and Traykovska, 2015).

Hydroxytriazenes and their transition metal complexes are increasingly being explored for potential use as antimicrobial agents. These compounds have exhibited antibacterial (Kodli et al, 2014; Chundawat et
al., 2014; Singh et al., 2014), antifungal (Joshi et al, 2010), anti-inflammatory (Jain et al, 2010) and insecticidal activities (Jodha et al, 2014; Ombaka, 2011). The biological activities of hydroxytriazenes can be tuned through variation of substituents on aryl groups and complexation to optimize their electronic properties and hydrophobicity (Kumar et al., 2014; El-Sawaf, 2016; Hasi et al., 2016). In this study, select hydroxytriazenes and their Cu (II) complexes were synthesized, characterized and their antimicrobial activities evaluated.

MATERIALS AND METHODS

Chemicals and solvents used in this study were of analytical grade. Nitrobenzene (98%), 3-nitrotoluene (98%), 4-aminobenzoic acid (99%), 3-aminobenzoic acid (98%), 4-toluidine (99%), absolute methanol (99%), acetone (98%), 1,4-dioxane (98%), Mueller Hinton Agar (99%), Luria Bertania broth medium (99%) and sodium chloride (98%) were obtained from Sigma Aldrich. Copper (II) acetate monohydrate (98%), sodium nitrite (98%) and bacto-tryptone (98%) were sourced from Merck. Zinc dust (99%) and dimethyl sulfoxide (98%) were purchased from Fluka and Finar, respectively. Chemicals and solvents were used as purchased without any further purification.

Synthesis of Hydroxytriazene Ligands

The hydroxytriazene ligands were synthesized following a standard method reported in the literature (Khan et al, 2013). In a typical synthetic protocol, a nitro aryl compound (0.1 mol) was reduced to aryl hydroxylamine with 20 g of Zn dust in the presence of 7.5 g of ammonium chloride (NH4Cl) in a water-alcohol medium at 50-60°C. Then, a primary aromatic amine (0.1 mol) was diazotized with 0.1 mol sodium nitrite (NaNO2) in an acidic solution containing 25 mL of HCl and 25 mL of distilled water. The aryl hydroxylamine and the diazonium salt were subsequently coupled at 0-5°C in an acetate buffer (pH 5-6) medium to yield the hydroxytriazene ligands. The synthesized ligands were designated L1-L5.

Synthesis of Copper (II) Complexes

Copper (II) complexes were synthesized following a method described in the literature (Aliyu and Mohammad, 2012). Briefly, 0.002 mol of copper (II) acetate monohydrate was dissolved in 15 mL of double distilled water and the pH of the resultant solution adjusted to ca. 5 with an acetic acid-sodium acetate buffer. In a separate beaker, 0.004 mol of the ligand was dissolved in a minimum amount of hot ethanol and the pH of the solution adjusted to ~5 with an acetic acid-sodium acetate buffer. The metal solution was then added dropwise to the warm solution (40-50 °C) of the ligand with continuous stirring. The resultant mixture was left to boil for about 1 h with continuous stirring. The resultant precipitate was filtered under reduced pressure, washed thoroughly with distilled water and hot ethanol and dried in an oven at 70 °C. The synthesized compounds were designated Cu-L1 to Cu-L5 with L1-L5 indicating the ligand used to synthesize the respective copper (II) complex.

Characterization of the Synthesized Compounds

The melting points of the synthesized compounds were determined with open glass capillaries using a MPA-12 Melting Point Apparatus. The elemental composition (C, H, N) of the ligands was determined using a Vario EL III Elementar CHNS analyzer. The amount of oxygen in the ligands was determined by difference. The concentration of copper in the complexes was determined by Flame Atomic Absorption (FAAS) spectroscopy using a PGI 990 Atomic Absorption Spectrophotometer. The functional groups present in the ligands and complexes were determined by Fourier Transform Infrared (FT-IR) spectroscopy using the KBr method (Shimadzu IRAffinity-1S FT-IR spectrophotometer). The chemical environment of protons in the ligands was studied by Nuclear Magnetic Resonance (1H NMR) spectroscopy. Spectra were recorded on a Bruker Ultra-shield 400 MHz spectrometer using deuterated DMSO-d6 as the solvent and tetramethylsilane (TMS) as the internal standard. The electronic properties of the ligands and the complexes were determined by Ultraviolet-Visible (UV-Vis) spectroscopy using a Shimadzu UV-1800 double-beam spectrophotometer. The molar conductivities of the complexes were determined in dimethyl sulfoxide (DMSO) using a HANNA Instruments EC 215 Conductivity meter.
Antibacterial Assays

In vitro screening tests were done to investigate the antibacterial efficacy of the synthesized compounds. The bacterial strains tested included enteropathogenic Escherichia coli (EPEC), enteroaggregative Escherichia coli (EAEC), enterohaemorrhagic Escherichia coli (EHEC), Pseudomonas putida, Proteus mirabilis, Shigella dysenteriae, Staphylococcus aureus, Vibrio cholerae, Klebsiella pneumoniae and Salmonella enteritidis. The strains used in the tests were clinical isolates obtained from Kenya Medical Research Institute. Antibacterial testing was done by disk diffusion method (Jorgensen and Ferraro, 2009) and tube dilution method (CLSI, 2012). Bacterial strains were first subcultured from freezer stocks onto Mueller Hinton agar plates and incubated at 37°C overnight.

In disk diffusion tests, 2000 µg/ml stock solutions of the ligands and the complexes were prepared in DMSO. The stock solutions were then diluted to prepare solutions of 1000, 500, 250, 125 and 62.5 µg/ml concentrations. Sterile filter paper disks (6 mm diameter) were soaked in the dilutions, then removed and allowed to dry. The test bacteria were inoculated on Mueller Hinton Agar (MHA) by streaking with the aid of a spreader. The dry paper disks were then placed at equidistant positions on the inoculated MHA. A paper disk impregnated with DMSO was placed in each plate to serve as solvent control. The plates were incubated at 37°C for 24 h. The diameters of inhibition zones (in mm) of triplicate sets were measured and recorded at the elapse of the incubation period.

The minimum inhibitory concentration (MIC) of the synthesized compounds was carried out by tube dilution method in two-fold serial dilutions. Stock solutions (1000 µg/ml) of the test compounds were prepared in DMSO, then serial diluted to give solutions of 100, 50, 25 and 12.5 µg/ml concentrations. The inoculum was prepared by growing the bacteria at 37°C in Mueller Hinton Agar. Discrete colonies were picked with a loop and emulsified in 0.45% (w/v) sterile aqueous normal saline. The suspension optical density was standardized to a McFarland density of 0.5 (equivalent to 10^8 CFU/ml) with the aid of a DensiChekTM densitometer (bioMerieux, USA) apparatus. Then 1 ml of this adjusted inoculum was added to tubes containing Luria Bertania (LB) broth and different concentrations of the test compounds. An un-inoculated tube of LB was incubated to serve as a negative growth control. In a different tube about 2 ml of DMSO was added and the tube was inoculated with test bacteria to serve as solvent control. The tubes were incubated at 37°C for 24 h. At the elapse of the incubation period, all the tubes were examined for turbidity. The presence of turbidity was an indication of bacterial growth while a clear solution signaled inhibition of the test microbes. The lowest concentration of the test compounds that inhibited growth of the microbes was designated the minimum inhibitory concentration. All the tests were done in triplicates.

RESULTS

Physical Properties of the Synthesized Compounds

Compound L₁ was synthesized by the coupling of the aryl hydroxylamine derived from nitrobenzene and the diazonium salt derived from 4-aminobenzoic acid. The target ligand was 3-Hydroxy-3-phenyl-p-carboxyphenyl triazene. Yellow crystals were obtained with a yield of 66% and a melting point of 169°C. Compound L₂ was synthesized by the coupling of the aryl hydroxylamine derived from nitrobenzene and the diazonium salt derived from 3-aminobenzoic acid. The target ligand was 3-Hydroxy-3-phenyl-m-carboxyphenyl triazene. Brown crystals were obtained with a yield of 61% and a melting point of 160°C. Compound L₃ was synthesized by the coupling of the aryl hydroxylamine derived from nitrobenzene and the diazonium salt derived from 3-aminobenzoic acid. The target ligand was 3-Hydroxy-3-m-tolyl-1-m-carboxyphenyl triazene. Yellow crystals were obtained with a yield of 64% and a melting point of 158°C. Compound L₄ was synthesized by the coupling of the aryl hydroxylamine derived from 3-nitrotoluene and the diazonium salt derived from 4-aminobenzoic acid. The target ligand was 3-Hydroxy-3-m-tolyl-1-p-carboxyphenyl triazene. Yellow crystals were obtained with a yield of 74% and a melting point of 158°C.
point of 176 °C. Compound $L_5$ was synthesized by the coupling of the aryl hydroxylamine derived from 3-nitrotoluene and the diazonium salt derived from 4-toluidine. The target ligand was 3-Hydroxy-3-\(m\)-tolyl-1-p-carboxyphenyl triazene. Yellow crystals were obtained with a yield of 56% and a melting point of 122°C. Compounds Cu-$L_1$ to Cu-$L_5$ were green-yellowish with melting points >300 °C. The compounds Cu-$L_1$ to Cu-$L_5$ were all obtained in high yields of 97.5, 98.4, 96.3, 95.4 and 96.8%, respectively. The molar conductance of Cu-$L_1$ to Cu-$L_5$ were 2.5, 4.9, 2.2, 1.2 and 0.8 S cm\(^2\) mol\(^{-1}\), respectively.

**Micro-Elemental Analysis**
Elemental analysis revealed that the synthesized ligands ($L_1$-$L_5$) were composed of carbon, hydrogen, nitrogen and oxygen. Moreover, copper (II) complexes (Cu-$L_1$ to Cu-$L_5$) were composed of copper, carbon, hydrogen, nitrogen and oxygen. The mass percentages of elements in each compound are summarized in Table 1.

**Table 1: Elemental Composition (Mass Percent) of the Synthesized Materials**

<table>
<thead>
<tr>
<th>Element</th>
<th>$L_1$</th>
<th>$L_2$</th>
<th>$L_3$</th>
<th>$L_4$</th>
<th>$L_5$</th>
<th>Cu-$L_1$</th>
<th>Cu-$L_2$</th>
<th>Cu-$L_3$</th>
<th>Cu-$L_4$</th>
<th>Cu-$L_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>61.14</td>
<td>59.31</td>
<td>61.45</td>
<td>61.25</td>
<td>69.29</td>
<td>55.67</td>
<td>55.41</td>
<td>56.09</td>
<td>54.30</td>
<td>61.75</td>
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<tr>
<td>H</td>
<td>4.32</td>
<td>4.50</td>
<td>4.94</td>
<td>4.95</td>
<td>6.26</td>
<td>3.46</td>
<td>3.81</td>
<td>4.16</td>
<td>3.90</td>
<td>5.32</td>
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<tr>
<td>O</td>
<td>16.87</td>
<td>18.53</td>
<td>17.22</td>
<td>17.41</td>
<td>7.75</td>
<td>14.63</td>
<td>14.38</td>
<td>14.80</td>
<td>17.09</td>
<td>5.43</td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.56</td>
<td>11.67</td>
<td>10.71</td>
<td>10.89</td>
<td>11.74</td>
</tr>
</tbody>
</table>

**Spectroscopic Analyses**
Figure 1 shows a representative $^1$H NMR spectrum of the synthesized compounds. The chemical shifts (\(\delta\), ppm) and multiplicities (singlet, s; multiplet, m) of signals in the $^1$H NMR spectra of compounds $L_1$-$L_5$ were: $L_1$: 7.55-8.11 ppm (m) and 12.28 ppm (s); $L_2$: 7.44- 8.07 ppm (m) and 12.15 ppm (s); $L_3$: 7.34-8.03 ppm (m) and 12.12 ppm (s); $L_4$: 2.43 ppm (s), 7.35-7.92 ppm (m) and 12.25 ppm (s); $L_5$: 2.26 ppm (s), 7.13-7.88 ppm (m) and 11.87 (s).
Figure 1: $^1$H NMR Spectrum of the L₁ Compound

Figure 2 shows a representative FT-IR spectrum of the synthesized compounds. The vibrational frequencies (cm$^{-1}$) of the major bands in the FT-IR spectra of L₁-L₅ compounds are as follows: L₁: 1220, 1288, 1314, 1426, 1524, 1678, and 3209 cm$^{-1}$; L₂: 1210, 1275, 1337, 1434, 1508, 1678, and 3206 cm$^{-1}$; L₃: 1219, 1277, 1334, 1420, 1507, 1689 and 3201 cm$^{-1}$; L₄: 1206, 1289, 1311, 1431, 1523, 1683 and 3181 cm$^{-1}$; L₅: 1217, 1289, 1304, 1304, 1455, 1521 and 3137 cm$^{-1}$. The vibrational frequencies of the Cu-L₁ to Cu-L₅ compounds were: Cu-L₁: 484, 545, 1172, 1293, 1317, 1411 and 1690. Cu-L₂: 497, 541, 1161, 1287, 1345, 1403, 1689. Cu-L₃: 495, 566, 1188, 1283, 1337, 1413, 1688. Cu-L₄: 506, 554, 1171, 1291, 1311, 1402 and 1693. Cu-L₅: 489, 514, 1175, 1296, 1317 and 1401.
Figure 2: FT-IR Spectrum of the L₁ Compound

Figure 3 shows a representative UV-Vis absorption spectrum of the synthesized materials. The spectra of all ligands exhibited an intense broad band in the 355.00-363.60 nm range. In addition, the spectra showed a weak absorption band in the 258.00-271.20 nm range.

Figure 3: The UV-Vis Spectrum of the L₁ Compound (2.5 x 10⁻⁵ M in DMSO)

Similarly, the spectra of the copper (II) complexes exhibited a weak broad band at 370.00-383.40 nm and a high intensity band at 273.80-276.88 nm. However, the λₘₐₓ of the two peaks were shifted to higher wavelengths relative to those of constituent ligands. The UV-Vis results of the synthesized compounds are summarized in Table 2.

Table 2: The UV-Vis Absorption Maxima of the Synthesized Compounds

<table>
<thead>
<tr>
<th>λₘₐₓ (nm)</th>
<th>L₁</th>
<th>Cu-L₁</th>
<th>L₂</th>
<th>Cu-L₂</th>
<th>L₃</th>
<th>Cu-L₃</th>
<th>L₄</th>
<th>Cu-L₄</th>
<th>L₅</th>
<th>Cu-L₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>λₘₐₓ₁</td>
<td>362.20</td>
<td>381.20</td>
<td>357.60</td>
<td>378.00</td>
<td>357.20</td>
<td>378.20</td>
<td>363.60</td>
<td>383.40</td>
<td>355.00</td>
<td>370.00</td>
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<tr>
<td>λₘₐₓ₂</td>
<td>269.00</td>
<td>274.60</td>
<td>271.20</td>
<td>274.00</td>
<td>258.00</td>
<td>274.00</td>
<td>269.00</td>
<td>273.80</td>
<td>263.80</td>
<td>276.88</td>
</tr>
</tbody>
</table>
Antibacterial Studies
With the disk diffusion method, there were no observable zones of inhibition for all concentrations used against the bacterial strains presumably due to the poor diffusibility of test compounds in the agar medium. The antibacterial activities of the test compounds were further investigated by the tube dilution method (12.5-100 μg/ml). Antibacterial data obtained by the tube dilution method is tabulated in Table 3.

Table 3: Minimum inhibitory concentrations (MIC) of the synthesized compounds

<table>
<thead>
<tr>
<th>Test compounds</th>
<th>Bacterial strains</th>
<th>Minimum Inhibitory Concentration (MIC) (μg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EPEC</td>
<td>Pp</td>
</tr>
<tr>
<td>L₁</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>L₂</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>L₃</td>
<td>ND</td>
<td>ND</td>
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<tr>
<td>L₄</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>L₅</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cu-L₁</td>
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<td>ND</td>
</tr>
<tr>
<td>Cu-L₂</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cu-L₃</td>
<td>ND</td>
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<tr>
<td>Cu-L₄</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cu-L₅</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>DMSO</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

Pp - Pseudomonas putida | Kp - Klebsiella pneumoniae | Sa - Staphylococcus aureus
Se - Salmonella enteriditis | Pm - Proteus mirabilis | Sd - Shigella dysenteriae
Vc - Vibrio cholera | ND - No MIC detected

The synthesized compounds were all inactive against Pseudomonas putida, Salmonella enteriditis, Klebsiella pneumoniae, enteropathogenic Escherichia coli, enteroaggregative Escherichia coli, and enterohaemorrhagic Escherichia coli. The ligands (L₁-L₅) were active against Vibrio cholera (25-50 μg/ml) and Proteus mirabilis (12.5-25 μg/ml). Ligands L₁-L₄ were active against Shigella dysenteriae (25 μg/ml) and Staphylococcus aureus (50 μg/ml). The copper (II) complexes were all inactive against Shigella dysenteriae and Staphylococcus aureus. However, complexes Cu-L₁ and Cu-L₂ were active against Vibrio cholerae (50 μg/ml) while complexes Cu-L₁ to Cu-L₄ were active against Proteus mirabilis (12.5-25 μg/ml).

DISCUSSION
The calculated mass percentages of elements in the synthesized compounds are in good agreement with theoretical values of the target compounds. The calculated molecular formulas of the ligands are as follows: L₁ (3-Hydroxy-3-phenyl-p-carboxyphenyl triazene): C₁₃H₁₁N₃O₃; L₂ (3-Hydroxy-3-phenyl-m-carboxyphenyl triazene): C₁₃H₁₁N₃O₃; L₃ (3-Hydroxy-3-m-tolyl-1-m-carboxyphenyl triazene): C₁₄H₁₃N₃O₃; L₄ (3-Hydroxy-3-m-tolyl-1-p-carboxyphenyl triazene): C₁₄H₁₃N₃O₃; and L₅ (3-Hydroxy-3-m-tolyl-1-p-carboxyphenyl triazene): C₁₄H₁₃N₃O₃. The molecular formulas of copper (II) complexes were: Cu-L₁: Cu(C₁₃H₁₁N₃O₃)₂; Cu-L₂: Cu(C₁₃H₁₁N₃O₃)₂; Cu-L₃: Cu(C₁₄H₁₃N₃O₃)₂; Cu-L₄: Cu(C₁₄H₁₃N₃O₃)₂; and Cu-L₅: Cu(C₁₄H₁₃N₃O₃)₂. The metal to ligand ratio in the copper (II) complexes was 1:2. The low molar conductivities of the complexes indicate that they are non-electrolytes.

The spectra of the five ligands showed a singlet signal at δ 11.87-12.28 ppm attributed to the proton of the OH group (Soni et al., 2016). Multiplet signals observed at δ 7.13-8.11 ppm are due to the presence of aromatic protons in the hydroxytriazene ligands (Soni et al., 2016). Ligands L₃, L₄ and L₅ also displayed...
signals at $\delta$ 2.26- 2.43 ppm, which were assigned to the protons of the methyl groups (Agrawal et al., 2016).

The FT-IR absorption frequencies of the synthesized compounds are comparable to those of hydroxytriazene ligands reported in the literature (Tomar et al., 2014). The spectra of the ligands and those of corresponding copper (II) complexes showed significant differences. The band appearing at 3137- 3209 cm$^{-1}$, attributed to the N-H stretching mode, is absent in the spectra of copper (II) complexes. The disappearance of this band strongly suggest the participation of the N-atom in formation of the complexes through deprotonation of NH group (Oliveria et al., 2009). Moreover, the band at 1507-1524 cm$^{-1}$, attributed to N-H bending mode, is also absent due to deprotonation of the N-H group. The new bands appearing in the spectra of copper (II) complexes at 484- 506 cm$^{-1}$ can be assigned to the Cu-N vibrational modes (Muthukumar et al., 2016; Thakar et al., A., 2011). Moreover, the $\nu_{\gamma}$N$\rightarrow$O bands for the tautomeric triazene 1-oxide [-NH-N=N(→O)-] exhibited greater intensity for the complexes compared to their ligands suggesting the strengthening of the N-O bond. The strengthening of this bond suggested the formation a new fragment (i.e. -N-O-Cu) incorporating the Cu-O bond in the metal complexes (Sajila and Mohabey, 2016). The bands appearing at 514-566 cm$^{-1}$ can been assigned to the new Cu-O bond formed on complexation (Rajasekar and Ramachandramoorthy, 2013).

The broad absorption band occurring at 355.00 - 363.60 nm in the UV-Vis spectra of the ligands is attributed to $\pi \rightarrow \pi^*$ intra-ligand transitions arising from a union of bands of the chromophore groups -N=N- for compounds $L_1$ - $L_5$ and -C=O for compounds $L_1$ – $L_4$ plus the auxochrome group -OH present in the all ligands (Bersch et al., 2014). The band appearing at 258.00 - 271.20 nm is attributed to $\pi \rightarrow \pi^*$ transitions within the aromatic rings (Domingues et al., 2010). The band occurring at 370.00-383.40 nm in the spectra of the synthesized copper (II) complexes was attributed to N $\rightarrow$ Cu ligand-metal charge-transfer transitions (Manoj et al., 2009). The intense band at 273.80- 276.88 nm is attributed to intra-ligand charge transfer transitions within the organic moiety of the complexes (Nkungli et al., 2015). The $\lambda_{\text{max}}$ of Cu-$L_1$ to Cu-$L_5$ compounds were shifted to higher wavelengths relative to those of constituent ligands suggesting complexation of the metal ions and the ligands (Salman, 2015). Scheme 1 shows the structures of the ligands ($L_1$- $L_5$) proposed on the basis of micro-elemental and spectroscopic results obtained in this study and the substrates used to synthesize the compounds.

![Scheme 1: Proposed Structures of the Synthesized Hydroxytriazene Ligands](image)
The biological activity of a compound is influenced by several factors including its lipophilicity and electronic properties (Patrick, 1995). Lipophilicity can be tuned by incorporation of hydrophobic or hydrophilic substituents. Introduction of methyl substituents increases lipophilicity while carboxyl substituents increase hydrophilicity (Bazzini and Wermuth, 2008; Hassan et al., 2011). Electronic properties of hydroxytriazenes can be tuned by incorporation of electron donating or electron withdrawing substituents on the aryl rings (Kumar et al., 2014). The activity can be tuned further through complexation with a suitable metal (El-Sawaf, 2016; Hasi et al., 2016).

The activity of ligands L₁- L₄ was more than of some hydroxytriazenes reported in the literature (Baroliya et al., 2014). Ligands L₁-L₄ were active against Staphylococcus aureus and Shigella dysenteriae while L₅ had no observable activity. This suggests that the carboxyl group is vital to the activity of the synthesized hydroxytriazenes against these bacterial strains. However, complexation deactivated L₁-L₄ against Staphylococcus aureus and Shigella dysenteriae. The minimum inhibitory concentrations of L₁ and L₂ against Proteus mirabilis were twice those of L₃ and L₄. This suggests that incorporation of a methyl substituent on the aryl ring enhanced the activity of the synthesized compounds against this bacterial strain. Complexation enhanced the activity of L₂ but decreased the activity of L₃, L₄ and L₅ against Proteus mirabilis. These results suggest that optimization of activities of the synthesized compounds with respect to a given bacterial strain should be performed independently.

CONCLUSION
Hydroxytriazenes having electron donating and electron withdrawing substituents and their copper (II) complexes were successfully synthesized using facile methods. The structures of the target compounds were determined by elemental analysis and spectroscopic studies. Some of the synthesized compounds exhibited promising activities against both Gram-positive and Gram-negative bacterial strains and are therefore worthy optimizing for potential use as alternative antibacterial agents.

RECOMMENDATION
Hydroxytriazenes and their complexes are promising antibacterial agents for both Gram-positive and Gram-negative bacterial strains. Further studies should be undertaken to optimize the lipophilicity and electronic properties of these compounds through a systematic variation of substituent groups. The effects of complexation on aforementioned properties should also be established through electron paramagnetic resonance studies.

ACKNOWLEDGEMENT
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POWER SPECTRAL ANALYSIS AND EDGE DETECTION OF MAGNETIC DATA OF MIGORI GREENSTONE BELT, KENYA

Odek Antony¹, Githiri John², K’Orowe Maurice² and Ambusso Willis³
¹Chuka University, Physical Sciences Department, P.O. Box 109-60400, Chuka
²Jomo Kenyatta University of Agriculture and Technology, Physics Department
³Kenyatta University, Kenya, Physics Department
Email: odekantony@gmail.com

ABSTRACT
With the continuous extraction of minerals in Migori greenstone belt, exploration is currently evolving from surface based exploration to subsurface exploration. This necessitates a good understanding of the geophysical features in the subsurface which are likely to have a direct bearing on the distribution of minerals. In this study, the measured total magnetic field data was subjected to cleaning process to remove perturbations which are not of geophysical interest, and later enhanced by removing long wavelength anomalies which are as a result of regional magnetic trend. Power spectral analysis of geologically constrained magnetic intensity field data was then conducted, in order to obtain the limiting depth of the anomaly causative bodies. Edge detection techniques were then employed on the delineated magnetic field intensity anomalies trending WNW–ESE along the belt. The power spectral analysis shows bodies of high magnetic field intensity from the ground surface to a limiting depth of approximately 400 m. The anomalous region is bounded by two major faults along rivers Migori and Munyu. Integrating the 2-D inversion of magnetic field intensity data and the geology of the area, the magnetic field perturbation is associated with banded iron formations which act as the host for the minerals.

Keywords: Magnetic, Anomalies, Migori Greenstone belt, Inversion, Minerals

INTRODUCTION
Geological and tectonic setting
Migori greenstone belt runs west-northwest to east-southeast between Lake Victoria and the Great Rift Valley. The belt is squeezed between the diapiric migori granite batholith to the south and a felsic volcanic succession to the north. The structure of the Migori greenstone belt appears to reflect diapiric movements of the migori Granite batholith. The geology of the area (Figure 2) consists of Archean greenstone belt that surrounds Lake Victoria. The Archean rocks in this area are principally of the Nyanzian system, the Kavirondian system and the post-Kavirondian granites that surround Lake Victoria (Shackleton, 1946). The history of gold mining in this area, especially the history of Macalder mine, situated to the north-west of Migori town indicates the potential this area has for mineral production. In the vicinity of Macalder mine, gold occurs mostly in concordant quartz veins, some of which crop out and are worked by artisanal miners as shallow opencast workings (Ngira exploration works, 2009). An explorer may need to know that systematic exploration is usually based on some conception of general or generic setting. In this case an ability to define host structures or units as well as vein location and orientations, coupled with the facility to discriminate mineralized from unmineralized terrain is required.

Study conducted by Shackleton (1946), deduced that the Macalder mine area consisted of sulphide replacement veins. He also described the rocks in the vicinity to be having a regional foliation trending west-northwest and steeply dipping to the north or south. He reported evidence of graded bedding and cleavage-bedding relations east of the mine in a south dipping sequence. According to this research the whole belt is sandwiched between Migori granite in the south and porphyritic andesites in the north. The area is also injected with dykes and sheets of granite and quartz-porphries and sills of epi-diorite and dolerite. Recent geological study conducted by Ichangi (1993) concludes that the belt is a Zn-Cu-Au-Ag massive sulphide deposit, with numerous gold occurrences restricted to the greenstone belt. In mapping the area and defining the lithofacies, he has divided the rocks into formations and adopted modern stratigraphic nomenclature in naming the lithostratigraphic units. A considerable economic potential for
gold exist in Migori as the type of gold mineralization, volcanogenic massive sulphides, is the most common and widespread in other Archeancratons. (Ngira exploration works Ltd, 2009).

**Study area**
The study was conducted within Migori county located in Western part of Kenya (Figure 1). It covered Kehancha, Masaba, Nyanchabo, Migori, Mukuro, Masaba and Macalder.

![Figure 1: Topographic map of the study area (Ogola, 1987)](image)

**Magnetic technique**
Magnetic survey method can provide comprehensive structural, genetic and target evaluation and achieve site discrimination in terms of potential economic deposits (Leaman, 1992). Magnetic data is acquired with the goal of determining variations in the magnetic field intensity. This physical property can be interpreted in terms of lithology and/or geological processes and their geometric distributions can help delineate geological structures and used as an aid to determine mineralization and subsequent drilling target (Philips *et al.*, 2010).

The magnetic field $B$ due to the pole of strength $m$ at the same distance $r$ is defined by equation 1, (Keary *et al.*, 2002).

$$B = \frac{\mu_0 m}{4\pi\mu_r r^2}$$

……………………………………………………………………………………………………… 1
Where $\mu_0$ and $\mu_R$ are magnetic permeability of vacuum and relative magnetic permeability of medium separating the poles respectively. The total field anomaly ($\Delta B$) due to both horizontal and vertical components is given by equation 2 which is related to susceptibility as in equation 3.

$$\Delta B = -\frac{\mu_0 m_0}{4\pi^3} \sin I + \frac{\mu_0 m_0}{4\pi^3} \cos I$$

$$\mu_0 = \frac{\mu}{k+1}$$

Figure 2: Local geology of Migori greenstone belt (Shackleton, 1946)

Data acquisition
Ground magnetic data was collected from 425 stations established over an area of approximately 200 km² bounded by the latitudes 34˚15'E -34˚40'E and longitudes 0˚55'S – 1˚12'S in Migori, Macalder and Kehancha areas, with station and profile spacing of approximately 300 m and 1 km respectively. Total magnetic field intensity measurements were taken using Proton precession magnetometer. Variations in the earth’s magnetic field intensity which did not result from the differences in magnetic intensity of the underlying rocks which includes instrumental drift and geomagnetic field were corrected from the ground survey data. Drift correction was done by having a base station which was preoccupied periodically in the day. A drift curve was plotted and readings made in other stations assumed to have a linear drift as fitted base readings. Using the drift rate each reading was corrected to what it would have read if there were no drift. The localized magnetic anomalies caused by rocks are superimposed on the normal magnetic field of the earth. The geomagnetic field exhibits irregular variation in both orientation and magnitude with latitude and time. The International Geomagnetic Reference Field (IGRF) which defines theoretical undisturbed magnetic field at any point on the Earth’s surface was used to remove from the magnetic data those magnetic variations attributed to this theoretical field.

Shaded colour contour map of the resulting magnetic field intensity variations (Figure 3) was drawn using Geosoft Oasis Montaj program.
The magnetic intensity signature was then subjected to total horizontal derivative (THDR) data filtering technique; which is highly suitable in isolating and enhancing anomaly features for mapping shallow basement structure and mineral exploration targets. It does not only accentuate and concentrates the structural features, but also accentuates potential leftover noise from levelling in the data (Geosoft Oasis Montaj program). Therefore, the undesirable striation and high frequency noise was simultaneously filtered using a low pass Butterworth filtered (Figure 4). THDR is defined as;

\[ \text{THDR} = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2} \]

Where THDR is the total horizontal derivative, \( f \) is the magnetic or gravity field, \( \frac{\partial f}{\partial x} \) and \( \frac{\partial f}{\partial y} \) are the first derivatives of the field \( f \) in the \( x \), and \( y \) directions. This result was later compared with the vertical derivative (Figure 5) which gives a good correlation in terms of the distribution of the high magnetic field intensity anomalies.
Figure 4: Shaded colour total horizontal derivative (THDR) of the residual magnetic field of Migori greenstone belt

**Spectral power analysis**

The quantitative interpretation of the magnetic field intensity data involved both direct and indirect methods, limiting depth is one of the most important parameters derived by direct interpretation and it may be deduced from magnetic anomalies by making use of their property of decaying rapidly with distance from the source. This effect may be quantified by computing the power spectrum of the anomaly; the log-power spectrum has a linear gradient whose magnitude is dependent upon the depth of the source (Spector and Grant, 1970). Such techniques of spectral analysis provide rapid depth estimates from regularly-spaced digital field data.

It originates from the mathematical distinction existing between periodic waveforms that repeat themselves at a fixed time period T, and transient waveforms that are more repetitive. By means of the mathematical technique of Fourier analysis any periodic waveform, however complex, may be composed into a series of sine (or cosine) waves whose frequencies are integer multiples of the basic repetitive frequency 1/T, known as fundamental frequency. The higher frequency components, at frequency of n/T (n=1, 2, 3 ...) are known as harmonics. A periodic waveform can be expressed either in time domain (expressing wave amplitude as a function of time) or in the frequency domain (expressing amplitude and phase of its constituent sine wave as a function of frequency). These spectra known as line spectra, are composed of a series of discrete values of the amplitude and the phase components of the waveform at set frequency values distributed between 0 Hz and the Nyquist frequency. Transient waveforms do not repeat themselves, that is, they have an infinitely long period (infinitesimally small fundamental frequency 1/T→0) and consequently harmonics that occur at infinitesimally small frequency intervals to give continuous amplitude and phase spectra rather than the line spectra of the periodic waveforms. However it is impossible to cope analytically with spectrum containing an infinite number of sine wave components (Keary et al., 2002).

Fourier transformation of digitized waveform is readily programmed for computers, using a fast Fourier transform (FFT) algorithm as in the Cooley-Tukey method (Brigham, 1974). FFT subroutines can thus be routinely built into data processing programs in order to carry out spectral analysis of geophysical waveforms. Fourier transformation can be extended into two dimensions (Rayner, 1971), and can thus be applied to a real distribution of data such as gravity and magnetic contour maps. Figure 6 below shows computed power spectrum of the magnetic anomalies of Migori greenstone belt.
Figure 5: First vertical derivative of the residual magnetic field of Migori greenstone belt
Figure 6: Computed power spectrum of the magnetic anomalies of Migori greenstone belt

**Edge detection methods**

A number of edge detection methods are currently being applied in the interpretation of magnetic data, the choice of the method to be applied depends on the estimated depth of the anomaly causative body. In this study, power spectral analysis was first computed in an attempt to obtain the limiting depth of the causative body. Shallow structures of limiting depth of about 400 m were delineated, this informed the choice of tilt angle derivative (TDR) and analytical signal (AS) edge detection techniques. The two techniques give good resolution at shallow depths.

**Tilt angle derivative (TDR)**

TDR is used for enhancing the anomaly causative body features including its edges, it is applicable in mapping shallow basement structures and mineral exploration targets (Geosoft Oasis Montaj, 2007). It produces positive values directly above the sources, negative values away from the sources and a zero value over or close to the source edges and therefore can be used to trace the edges (Miller and Singh, 1994). It is given by equation 5

\[
TDR = \tan^{-1}\left(\frac{VDR}{THDR}\right)
\]
Where VDR is the vertical derivative and THDR is the total horizontal derivative. It can further be expressed in terms of the magnetic or gravity field (f) and the first derivative of the field f in the x, y and z directions $\frac{\partial f}{\partial x}$, $\frac{\partial f}{\partial y}$ and $\frac{\partial f}{\partial z}$ respectively as;

$$TDR = \tan^{-1} \left[ \frac{\delta f}{\delta z} \right]$$

The amplitude of TDR range between $-\pi/2$ to $+\pi/2$ radians regardless of the amplitude of the vertical or the absolute value of the total horizontal gradient (Salem et al., 2008). Figure 7 shows the shaded colour map of the TDR of Migori greenstone belt.

Figure 7: Shaded colour map of tilt angle derivative (TDR) of the magnetic anomalies of Migori greenstone belt

**Analytic signal (AS)**

Analytic Signal (Figure 8) is a very useful technique for delineating edges of shallow magnetic sources given that the amplitude of the analytical signal peaks over the magnetic sources (Cooper, 2009). The fact that it is independent of magnetization direction in the 2D case, makes it more appropriate in determining magnetic parameters from magnetic anomalies (Li, 2006). However, it suffers from the assumption that near surface structures can be characterised adequately by step models. It is defined as equation 7
Where, \( \frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z} \) are the first derivatives of the total magnetic field in the x, y and z directions (Roest et al, 1992).

\[
AS = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 + \left(\frac{\partial f}{\partial z}\right)^2}
\]

DISCUSSION AND CONCLUSION

The total magnetic field intensity over Migori greenstone belt delineates high magnetic anomalies over the causative structures trending ESE-WNW from Kenya-Tanzania border through Kehancha, Masaba, Nyanchabo, Migori, Mukuro, Masara, all through to Macalder. The anomalies peak at Kehancha, Masara and Macalder, regions that have witnessed a lot of artisan mining using opencast method. The magnetic highs are sandwiched by the high magnetic intensity gradients that are interpreted as fault lines. In order to better interpretation of these sources power spectral analysis technique was used to estimate the depth of the causative bodies and both tilt angle derivative (TDR) and analytic signal (AS) were used for edge detection. The computed power spectrum of the magnetic anomalies (Figure 6) gives a depth of approximately 400 m as the limiting depth of the causative bodies, with some anomalies featuring at
shallow depths of about 100 m. From both TDR and AS results, the width of the productive parts of the belt ranges from approximately 6000 m at Kehancha and slightly widens towards Masara and Macalder to approximately 15000 m (Figure 7 and Figure 8). The causative structures are associated with granitic intrusive characterised by the banded iron formations.

RECOMMENDATION
We are grateful to National Commission of Science, Technology and Innovation (NACOSTI) and Chuka University both of Kenya for their financial support. We are also grateful to both Jomo Kenyatta University of Agriculture and Technology and Kenyatta University for availing research equipment and technical support. We also recognize Ministry of mining, Kenya for the data analysis program.

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DETERMINATION OF THE CRITICAL TIME WHEN LEVELS OF THE CYANIDE POTENTIAL IN CASSAVA ARE AT PEAK CONCENTRATION.

Weru, S.M.1, Filippo de Monte2, Kanamu, J.M1, Farring, C N.2, Mwiti, G.M.3 and Rewe, M.N.4

1 Kenya Agricultural and Livestock Research Organization Mtwapa, P.O Box 16-80109 Mtwapa.
2 CAST NGO, P.O Box 251-80108, Kilifi.
3 Ministry of Agriculture, Fisheries and Livestock, P.O Box 19-80108 Kilifi.
4 Kenya National Farmers Federation, P.O Box 19-80108 Kilifi.

Corresponding author Email: swerusi@yahoo.com; mobile 0722454283

ABSTRACT
Cassava (Manihot esculenta Crantz) is the second most important food crop and a main source of income for the rural communities with potential for industrial use in the coastal region of Kenya. Cassava, now widely grown in the coastal region of Kenya is a domesticated plant derived from one or more species of the Genus Manihot in the Euphorbiaceae family. Cassava contains naturally occurring, but potentially toxic compounds called cyanogenic glycosides, which release hydrogen cyanide (HCN) as a result of enzymatic hydrolysis following maceration of the plant tissue. The objective of the study is to sustain and enhance the food security and livelihood of coastal lowland farmers and processors by assisting them to successfully produce/trade/export their produce in compliance with food safety standards for cassava and cassava products. The study was to conduct a scientific assessment to determine ways along the food chain/commodity pathway to minimize the hydrocyanic acid content in cassava and its products and thus provide methods of meeting food quality standards requirement. This would be achieved by determining, through study and analysis, the effect on cyanide content based on agronomic factors (e.g. cultivars, stress, ), agro ecological zone (CL 3, CL 4, and CL 5) and harvest/post-harvest practices i.e. age at harvest. The study was conducted in 2016 in Kilifi County in three agro ecological zones. They are coastal lowlands 3, 4 and 5. The genotypes studied and analyzed are Tajirika (improved), Shibe (improved), Karembo (improved) and Kibandameno (traditional). The analysis was carried out at 5, 8 and 11 months after planting. At five months after planting in loamy soils for the Kibandameno variety, the cyanide level is recorded 0.5mg/kg while at 11 months after planting in the same soils and AEZ, the level is 0.33mg/kg. At five months after planting, Tajirika, Shibe and Kibandameno varieties in CL5 recorded cyanide levels of 0.44 and 0.48mg/kg respectively in sandy loam soils. In the eleventh month, Shibe and Kibandameno varieties in the same soil type recorded 0.41 and 0.45mg/kg respectively. There is a slight indication that as the plant ages the levels of the CNP declines.

Keywords: Cassava, domesticated, genotypes, species, cyanogenic glycosides, enzymatic hydrolysis.

INTRODUCTION
Cassava is the second most important food crop and a main source of income for the rural communities with potential for industrial use in the coastal region of Kenya. Cassava, now widely grown in the coastal region of Kenya is a domesticated plant derived from one or more species of the Genus Manihot in the Euphorbiaceae family (Allem, 2002). Cultivated cassava is Manihot esculenta Crantz. Since its domestication thousands of years ago in the Amazon region, cassava is now spread around the world and is widely cultivated for consumption in the tropics and sub-tropic. Thousands of cultivars are in existence most adapted to local conditions. Cassava is a very flexible crop that grows well under marginal conditions where other crops could not survive and does not require a large amount of agricultural input (e.g., water, fertilizer and pesticides). Most cassava varieties are drought tolerant and are naturally tolerant to acidic soils making cassava a fundamental food security component in marginal agricultural land. Cassava is grown primarily for its starchy tuberous roots, which are important staple for more than 800 million people, mostly in sub-Sahara but also in other parts of Africa, Asia and South America (Burns et.al. 2010.). It has also become a very important root crop in the coastal region where not only has it become a dietary staple but also traded as a raw product or in processed form like chips and flour. Breeding work has been carried out at KALRO Mtwapa for the last ten year and cultivars that are resistant to debilitating biotic stresses due to viral infections have been developed. The traditional cultivars found in the coastal region are inherently low yielding (5 to 9 t ha-1) and are highly susceptible.
to diseases. However, their dry matter content and low cyanide levels produces roots that are quite palatable. These are qualities introgressed in the varieties developed. As such, these developed varieties have dry matter (DM) of over 30% and cyanogenic potential (CNP) of 4.0 in the Piccric acid scale of 1 to 9.

Cyanide forms when cassava is processed. But the toxin is volatile and is released into the air, rather than remaining in the food. Correct processing methods ensure that the cyanogen content in cassava plants will be within an acceptable range (Sayre et al., 2011). The United Nations’ Food and Agriculture Organization has established maximum recommended cyanide levels for foods. Classifications of cassava safety limits indicate:

- Mild (safe): 50 mg HCN/kg/fresh peeled storage root;
- Moderately poisonous: 50-100 mg HCN/kg fresh peeled storage root;
- Dangerously poisonous: over 100 mg HCN/kg fresh peeled storage root.

**Cyanide in Cassava**

Cassava belongs to the same sub-family as rubber (*Hevea brasiliensis*) and like rubber contains both cyanogenic glucosides and latex (Jorgensen et al., 2005). Cassava roots contain considerable quantities of cyanide which occurs in the form of cyanogenic glycosides, primarily linamarin and a small amount of lotaustralin (Uyoh et al., 2007). These cyanogenic glycosides break down to release toxic hydrogen cyanide gas during digestion (Poulton, 1988). The consumption of cassava can therefore be harmful to human health. Despite the presence of these naturally occurring toxins, millions of people all over the world have been safely consuming cassava for hundreds of years. The on-going challenge is to ensure that the presence of these cyanogenic glycosides are minimized through proper understanding and control measures through processing to reduce effects of cyanogenic glycoside content of cassava. Roots and leaves contain the highest amount of linamarin (Cereda and Mattos, 1996).

**Postharvest Practices**

Post-harvest deterioration is the most important cause of loss in cassava production and this is mainly as a result of microbial invasion of the tuber (Okigbo et al., 2009). Post-harvest deterioration can render cassava unpalatable and un-marketable within 24-72 hours (Rielly et al., 2004). Cassava must also be processed before being eaten.

The Amerindians, who first cultivated cassava, over the years, have devised numerous processing techniques not only to increase palatability and extend shelf life, but also to decrease its cyanogenic potential. Today, a great diversity of processing methods are found in the various parts of the world where cassava is consumed (Lancaster et al., 1982). These methods consist of different combinations of peeling, chopping, grating, soaking, drying frying, boiling and fermenting. In Africa where cassava flour is a major product, wetting (Bradbury 2006; Cumbana et al. 2007) is an effective method of cyanide removal.

In the lowland coastal Kenya where cassava is a dietary staple, boiling freshly harvested cassava roots is the norm. Cooke and Maduagwa (1999) reported a 55% reduction of bound cyanide by cooking of cassava. Similar figures (50-60%) were reported by Aalbersberg and Limalevu (1991) and 25-75% by Nambisan and Sundarsan (1985). The figures by Nambisan and Sundarsan were dependent on cooking time and chips size, with smaller chips size recording highest cyanide losses.

Methods which use grating and crushing are very effective in removing cyanide because of the intimate contact in the finely-divided wet parenchyma between linamarin and the hydrolyzing enzyme linamarase, which promotes rapid breakdown of linamarin to hydrogen cyanide gas that escapes into the air (Cardoso et al., 2005). This in combination with wetting, fermentation and drying can reduce cyanide contents up to 99%. 

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*Proceedings of the Fourth International Research Conference*
Factors Affecting Cyanide Content of Cassava

1. **Cultivar.**
Thousands of cassava cultivars exist and differ in their ability to tolerate pest and diseases, yield, nutritional and cooking qualities of food products. Cassava is propagated clonally from stem cuttings so there is minimal variation between individuals of one cultivar when grown under the same environmental conditions. All cassava cultivars contain cyanogenic glucosides however a wide variation in the concentration of cyanogens exists among different cultivars. This can range from 1 to 2,000 mg/kg (Cardoso et al., 2005, CIAT 2007). Cultivars with <100mg/kg hydrogen cyanide can be referred to as mild while those >100mg/kg can range from moderate to extreme (Wheatley et al., 1993).

2. **Climatic Conditions**
Cassava, a perennial shrub thrives in tropical and sub-tropical conditions. In general, the crop requires a warm humid climate. Temperature is important, as all growth stops at about 10ºC. The highest root production can be expected in the tropical lowlands, below 150 m altitude, where temperatures average 25-27ºC, but some varieties grow at altitudes of up to 1500 m. The plant produces best when rainfall is fairly abundant, but it can be grown where annual rainfall is as low as 500 mm or where it is as high as 5,000 mm. The plant can stand prolonged periods of drought in which most other food crops would perish. This makes it valuable in regions where annual rainfall is low or where seasonal distribution is irregular. Cassava is drought resistant and grows well in poor soil (Java Cassava, 2007). The problem however is that cyanide content of cassava tends to increase during periods of droughts and /or prolonged dry weather due to water stress on the plant (Bokanga et al., 2004). Splittstoesser and Tunya (1992) reported that cassava grown in wet areas contain relatively lower amount of cyanide than those grown in drier areas.

3. **Fertilizer**
There is a general consensus that crop yields do increase with application of fertilizer. There is debate however on the relationship between addition of fertilizer and cyanide content of cassava.
Studies in the Philippines (Rolinda et.al, 2008) concluded that application of fertilizer does not significantly affect cyanide content. It further suggested that the amount of nutrient in the soil does not considerably contribute to the cyanogenic character of the cultivar. In Ethiopia, Endris (1977) suggested that the cyanogenic content of cassava roots were significantly reduced by potassium application.

4. **Harvesting**
Harvesting of cassava can be done throughout the year when the roots reach maturity. Maturity differs from one variety to another, but for food, the tubers can be harvested at 6 to 12 months (FAO, 1977) and can remain in the soil for up to three years after maturity (Lebot, 2009).
Delayed uprooting causes sprouting during the rains resulting in a drastic fall in the starch content of the tubers. While the effect of harvesting method on cyanide is not clear, injuring the roots increases rate of post-harvest deterioration.

5. **Age of Cassava at Harvesting**
A study by Hidayat et al. (2002) on ninety nine variety of cassava showed that there is a significant correlation between cyanide potential of roots and leaves. The cyanide content was higher in younger leaves compared to older ones, suggesting that cyanide potential of roots drops as plant ages. This seems to agree with investigations by Chotineeranati, et al (2006). Cooke and Elba, (1982) reported that the root parenchymal tissue and root cortex were not significantly different between 6 and 14 months; both tissues displayed peak concentrations at 6 and 14 months.

**Cassava and Health**
Despite the presence of these naturally occurring toxins, millions of people all over the world have been safely consuming cassava for hundreds of years. Usually, cassava is well processed before being...
consumed. Inadequate processing however may result in appreciable amounts of cyanogenic glycosides remaining and this may pose a public health risk (FSANZ 2008.). Konzo is a condition resulting from the excessive ingestion of cyanide compounds from inadequately prepared cassava and cassava products is characterized by irreversible paralysis of the legs in and other developmental disorders. They occurs mainly amongst children and women of child bearing age in Democratic Republic of Congo, where a reported 100,000 cases exist, Tanzania, Mozambique, Central African Republic, Cameroon and probably other countries (CCDN News, 2007). Tropical Ataxic Neuropathy (TAN) is another syndrome attributed to dietary cyanide exposure from inadequately prepared cassava. In contrast to Konzo, TAN is a progressive disorder that mainly affects older adults (CCDN News, 2008). It has been shown that different varieties of cassava have varying cyanide content and this quantity is affected by climatic conditions and other factors (Raji et al., 2007, CIAT, 2007). Studies in Africa have linked varying cyanide content in cassava to seasonal changes with higher concentrations of cyanide recorded in drought conditions. Iodine deficiency diseases are exacerbated by the intake of cyanogenic plants such as cassava.

Objectives
To sustain and enhance the food security and livelihood of coastal lowland farmers and processors by assisting them to successfully produce/trade/export their produce in compliance with food safety standards for cassava and cassava products.

Justification
The purpose of the study is to conduct a scientific assessment to determine ways along the food chain/commodity pathway to minimize the hydro cyanic acid content in cassava and its products and thus provide methods of meeting food quality standards requirement. This would be achieved by determining, through study and analysis, the effect on cyanide content based on:
- Agronomic factors (e.g. cultivars, stress,)
- Agroecological zone (CL 3, CL 4, and CL 5).
- Harvest/postharvest practices i.e. age at harvest.

MATERIALS AND METHODS
Sites: The study was conducted in Kilifi County in three agro ecological zones. They are coastal lowlands 3, 4 and 5 (CL3, CL4 and CL5). The locations were;
- CL3 Kikambala / Mtwapa
- CL4 Vitengeni / Madamani
- CL5 Bamba / Ganze.

Genotypes:
The varieties studied and analysed were;
- Tajirika (improved)
- Shibe (improved)
- Karembu (improved)
- Kibandameni (landrace)

The analysis of the varieties for CNP was carried out at;
- 5 months after planting
- 8 months after planting and
- 11 months after planting

Procedure:
The sampling was done for 3 maturation stages; at 5, 8 and 11 months. Sampling was done at farmer’s cassava plots where 3 samples of each varieties was collected for analysis. The samples of fresh roots
were washed and labelled and be then transported to the SGS LABS same day when the samples were still fresh. This was done thrice in a time span of 7 months. Data was analysed using the R software and SPSS was used for coding of the data.

RESULTS
The varieties under the trial, i.e. Kibandameno, Tajirika, Shibe and Karembro are generally low in cyanide levels. Kibandameno, the traditional variety is very palatable with desired qualities valued by the community. The variety have low levels of the CNP and high dry matter (DM) content. However, it is highly susceptible to diseases especially cassava mosaic and cassava brown streak diseases. Tajirika, Shibe and Karembro are the improved varieties whose levels of CNP is low, have high DM and which are resistant to those two diseases and are high yielders (50t/ha compared to KIB -5ton/ha).

Table 1: Mean and Standard Deviations of the cynogenic potential levels (CNP) in the Agroecological zones and varieties.

<table>
<thead>
<tr>
<th>AEZ</th>
<th>Variety</th>
<th>Mean (mg/kg)</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL3</td>
<td>Karembo</td>
<td>0.438</td>
<td>0.056</td>
</tr>
<tr>
<td>CL4</td>
<td>Kibandameno</td>
<td>0.368</td>
<td>0.098</td>
</tr>
<tr>
<td>CL5</td>
<td></td>
<td>0.423</td>
<td>0.055</td>
</tr>
<tr>
<td></td>
<td>Karembo</td>
<td>0.41</td>
<td>0.0565</td>
</tr>
<tr>
<td></td>
<td>Kibandameno</td>
<td>0.41</td>
<td>0.0928</td>
</tr>
<tr>
<td></td>
<td>Shibe</td>
<td>0.352</td>
<td>0.0906</td>
</tr>
<tr>
<td></td>
<td>Tajirika</td>
<td>0.400</td>
<td>0.077</td>
</tr>
</tbody>
</table>

In Table 1, in the agroecological zones there was significant difference in the cyanide levels while in the varieties there was no significant difference. The Karembo variety samples of the same age (11months) in clay loam soils in both CL 3 and 4 had cyanide levels of 0.45 and 0.37 mg/kg respectively. Kibandameno variety recorded the highest levels of CNP of 0.5 mg/kg in CL3 at 5 months and CL4 at 11 months in loamy soils and sandy loam respectively. Four samples of Shibe variety were collected in CL 4 and 5 giving the highest CNP level of 0.44mg/kg in sandy loam for 5 months old sample in CL5. The lowest levels were in loamy soils at 0.24mg/kg at 5 months at CL4. Tajirika variety had the highest CNP level of 0.54mg/kg at CL4 in cassava sample harvested 11 months after planting while the lowest level of 0.28 was in CL4 in cassava sample harvested at 11 months in red loamy soils. Tajirika variety in CL3 at eleventh month after planting in clay soil has cyanide level of 0.39mg/kg. In CL3 at five months after planting in loamy soils for the Kibandameno variety, the cyanide level is recorded 0.5mg/kg while at 11 months after planting in the same soils and AEZ, the level is 0.33mg/kg. For Kibandameno, no sample was collected at 8 months after planting. In CL4, both Shibe and Tajirika varieties planted five months after planting in loamy soils recorded lower cyanide levels (0.24 and 0.33mg/kg respectively) compared with those planted eleven months ago in red loam soils (0.32 and 0.54 mg/kg).

At five months after planting, Tajirika, Shibe and Kibandameno varieties in CL5 recorded cyanide levels of 0.44 and 0.48mg/kg respectively in sandy loam soils. In the eleventh month, Shibe and Kibandameno varieties in the same soil type recorded 0.41 and 0.45mg/kg respectively. The Tajirika variety at eleventh month in sandy soils indicated cyanide levels of 0.32mg/kg in the CL5. In CL3, Kibandameno in loamy soils recorded 0.5 and 0.33 at five and eleven months respectively. An indication that the cyanide levels reduces as the plant ages. In the same AEZ, Tajirika, at 8 and 11 months in sandy soils recorded 0.45mg/kg showing no difference in the cyanide level. At eleven months, both Kibandameno and Tajirika in clay loam have a cyanide levels of 0.39mg/kg. In the CL4, Kibandameno, Tajirika and Shibe at eleven months and in red loamy soil had cyanide levels of 0.26, 0.28 and 0.32mg/kg respectively. At 5 months, Shibe and Tajirika cassava samples in CL4 had cyanide levels of 0.24 and 0.3 mg/kg respectively. In the
CL5, Tajirika, Shibe and Kibandameno planted five months showed 0.44, 0.44 and 0.48mg/kg concentration of CNP while at 11 months the levels are 0.32, 0.41 and 0.45 respectively.

CONCLUSION

From the results, there is an indication that as the plant ages the levels of the CNP declines. This is supported by a study by Hidayat et al. (2002) on ninety nine variety of cassava that showed there is a significant correlation between cyanide potential of roots and leaves. The cyanide content was higher in younger leaves compared to older ones, suggesting that cyanide potential of roots drops as plant ages. This seems to agree with investigations by Chotineeranati, et al (2006). Also the noted, is the continuous maintenance of the low cyanide levels by the four cassava genotypes for the entire period of the study. This suggest they are safe for consumption throughout their growth period.

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ABSTRACT
The study was carried out to determine the concentration of heavy metals in tea fields in Kericho, Kenya. Soil samples were collected from different plots and the treatments were NPK at 180 kg N/ha/yr, sheep manure alone, enriched sheep manure at 4:1 enriched sheep manure at 8:1 at the rates of 60, 120, 180 and 240 kg N/ha/yr. A control site was established where no fertilizer was applied for determination of five heavy metals: Zn, Cu, Al, Fe and Cd. Soils were obtained at depths of 0-15, 15-30 and 30-45cm. The samples were analyzed using Inductive Couple Plasma Emission for determination of heavy metal contents. Results were subjected to ANOVA to determine significant mean differences in the content of heavy metals. Significant (p≤0.05) variations in heavy metal contents with respect to fertilizer types, rates and sampling depths were demonstrated. Farmers should use enriched fertilizers judiciously to avoid excess accumulation in fields which may end up contaminating tea plant leaves and impacting negatively the health of tea consumers.

Keywords: Camellia sinensis, Mineral nutrition, Soil fertility, Tea production

INTRODUCTION
The tea plant (Camellia sinensis) was discovered by the Chinese in 2737 B.C (Ukers 1935). It was then dispersed eastwards and westwards through secondary centers to different regions of the world. Tea is the leading foreign exchange earner in Kenya, contributing about 26% of the total export earnings (Tabu et al., 2015). The tea industry is mostly labor-intensive and more than 3 million persons directly and indirectly derive their livelihood from tea related activities. Tea growing and manufacture are carried out in rural areas contributing significantly to development of rural infrastructure as well as enhancing the economic well-being of rural communities (Tea Board, 2011).

Kenya is the world’s fourth largest exporter of black tea after India, China and Sri Lanka accounting for more than 13% of world exports and over 60% of Africa’s tea exports (Varun, 2008). The tea shrub is moisture loving requiring humid air and ample rainfall well distributed over the year so that continuous water supply is assured throughout the growing season. It also requires the absence of frost. The rainfall should range between 1200-2700 mm per annum. The tea plant also requires soil temperature ranging between 21-25°C and a soil moisture of high water holding capacity (Othieno, 1991). Tea is cultivated for its fresh leaves in plantations as monocrop and requires high levels of soil nutrients especially N, P, K, Ca and Mg (Bore, 1996). These nutrients are critical and their deficiency leads to poor tea seedling establishment and performance on the yield. Application of organic manure increases the yields of tea more than the use of inorganic fertilizers although the combination of both inorganic and organic manures that is enriched fertilizers significantly increases the yield and quality of tea (Shiganya et al., 2009).

Tea cannot be produced optimally without fertilizer application. Enriched fertilizers results in higher yields as compared to use of organic manure or inorganic fertilizers alone hence can be used for sustainable tea production (Anon, 2008). Heavy application of inorganic fertilizers leads to deterioration of cation exchange capacity and clay content of the soils, high concentration of Aluminum and silicate in drainage water in addition to air pollution through nitrous gas emission, excessive leaching leads to underground water pollution (Jarvis, 1996). Heavy metals are dangerous substances in the environment due to their high level of persistence and toxicity to the biota. Heavy metals will tend to adsorb very firmly to the soil matrix and once released into the environment they will not be degraded like organics by microbial activity or through chemical oxidation (Beiergrohslein, 1998). Some synthetic fertilizers are known to contain levels of heavy metals including Cd and Cu (Kabata-Pendas and Pendias, 1992). The
compounds used to supply these elements contain trace heavy metals such as Cd and Pb as impurities which after continued fertilizer application significantly increase in the soil (Jones and Jarvis, 1981).

Application of certain phosphatic fertilizers inadvertently adds Cd and other potentially toxic elements to the soil, including F, Hg and Pb (Raven et al., 1998). The presence of heavy metals in inorganic fertilizers may be due to fertilizer products as some phosphate and micronutrient fertilizers, and liming materials contain elevated levels of arsenic, cadmium, and lead compared to other fertilizers types such as nitrogen and potash. This study was carried out to determine the possible effects of different fertilizers that is enriched fertilizers both sheep manure and inorganic fertilizers on heavy metal accumulation in tea leaves. Samples were collected and weighed for identification of concentrations of Cd, Fe, Al, Cu, Zn and processed in the lab for chemical analyses.

Statement of the Problem
Application of fertilizers in tea field enhances the soil quality and thus increasing its yield as most nutrient i.e. N, P, K, and Ca are required by tea for better performance and establishment in the field. Tea farmers in various geographical regions of Kenya are usually advised to apply inorganic fertilizers in the rates between 100-200 kg N ha\(^{-1}\) yr\(^{-1}\). However, some farmers have been reported to apply higher rates with expectation of getting better yields. Farmers have also adopted application of enriched fertilizers consisting of both inorganic and organic components at varying ratios hence likely to lead to accumulation of some heavy metals contained in the fertilizers into the soil. However, there is no documentation that has been done on the content of heavy metals in the soils of tea fields treated with varying ratios of enriched fertilizers. This study will therefore investigate the effects of enriched fertilizers on heavy metals content as well as tea yields in Kericho.

General Objective
To evaluate the effects of enriched fertilizers on heavy metal content in tea soils and yield of tea.

Specific Objectives
i. To determine the effects of enriched sheep manure on heavy metal content in tea soils.
ii. To determine the effects of inorganic fertilizers on heavy metal content in tea field soils.
iii. To determine the effects of enriched sheep manure on tea yields.

Hypotheses (H\(_0\))
This study was based on the following hypotheses:
H\(_0\): there is no effect of enriched sheep manure on heavy metal content in tea soils.
H\(_0\): there is no effects of inorganic fertilizers on heavy metal content in tea field soils.
H\(_0\): there is no effects of enriched sheep manures on tea yields.

LITERATURE REVIEW
Tea origin and spread
Tea [Camellia sinensis (L) O. Kuntze], is a perennial, evergreen shrub which when left unpruned, grows a single stem to a height of 10 m. Its origin and distribution is said to be the mountainous areas of South East Asia where the natural habitat is a monsoon climate. It is also said to have originated in china as a medicinal drink and it was introduced to here by the Portuguese merchants during the 16t century (Okinda et al., 2010). Tea was introduced in Kenya in 1903 but it was not until early 1920's that planting on commercial basis was undertaken. Expansion of production in 1930's and 1940's was severely restricted under the International Tea Agreement to which East Africa adhered until 1947 the total hectare was increased to 6,565 ha but since then the industry has grown rapidly (ITC, 2015). By 1957, acreage in Kenya had increased by nearly 100% to 12,300 ha. The growth of the estates continued at a steady pace while Kenya's overall 8.2% per annum increase in output between 1958 and 1965 was considerably ahead of the 2% per annum increase in world supply over the same period. In 1957 tea exports accounted for
10.8% of the value of the country's agricultural exports of $26.4 million. Tea production has considerably increased over a 10 years period in Kenya and other major producer countries. Kenya and Vietnam recorded gains of 107 M kg and 61 M kg made tea respectively. Smallholder growers contributes a larger percentage than estates whereby smallholder produced 249,835 metric tons in 2013, whereas estates produced 182,618 metric tons (ITC, 2015).

**Importance of Tea**

Tea is a major foreign exchange earner and a source of livelihood to millions of people in the tea growing world (Reeves et al., 1987). Kenyan tea being one of the leading cash crop, 95% of it is usually exported as a generic product used to blend other low quality teas. The tea industry in Kenya, in rural areas where the vast majority of Kenyans live and over 62% of the crop is produced by the highly successful small-scale farmers, offers a direct source of livelihood to around 10% of Kenya’s total population (TBK Statistics, 2010). It contributes towards poverty eradication and infrastructural development in the rural areas. It also contributes to environmental conservation by enhancing water infiltration, reducing surface erosion and mitigation of global warming through carbon sequestration (Cheserek, 2011). Tea also have some health benefits as green tea contain large amount of antioxidant called polyphenols which are though to cause both anti-inflammatory, analgesic and anti-cancer health benefits. Antioxidants are molecules that inhibit oxidation of other molecules reducing free radical cell damage and leaving the body healthier. The bitter flavor helps encourage liver secretions and enzymatic productions helping to digest food and encourage proper elimination. Green tea inhibits the growth of breast cancer.

**Tea environment**

Tea in Kenya is grown in high altitude areas of between 1800 and 2700 m above the sea level, where annual rainfall ranges from 1800 mm to 2500 mm. Tea requires temperatures of between 18-30°C provided moisture is not limiting. The tea growing areas have varying topographical characteristics ranging from gentle slopes to steep slopes and are spread throughout the country, but mainly on foothill of Aberdares ranges, in the East of the Great Rift Valley and the Mau Ranges; Nandi, Kisii and Kakamega hills and slope of Mt. Elgon in the west of the rift valley (Owuor et.al, 2008).

**Tea fertilizers**

Tea cultivation practice is based on use of synthetic fertilizers and pesticides for conventional tea production which has jeopardize the soil health particularly due to micronutrient deficiency, instability in yield and reduced product quality leading to emergence of use of organic farming practice for improvement of crop yield and product quality which has less impact on human health. Organic farming leads to improved soil health by improving availability of micronutrients which improves crop yield and quality of tea (Bagchi et al., 2015).Cattle manure is recommended organic fertilizer to be applied in tea field in Kenya however it is limited by the low amount and quality of resource available at farm level. Combined use of organic and inorganic fertilizers is recommended as it concurrently increases crop yield and soil health (Vanlauwe et al., 2003). Inclusion of organic fertilizers in cropping systems is acknowledged because they enhance soil organic matter, preserve ecological harmony and promote biological diversity (Omare and Woomer, 2003).

**Heavy metals**

Metals are substances with high electrical conductivity, malleability, and luster which voluntary loss their electrons to form cations. Metals are found naturally in the earth’s crust and their compositions vary among different localities resulting in spatial variations of surrounding concentrations. The metal distribution in the atmosphere is monitored by the properties of the given metal and by various environmental factors (Khlifi and Hamza-Chaffai, 2010). Heavy metals are environmental pollutants and their toxicity is a problem, are of increasing significance for ecological, evolutionary, nutritional and environmental reasons (Jaishankar et al., 2013). The accumulation of heavy metals in plants has been a serious environmental concern because their uptake by plants from contaminated soils is the principal
process by which heavy metals enter the food chain and then to men and animals and are relatively toxic at levels slightly above than those required for maintaining normal metabolic activities (Hapke, 1991). The uptake of heavy metals by plants from soil depends on their concentration in soil, organic matter, soil, clay content and on their specific geochemical properties (Bansal, 2004). Heavy metal accumulation and contamination in tea has caused concerns for consumers and producer (Han et al., 2005). Exposure to various metal containing components of tea have varying health implications (Soomro et al., 2007.) Chemical farming practice brings many changes in soil ecology, crop productivity and quality, inn tea farming system and this makes organic farming an option to adopt as organically produced tea possesses high quality than conventional one. Organic crops mostly contain higher levels of phenolic metabolites than conventionally grown ones, in organic tea the quality is considered with minimum or zero chemical residues that is heavy metals and pesticides in the final product, high level of secondary metabolites including metabolites and these parameters are marketed in organic tea. (Kumar et al., 2012).

**Interaction of enriched fertilizer application on heavy metal content in tea fields**

For productivity of tea to increase a huge amount of inorganic fertilizers are applied in tea estates soils which enhances soil fertility and yield of tea but itself contain sufficient amount of heavy metal, therefore concentration of heavy metals is gradually increased with continuous use of synthetic fertilizers (Jeevan, 1998). Heavy metals accumulation can be derived naturally by soil contamination, use of pesticides and fertilizers (Ebadi et al., 2005). The tea plant grows in acidic soils and planting it makes soils more acidic hence increasing accumulation of heavy metals in tea (Song, 1990). Some trace metals such as Cr, Fe, Co, Ni and Zn are essential for growth of organisms, while other heavy metals Pb, Cd, Hg, and As are not only biologically non-essential but toxic (Shuklar, 2007). Chronic metal toxicity can be characterized by organ and tissue damage resulting in mortalities related to physiological disturbance and the extent of damage depends upon uptake and bioaccumulation of metals (Seenivasan, 2007). Soil pH and clay and organic matter content are the major factors controlling heavy metal toxicity and they influence their bioavailability (Peijnenburg et al., 1999). Humans introduce heavy metals into the environment through urbanization and anthropogenic activities. Anthropogenic processes includes acidification of soil through pollution in form of acid precipitation and agricultural practices, land use changes can affect forms accumulation of organic matter in soil hence influencing the availability of heavy metals in soils (Lindsay 1979; Impelliteri et al., 2000). When they are carried into the soil they accumulate in the ecosystem food chain causing harm to human health (Xing and Chen, 2004.)

**METHODOLOGY**

**Site Description**

The experiment was conducted in Agro 7, Timbilil Tea Estate in Kericho, Kenya, which lies at latitude 0° 22’S and longitude 35° 2’E, altitude of 2178 m above the sea level. The soils in the area are relatively uniform and strongly acidic. The soils are classified as Acrisols with a pH of 4.53; the rainfall in the area averages 1200-2700 mm per year and a temperature ranges from 16-25 °C (Anon., 2011, TRFK).

**Experimental Set-up**

The experiment is set on clone 31/8 and comprises of 14 main treatments replicated 3 times. The experiment was set-up in a Randomised Complete Block Design.

The main treatments were:

1. CONTROL no fertilizer, 0 kg N/ha/year
2. NPKS 25.5.5.5, 180 kg N/ha/year
3. SHEEP MANURE: 60, 120, 180, 240 kg N/ha/year
4. 8:1 MIXTURE: 60, 120, 180, 240 kg N/ha/year
5. 4:1 MIXTURE: 60, 120, 180, 240 kg N/ha/year
Data Collection

Soil sampling
Soils were sampled at a depth of 0-15, 15-30, 30-45 cm by auguring at each identified site following random sampling method from each treatment. The samples were put in the polythene tube and labelled well and taken to KALRO-Tea Research Institute laboratories for chemical analyses. Soil for soil pH measurement were taken for reading and the rest of the portion were air dried and sieved through a 2mm sieve for heavy metals analysis.

Laboratory analysis
Soil samples of 5 g were weighed and 40 g ammonium acetate, nitric acid (4 ml), acetic acid, EDTA solution (8 ml) and concentrated hydrochloric acid used as extractants for determination of heavy metal contents. A 50 ml of extractant was added to the soils samples and put in mechanical shaker for 10 minutes and the solution filtered. Addition of 2 ml of strontium was added to each and the mixture subjected to ICPE –Shimadzu, Japan for determination of heavy metals.

Data Analysis
The data values obtained were subjected to analysis of variance (ANOVA) using MSTAT-C (Version 2.1) and means were separated using Duncan’s Multiple Range Test for LSD values.

RESULTS AND DISCUSSION
The experimental results for the analysis at three depths (0-15) cm, (15-30) cm and (30-45) cm are represented from Tables 1 to 5 for the concentration of heavy metals in tea soils.

Zinc (Zn)
Zinc content in the tea field soils studied varied significantly (p≤0.05) with respect to fertilizer rates and depths (Table 1). The rates of fertilizer application at 0, 60, 120, 180 and 240 led to the accumulation of zinc in soil and the concentration of zinc decrease with an increase in depth.

Table 15: Effects of varying depths, rates and types of fertilizer on Zinc content in tea fields

<table>
<thead>
<tr>
<th>Rate mean</th>
<th>0</th>
<th>60</th>
<th>120</th>
<th>180</th>
<th>240</th>
<th>Depth mean</th>
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<tbody>
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<td>30-45</td>
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<td>15.5</td>
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<tr>
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<td>12.59</td>
<td>10.26</td>
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<td>Type mean</td>
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<td>5.6***</td>
<td>2.22**</td>
<td>NS</td>
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<tr>
<td>CV%</td>
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<tr>
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<td>5.6***</td>
<td>2.22**</td>
<td>NS</td>
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</table>

KEY: ** and *** are significant at p<0.01 and p<0.001 probability levels respectively.

Copper (Cu)
The concentration of copper in tea soils was significant in relation to depth ($P\leq0.001$) (Table 16). The different types of fertilizers did not have any effect on the concentration of copper in the soil.

Table 16: Effects of varying depths, rates and types of fertilizer on Copper content in tea fields

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<tr>
<th></th>
<th>0</th>
<th>60</th>
<th>120</th>
<th>180</th>
<th>240</th>
<th>Depth mean</th>
<th>type mean</th>
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<tbody>
<tr>
<td>NIL</td>
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<td>6.33</td>
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<td>SOM</td>
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<td>Rate mean</td>
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<td>6.96</td>
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<tr>
<td>CV%</td>
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<tr>
<td>LSD($p\leq0.05$)</td>
<td>NS</td>
<td>NS</td>
<td>0.44***</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
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</tr>
</tbody>
</table>

KEY: * is significant at $p<0.05$, ** is significant at $p<0.01$, *** is significant at $p<0.001$ probability levels.

Aluminum (Al)

There was significant ($p\leq0.05$) difference in the content of Aluminum content (Table 3). Aluminum content was higher in the fields treated with NPK fertilizers alone than the use of sheep manure only. This indicates that inorganic fertilizers may lead to accumulation of Aluminum content in the soil.

Table 17: Effects of varying depths, rates and types of fertilizer on Zinc content in tea fields

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>60</th>
<th>120</th>
<th>180</th>
<th>240</th>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate mean</td>
<td>921.33</td>
<td>802.93</td>
<td>852.81</td>
<td>776.07</td>
<td>776.22</td>
<td>1007</td>
<td></td>
</tr>
<tr>
<td>Type mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td>14.22%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD($p\leq0.05$)</td>
<td>53.04***</td>
<td>61.25*</td>
<td>53.04***</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

KEY: *, ** and *** are significant at $p<0.05$, $p<0.01$ and $p<0.001$ probability levels respectively.

Iron (Fe)
The rates and types of fertilizers used affected the concentration of Fe (ppm) in tea soils as there were significant (p≤0.05) differences in the content of iron in tea soils based on rates and type of fertilizer used (Table 4). Different depths affected the concentration of Fe (ppm) in the soil as with an increase in depth Fe content decreases. The existing Fe content in the soil may also cause an increase in the concentration of iron content in the soil.

**Table 18: Effects of varying depths, rates and types of fertilizer on Iron content in tea fields**

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>60</th>
<th>120</th>
<th>180</th>
<th>240</th>
<th>Depth mean</th>
<th>Type mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIL</td>
<td>0-15</td>
<td>46.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>49.68</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td>50.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOM</td>
<td>0-15</td>
<td>57</td>
<td>64</td>
<td>71.33</td>
<td>90.67</td>
<td>70.75</td>
<td>61.14</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>56.33</td>
<td>52.33</td>
<td>56</td>
<td>77</td>
<td>60.42</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td>55.33</td>
<td>49.33</td>
<td>50</td>
<td>54.33</td>
<td>52.25</td>
<td></td>
</tr>
<tr>
<td>EN 4:1</td>
<td>0-15</td>
<td>64</td>
<td>101.67</td>
<td>139.67</td>
<td>119.33</td>
<td>106.17</td>
<td>83.2</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>55.67</td>
<td>69.67</td>
<td>71.33</td>
<td>68.67</td>
<td>66.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td>61</td>
<td>94</td>
<td>72.67</td>
<td>80.67</td>
<td>77.09</td>
<td></td>
</tr>
<tr>
<td>EN 8:1</td>
<td>0-15</td>
<td>57.67</td>
<td>98.67</td>
<td>106.33</td>
<td>101.67</td>
<td>91.09</td>
<td>72.78</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>59.33</td>
<td>65.33</td>
<td>71.67</td>
<td>68.67</td>
<td>66.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td>62.33</td>
<td>59</td>
<td>58.67</td>
<td>64</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>NPK</td>
<td>0-15</td>
<td>59.67</td>
<td></td>
<td></td>
<td></td>
<td>56.89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56.67</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54.33</td>
<td></td>
</tr>
<tr>
<td>Rate mean</td>
<td>49.68</td>
<td>58.74</td>
<td>72.67</td>
<td>72.36</td>
<td>80.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>type rate depth T*R TXD RXD TXRXD</td>
<td>CV% 23.88%</td>
<td>LSD0.05 8.06*** 9.31*** 8.06*** NS NS 16.13** NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**KEY:** ** and *** are significant at p<0.01 and p<0.001 probability levels, respectively.

**Cadmium (Cd)**

The type of fertilizer used significantly (p≤0.05) affected the concentration of Cd in the soils studied (Table 5). The concentration of Cd (ppm) was highest when using sheep manure and lowest in NPK alone treated fields (Table 5). Cadmium is normally found in phosphatic fertilizers as these fertilizers are produced from phosphate rocks.

**Table 19: Effects of varying depths, rates and types of fertilizer on Zinc content in tea fields**

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>60</th>
<th>120</th>
<th>180</th>
<th>240</th>
<th>Depth mean</th>
<th>Type mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIL</td>
<td>0-15</td>
<td>6.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.44</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>3.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td>3.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOM</td>
<td>0-15</td>
<td>8</td>
<td>8.67</td>
<td>10.67</td>
<td>11.33</td>
<td>9.67</td>
<td>7.83</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>5.67</td>
<td>6.33</td>
<td>8.33</td>
<td>10</td>
<td>7.58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td>5.67</td>
<td>4.33</td>
<td>7.67</td>
<td>7.33</td>
<td>6.25</td>
<td></td>
</tr>
<tr>
<td>EN 4:1</td>
<td>0-15</td>
<td>7.33</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>5.83</td>
<td>5.39</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>5.67</td>
<td>5.33</td>
<td>5.67</td>
<td>4.67</td>
<td>5.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td>5.67</td>
<td>5</td>
<td>5</td>
<td>4.33</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>EN 8:1</td>
<td>0-15</td>
<td>8.33</td>
<td>6.67</td>
<td>6.67</td>
<td>6.67</td>
<td>7.09</td>
<td>6.47</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>6.33</td>
<td>6.67</td>
<td>6.67</td>
<td>5.67</td>
<td>6.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td>6.33</td>
<td>5</td>
<td>7</td>
<td>5.67</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>NPK</td>
<td>0-15</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>3.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.33</td>
<td></td>
</tr>
<tr>
<td>Rate mean</td>
<td>4.44</td>
<td>6.56</td>
<td>6.00</td>
<td>6.03</td>
<td>6.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>type rate depth T*R TXD RXD TXRXD</td>
<td>CV% 23.98%</td>
<td>LSD(p≤0.05) 0.73*** NS 0.73*** 1.47 NS NS NS NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**KEY:** *** is significant at p<0.001 probability levels respectively.
Soil pH and high total organic matter content have high retention capacity of heavy metal in soil (Bansal, 2004). All the heavy metals decreased in concentration as soil depth increased. Reducing the application of acidifying fertilizers, such as ammonium, and regular application of smaller quantities of lime materials may be an efficient way of maintaining soil pH at levels greater than 4.5 and thus decreasing the impact of heavy metals on tea plants. Sheep manure seems to alleviate the effects of heavy metals in soil.

CONCLUSION AND RECOMMENDATION
The results indicate that the soil had slightly increasing trends of heavy metal concentration but still within tolerable levels. However, the obtained mean values of heavy metals in the study sites are higher than found in the control site. Among these heavy metals Ni, Cr, Pb and Cd are soil pollutants and Cu, Zn, Mn and Fe are known as micronutrients or trace elements as these are required in small quantities by plants. The micronutrient elements in minute quantities produce optimum effects. On the other hand, even a slight deficiency or excess is harmful to the plants. By the application of fertilizers, animal wastes and fungicides into the soil not only supply the essential nutrients but also enrich the soil with the heavy metals. These are capable of interfering with biological activities, persistent toxicants within ecosystems and create acute health hazards for humans, animals and plant kingdoms. Therefore, there is need for optimization of fertilizers, animal wastes and fungicides for improvement of the soil productivity without creating environmental problems.

RECOMMENDATION
Farmers should apply enriched sheep manure in order to reduce the effects of heavy metal accumulation in tea soils and this reduces harm to human health. There is need to determine the content of heavy metals in the tea leaves within fields treated with enriched sheep organic manure.

REFERENCES


ABSTRACT

The mushroom is a fleshy, spore bearing fruiting body of a macro-fungus. Mushrooms often grow in association with trees. They can appear either below the ground or above the ground. They are found mostly late summer, early fall. Most mushroom are wild, however there are some that are cultivated. There are edible and poisonous mushrooms. Some of the edible types are a good source of protein, thiamine, vitamin B6, magnesium zinc, manganese, dietary fibre, riboflavin, potassium, copper, selenium, niacin, and pantothenic acid. It is useful in the treatment of diabetics, have immunotherapeutic properties, important in prevention of cancer and many other uses. The popularity of the mushroom is growing in many parts of Kenya. Although mushroom has high value, no market in Tharaka-Nithi County provides the produce for sale. During a preliminary survey conducted in Chuka, Tharaka and Maara, wild mushroom types were noted as highly existent in this County but the community seemed not to understand the usefulness of the product in food and nutrition security. Only two large hotels in the County were observed as utilizing mushroom flour for making appetizer. Generally the mushroom was indicated as not popular in Tharaka-Nithi County because of; lack of knowledge on food, nutritional and medicinal value, fear that mushroom is poisonous, unfavourable taste, high perish ability, lack of knowledge on value addition and preparation. This study therefore recommended various ways of sensitizing the communities about the importance and utilization of the mushroom. Some of the suggestions were; educating people on how to distinguish between poisonous and non-poisonous mushroom, training of various groups on how to prepare mushroom, fortification of mushroom with other foods, value addition, and advertisement of mushroom products.

Keywords: Mushroom, Utilization, Value addition, Food, Human nutrition

INTRODUCTION

Food insecurity has negatively affected livelihoods both in rural and urban communities especially in Asia and Sub-Saharan Africa (Food and Agricultural Organization (FAO, 1999). Some communities are victims of food insecurity due to unsustainable dietary choices. In line with development goals and the Kenya’s Vision 2030, there is need to develop strategies that expand dietary choice circles as well as increase agricultural productivity for food security and incomes in order to improve livelihoods(Ogalo, 2012). This can be enhanced through introduction and utilisation of high value crops like mushrooms.

Mushroom (Basidiomyota, Agaricomycetes) is a fleshy, spore bearing fruiting body of a macro-fungus that often grow in association with trees. The growth of the wild as well as cultivated mushroom fits very well with sustainable farming. There are many types of mushroom that can be cultivated in Kenya but the most popular are Agaricus bisphorus (Buttons) Pleorotus (Oyster), Lentininus (Shiitake) and Ganoderma. The mushroom industry in Kenya is still in its infancy and is growing slowly and to many people, its growing is still a myth because there is a lack of communication between the researchers in this field and the farmers, and the exchange of cultural knowledge is rather poor (Wambua, 2004).

Mushrooms are grown utilizing agricultural wastes, e.g. cereal straws, maize stocks, bean stock, Cotton husks, maize cobs, coffee husks, coffee pulp, paper waste, papyrus, water hyacinth, banana fronds. The mushrooms are important in the following ways: It has nutritional value with high protein content (35%), low fat, high linoleic acid, contain vitamins such as thiamine (Vitamin B). Riboflavin(Vitamin B2), niacin, biotine, ascorbic acid (Vitamin C) and folic acid; It has medicinal value with antibiotic substances that lower cholesterol levels, suppress growth rate of cancer tumours, reduce diabetics and boost body immunity; they are bio-degraders and are also used for cultural purposes. Therefore, mushroom
cultivation fits in very well with sustainable farming and has several advantages in that it uses agricultural waste products, yields high production per surface area and after picking, and its spent substrate is a good soil conditioner (Oei, 2005).

Mushroom production was introduced into Kenya in 1969. However, its cultivation and utilisation have been hampered by lack of information, extension, research and reluctance of those in possession of skills to share with interested parties. Among the 48 indigenous tribes in Kenya, 38 of them are known to use mushrooms as food. Also many immigrants and visitors from Asian, European and American origin utilise the mushroom. However, the current producers can hardly meet the demand in the supermarkets and sometimes the supermarkets run out of stock of the mushrooms. This creates an opportunity in the promotion and increasing the capacities for mushroom production to take advantage of the high demand. Tharaka Nithi is one of the Counties where there is massive growth of wild mushroom yet the nutritional and medicinal utilisation is minimal. The study therefore sought to identify the common types of mushroom that grow in Tharaka-Nithi County, investigate the level of awareness on usefulness of the mushroom, and determine factors affecting their acceptability with the aim of promoting production and utilization in the County.

METHODOLOGY
The study was undertaken in Tharaka-Nithi County in Eastern Kenya between April 2016 and November 2016. Tharaka-Nithi County is on the south Eastern side of Mt. Kenya at 0.30°S, 38.06°E and lies at an elevation of 600–1500 m (a.s.l) (Mairura et al., 200). The area is largely semi-arid and receives a bimodal pattern of rainfall, which is <1000 mm per year (Njeru et al., 2013). The County residents are subsistence farmers with intensively managed crop–livestock enterprises and slope cultivation that cover up to 60% (Recha et al., 2012). The agricultural sector is dominated by coffee, tea, bananas, beans, macadamia, mangoes, sorghum and livestock production that comprises of dairy cattle, goats and sheep. There is a dense population of trees which favours growth of some mushroom species.

Data was collected using field surveys, questionnaires, interviews, key informant interviews and focus group discussions in a sample of 400 respondents which included household heads, market vendors, hotel staff, nutritionists, change agents, administrators and other community members. Field surveys involved use of field sampling where various sample types of wild mushrooms growing in about 10 locations were collected and identified. The household heads were guided in the identification of the mushroom species present in the County. The household heads were guided in the identification of the mushroom species present in the County. The researchers used charts with clear pictures of various wild mushroom varieties to guide the identification. Interviews were also used to collect data about awareness about mushrooms from 5 purposively selected vendors in each of the following markets: Magumoni, Etuguru, Chera, Chuka, Kathuko, Kaanwa, Kathwana, Marima, Chogoria, and Marimanti. Data was also collected using key informant interviews with two nutritionists and two change agents in the County to determine importance and acceptability of the mushrooms in the area.

Questionnaires were used to collect data on acceptability of mushrooms from one manager and 4 waiters from each of the 5 well established hotels that were purposively sampled in the County. Focus group discussions (FGDs) were held to discuss the potential and acceptability of the mushroom in the County. The FGDs involved community members, hotel staff, market vendors, food nutritionists, administrative officers and change agents. The FGDs were held to conduct SWOT analysis (Strength, Weaknesses, Opportunities and Threats) on performance and acceptability of mushroom in Tharaka-Nithi County. The data values were analysed using descriptive statistics.

RESULTS AND DISCUSSION
The wild mushroom in Tharaka-Nithi County.
About four varieties of mushroom were found to be existent in the County. The varieties were; Shiitake (60%), Oyster (20%), Enoki (10%), and Portabella (10%) (Plate 1). The mushrooms grow in rotting plant
remains and on barks of dead stumps of trees. They are commonly called “Makuno” in Tharaka-Nithi County. The appearance of the mushrooms in this County is in two seasons. Most of them appear between October and November and also between March and April where there is some rainfall received. Probably occurrence of rainfall leads to the growth of the mycelia on these dead rotting plant material. Some Enoki was also observed on manures that had decomposed and stayed on before it was delivered to farm for planting crops. Farmers were advised that mushrooms can be grown in unused buildings or mud thatched houses or brick and stone constructed houses. It was noted that custom built structures with air conditioning can also be constructed but they are expensive and beyond the ability of many farmers especially without source of funding. There is need to sensitize farmers in Tharaka Nithi on growing mushroom utilizing cheap and locally available materials to enable lower cost of start-up.

![Shitake](image1.png) ![Oyster](image2.png) ![Enoki](image3.png) ![Portabella](image4.png)

Plate 1: Types of mushrooms observed during the survey

**Awareness about the value of Mushroom**

Results of the study indicated that the level of awareness about the growing and the value of mushrooms was less in the County. The data collected on awareness, utilization and value of mushroom on a sample of 400 people is indicated in Table 1 below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have seen the mushroom</td>
<td>100%</td>
</tr>
<tr>
<td>Have never seen the mushroom</td>
<td>0%</td>
</tr>
<tr>
<td>Have eaten the mushrooms</td>
<td>40%</td>
</tr>
<tr>
<td>Have never eaten the mushrooms</td>
<td>60%</td>
</tr>
<tr>
<td>Know the value of mushrooms</td>
<td>2%</td>
</tr>
<tr>
<td>Don’t know value of mushrooms</td>
<td>98%</td>
</tr>
</tbody>
</table>

**Factors affecting the acceptability of the mushrooms in the County**

During the survey it was observed that the acceptability of mushroom production has been low due to lack of knowledge about the crops value, fear about some species being poisonous, lack of skills for preparation of mushrooms, some respondents indicated that they dislike mushroom taste, and also their culture does not value mushrooms in food security.

<table>
<thead>
<tr>
<th>Factors affecting acceptability of mushroom</th>
<th>Percentage (%) of population affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lack of knowledge about mushrooms’ value</td>
<td>60%</td>
</tr>
<tr>
<td>2. Fear about poisonous nature of mushrooms</td>
<td>82%</td>
</tr>
<tr>
<td>3. Lack of skills for preparation of mushrooms</td>
<td>90%</td>
</tr>
<tr>
<td>4. Dislike of the mushroom taste</td>
<td>30%</td>
</tr>
<tr>
<td>5. No cultural value</td>
<td>92%</td>
</tr>
</tbody>
</table>
**SWOT Analysis on mushroom production in Tharaka-Nithi**

Using the information gathered a strength, weakness, opportunities and threats (SWOT) analysing on mushroom production in Tharaka Nithi was performed and the results are indicated in Table 2 below.

<table>
<thead>
<tr>
<th>Strengths about mushrooms</th>
<th>Opportunities about Mushroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mushrooms are highly present in the area</td>
<td>1. The dense tree population favours growth of wild mushroom.</td>
</tr>
<tr>
<td>2. Most mushrooms existent in the county are edible</td>
<td>2. Existence of diverse cultures in the County, increases chances for acculturation and marketability of mushrooms.</td>
</tr>
<tr>
<td>3. The mushrooms are nutritious and medicinal.</td>
<td>3. Presence of nutritionists and change agents in the County.</td>
</tr>
<tr>
<td>4. Mushroom can be used as a source of income</td>
<td>4. Existence of food insecurity in some parts of the County.</td>
</tr>
<tr>
<td>5. Mushroom can be cultivated.</td>
<td>5. Presence of the hotel industry in the County</td>
</tr>
<tr>
<td>6. Mushroom can be dried and stored for longer periods of time</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weaknesses</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lack of knowledge about value of mushrooms</td>
<td>1. Fear about poisonous mushroom</td>
</tr>
<tr>
<td>2. Dislike of the mushroom taste</td>
<td>2. Negative cultural perceptions about mushroom</td>
</tr>
<tr>
<td>3. Lack knowledge and skills on preparation of mushroom</td>
<td></td>
</tr>
<tr>
<td>4. Low marketability</td>
<td></td>
</tr>
</tbody>
</table>

**Usefulness of Mushroom**

In all the areas visited the respondents were informed of the usefulness of taking mushroom production as a key enterprise in Tharaka Nithi County. They were informed that mushrooms can be used either fresh or dried state and they can go well with a majority of dishes. They can be eaten raw in salads, sautéed or cooked for about 10 minutes and overcooking should be avoided to maintain the flavor. The usefulness of the mushroom was detailed to the respondents as indicated in Table 4 below.

<table>
<thead>
<tr>
<th>Nutritional values</th>
<th>Medicinal uses</th>
<th>Other uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The have high protein content of dry weight is between 19% and 35%</td>
<td>1. As fungi some mushroom yield important medicines like antibiotics</td>
<td>1. The mushroom is a saprophyte (feeds on dead matter) hence it’s a good degrader of cellulose and lignin that occurs in agricultural wastes. The biodegraded substances can be used for soil conditioning.</td>
</tr>
<tr>
<td>2. They have low rate of fat content between 1-8%</td>
<td>2. They contain substances which lower the cholesterol level in serum and liver which makes it good for those suffering from heart diseases.</td>
<td>2. In some cultures mushroom is considered as sacred and used to feed only the nobles.</td>
</tr>
<tr>
<td>3. They have high linoleic acids as one of the reasons why mushrooms are considered healthy food.</td>
<td>3. Most mushrooms contain substances, which suppress the growth rate of cancer tumours.</td>
<td></td>
</tr>
<tr>
<td>4. They are a good source of vitamins such as thiamine (Vitamie B).Riboflavin (vitamin B2), niacin, bio tine and ascorbic acid (vitamin C), folic acid.</td>
<td>4. Many (e.g. Oyster) have a positive effect on reduction of diabetes.</td>
<td></td>
</tr>
<tr>
<td>5. They contain significant phosphorus, sodium, potassium, calcium, magnesium, iron and zinc.</td>
<td>5. Many mushrooms contain anti-oxidants which boost the body immunity</td>
<td></td>
</tr>
</tbody>
</table>

**How to enhance acceptance of mushroom in Tharaka-Nithi County**

The following suggestions were made by respondents on how to enhance acceptance of mushroom in Tharaka-Nithi County.
Educating people on how to distinguish between poisonous and non-poisonous mushroom
Advertisement through media
Fortification of mushroom with other foods especially children’s and people with dietary requirements food
Commercialization and value addition of mushroom by experts
Exchange program through workshops and seminars to enhance training of various groups on production and processing of mushroom
Sensitization of women and youth groups
Medical prescriptions
Introduction of cultivated mushroom in the area
Avail recipe
Introduction to hotels
Use of entertainment like drama, songs, poems etc.

In the areas they are produced mushroom arise from lignocellulosic wastes, yet they become beautiful and nourishing. They can greatly benefit the environmental conditions because they biosynthesize their own food from agricultural crop residues which could otherwise have caused health hazards. They can be used as a means of promoting equitable economic growth in the society. The lignocellulosic wastes are available in all corners of the world and they can be used in cultivation of mushroom which can lead to white agricultural revolution especially in the least developed areas. Mushroom cultivation can therefore have a great impact on agriculture and environment, which contributes greatly to socioeconomic human welfare. Agricultural policies that promote mushroom production should be developed especially in this era of climate change to be able to sustain the environment for current and future generations.

CONCLUSION AND RECOMMENDATION
It was observed that mushroom can be a potential crop that can be introduced in Tharaka Nithi County to enhance food and nutritional security. The acceptance of mushroom production and utilization can therefore be enhanced through; educating people on how to distinguish between poisonous and non-poisonous mushroom, training of various groups on how to prepare mushroom and its fortification with other foods, its value addition and advertisement of mushroom products. This will increase acceptance, production and utilization and improve food security. There is therefore need for different stakeholders to work together at all levels of mushroom production value chain to increase productivity and diversification of food products. Stakeholders with collaborate in advising on construction of mushroom houses, production of quality spawn and educate farmers on mushroom crop management and value addition.

REFERENCES
ABSTRACT
In this paper, we introduce notions of \(A\)-almost similarity and the Lie algebra of \(A\)-skew-adjoint operators in Hilbert space. In this context, \(A\) is a self-adjoint and an invertible operator. We show that \(A\)-almost similarity is an equivalence relation. Conditions under which \(A\)-almost similarity implies similarity are outlined and in which case we also locate their spectra. We also give conditions under which an \(A\)-skew adjoint operator reduces to a skew adjoint operator. By relaxing some conditions on normal and unitary operators, new results on \(A\)-normal, binormal and \(A\)-binormal operators are proved. Finally we characterize \(A\)-skew adjoint operators and give the relationship between \(A\)-self- adjoint and \(A\)-skew adjoint operators.

**Keywords:** Skew-adjoint, Hilbert space, \(A\)-normal, Binormal

INTRODUCTION
In this paper, Hilbert space(s) or subspace(s) will be denoted by capital letters, \(H\) and \(K\) respectively and \(\mathcal{T}, \mathcal{A}, \mathcal{B}\) etc denote bounded linear operators. In this context, an operator will mean a bounded linear transformation. \(\mathcal{B}(H)\) will denote the Banach algebra of bounded linear operators on a Hilbert space \(H\) and \(\mathcal{B}(H, K)\) denotes the set of bounded linear transformations from one Hilbert space \(H\) to another one \(K\), which is equipped with the (induced uniform) norm.

If \(T \in \mathcal{B}(H)\), then \(T^*\) denotes the adjoint while \(\text{Ker}(T), \text{Ran}(T), \overline{M}, \text{and } M^\perp\) stands for the kernel of \(T\), range of \(T\), closure of \(\overline{M}\) and orthogonal complement of a closed subspace \(M\) of \(H\) respectively. For an operator \(T\), we also denote by \(\sigma(T), \|T\|\) the spectrum and norm of \(T\) respectively. A contraction on \(H\) is an operator \(T \in \mathcal{B}(H)\) such that \(T^*T \leq I\) (i.e. \(\|Tx\| \leq \|x\| \quad \forall\ x \in H\)). A strict or proper contraction is an operator \(T\) with \(T^*T < I\) (i.e. \(\sup_{0 \neq x \|x\| < 1} \frac{\|Tx\|}{\|x\|} < 1\)). If \(T^*T = I\), then \(T\) is called a non-strict contraction (or an isometry). Many authors like Kubrusly [5] and Nzimbi et al [10] have extensively studied this class of operators.

An operator \(T \in \mathcal{B}(H)\) is said to be positive if \(\langle Tx, x \rangle \geq 0 \quad \forall\ x \in H\). Suppose that \(A \in \mathcal{B}(H)\) is a positive operator, then an operator \(T \in \mathcal{B}(H)\) is called an \(A\)-contraction on \(H\) if \(T^*AT \leq A\). If equality holds, that is \(T^*AT = A\), then \(T\) is called an \(A\)-isometry, where \(A\) is a self adjoint and invertible operator. In this research, we put more conditions on \(A\). In particular, if \(A\) is a self adjoint and invertible operator, then we call such an \(A\)-isometry an \(A\)-Unitary. Let \(T\) be a linear operator on a Hilbert space \(H\). We define the \(A\)-adjoint of \(T\) to be an operator \(S\) such that \(AS = T^*A\) whose existence is not guaranteed. It may or may not exist. In fact a given \(T \in \mathcal{B}(H)\) may admit many A-adjoints and if such an \(A\)-adjoint of \(T\) exists, we denote it as \(T^{[s]}\). Thus \(AT^{[s]} = T^*A\). As it were before, \(A\) is invertible and so \(T^{[s]} = A^{-1}T^*A\). It is also clear that \(A\)-adjoint of \(T\) is the adjoint of \(T\) if \(T = I\). Earlier results proved by Kubrusly [5] have shown that, \(T\) admits an \(A\)-adjoint if and only if \(\text{Ran}(T^*A) \subset \text{Ran}(A)\). In this case the operator \(A\) is acting as a signature operator on \(H\). Two operators
Two operators are considered the “same” if they are unitarily equivalent since they have the same properties of invertibility, normality, spectral picture (norm, spectrum and spectral radius).

The following classes of bounded linear operators shall be defined in this paper:

Let $H$ and $K$ be Hilbert spaces. An operator $X \in B(H,K)$ is invertible if it is injective (one-to-one) and surjective (onto or has dense range); equivalently if $\text{Ker}(X) = \{0\}$ and $\text{Ran}(X) = K$. We denote the class of invertible linear operators by $\mathcal{G}(H,K)$.


BASIC RESULTS

Definition 2.1: Let $H$ denote a Hilbert Space and $B(H)$ denote the Banach algebra of bounded linear operators. Two operators $A \in B(H)$ and $B \in B(K)$ are similar (denoted by $A \approx B$) if there exists an invertible operator $N \in \mathcal{G}(H,K)$ where $\mathcal{G}(H,K)$ is a Banach subalgebra of $B(H,K)$ which is an invertible operator from $H$ to $K$ such that $NA = BN$ or equivalently $A = N^{-1}BN$ or $B = NAN^{-1}$.

Two operators $A$ and $B$ in $B(H)$ are said to be almost similar (a.s) (denoted by $A \approx a B$) if there exists an invertible operator $N$ such that the following two conditions are satisfied:

$$A^*A = N^{-1}(B^*B)N$$

$$A^* + A = N^{-1}(B^* + B)N$$
It has already been shown by many authors like [9], [12] and [13] that similarity, almost similarity and unitary equivalences are equivalence relations.

An operator $T \in B(H)$ is said to be self-adjoint or Hermitian if $T^* = T$ (equivalently, if $\langle Tx, x \rangle \forall x \in H$).

**Remark 2.2:** It has to be noted that almost similarity generally does not imply similarity. However, certain conditions can guarantee this preservation. These may include the following:

**Theorem 2.3 [13]:** If $T \in B(H)$ and $S \in B(H)$ are almost similar projection operators, then $\sigma(T) = \sigma(S)$.

Proof: See [13].

**Corollary 2.4 [13]:** If $T \in B(H)$ and $S \in B(H)$ are almost similar self-adjoint operators, then they are similar.

Proof: See [13].

**Corollary 2.5 [13]:** If $T \in B(H)$ and $S \in B(H)$ are almost similar self-adjoint operators, then $\sigma(T) = \sigma(S)$.

**Remark 2.6:** Equality of spectrum does not in general imply similarity of operators $T$ and $S$ unless if their multiplicities are the same. As an example if we consider operators $T$ and $S$ as $T = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$ and $S = \begin{pmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$. Clearly, both these operators are self-adjoint. However, by computation we see that they are not almost similar because $\sigma(T) \neq \sigma(S)$, that is $\sigma(T) = \{-1, 1, 1\} \neq \{-1, -1, 1\} = \sigma(S)$ and so their multiplicities do not coincide.

**Theorem 2.6 [10]:** $T \in B(H)$ is $A$-self adjoint, if and only if is $AT$ self adjoint.

Proof: See [10].

**Corollary 2.8 [10]:** Let $T \in B(H)$ be $A$-self adjoint, $T$ is self adjoint if $AT = TA$.

Proof: See [10].

### A-ALMOST SIMILARITY OF OPERATORS

**Definition 3.1:** Let $T \in B(H)$ and $S \in B(H)$. Then $T$ is said to be $A -$ almost similar to $S$ (denoted by $T \sim_{a,a} S$) if there exists an invertible operator $N \in B(H, K)$ such that the following two conditions are satisfied:

$$T^{[i]} N = N^{-1}(S^{[i]} + S) N$$

where $T^{[i]} = T$ and $S^{[i]} = S$ are $A$-self-adjoint operators, that is $T = A^{-1}T^*A$ and $S = A^{-1}S^*A$ respectively.

**Theorem 3.2:** $A -$ almost similarity is an equivalence relation.

Proof: We show that this relation is reflexive, symmetric and transitive.

First we show reflexivity. Let $T \in B(H)$. Then $T^{[i]} N = N^{-1}(T^{[i]} + T) N$ where $N$ is an invertible operator.

It is also clear that $T^{[i]} + T = N^{-1}(T^{[i]} + T) N$. Hence $T \sim_{a,a} T$. In this case we can choose (w.l.o.g) $N = 1$.

Next we show symmetry, that is if $T \sim_{a,a} S$ then there exists an invertible operator $N$ such that

$$S^{[i]} + T = N^{-1}(T^{[i]} + T) N$$

This implies that $S \sim_{a,a} T$. Supposing that $T \sim_{a,a} S$, there exists an invertible operator $N$ such that
\[ T^{[s]} T = N^{-1}(S^{[s]}S)N \quad \ldots \ldots \quad (1) \]
\[ \text{and} \quad T^{[s]} + T = N^{-1}(S^{[s]} + S)N \quad \ldots \ldots \quad (2) \]

Pre-multiplication of (1) and (2) by \( N \) and post multiplication of (1) and (2) by \( N^{-1} \) and applying the adjoint operation, we have

\[ S^{[s]} S = M^{-1}(T^{[s]}T)M \quad \text{and} \]
\[ S^{[s]} + S = M^{-1}(T^{[s]} + T)M \quad \text{where} \quad N = M^{-1} \quad \text{which is an invertible operator, since} \quad N^{-1} \quad \text{is invertible. Hence} \quad S \stackrel{a.a.s}{\sim} T. \]

Finally, let \( T, S \) and \( Q \) be in \( B(H) \). Suppose that \( T \stackrel{a.a.s}{\sim} S \) and \( S \stackrel{a.a.s}{\sim} Q \). Then we have

\[ T^{[s]} T = N^{-1}(S^{[s]}S)N, T^{[s]} + T = N^{-1}(S^{[s]} + S)N \quad \ldots \ldots \quad (3) \]
\[ S^{[s]} S = M(Q^{[s]}Q)M, \quad S^{[s]} + S = M^{-1}(Q^{[s]} + Q)M \quad \ldots \ldots \quad (4) \]

where \( M \) and \( N \) are invertible operators. Using (3) and (4) we have that

\[ T^{[s]} T = N^{-1}[M^{-1}(Q^{[s]}Q)M]N = (MN)^{-1}Q^{[s]}Q(MN) = X^{-1}(Q^{[s]}Q)X \quad \text{and} \]
\[ T^{[s]} + T = N^{-1}[M^{-1}(Q^{[s]} + Q)M]N = (MN)^{-1}Q^{[s]} + Q(MN) = X^{-1}(Q^{[s]} + Q)X \quad \text{where} \]
\( X = MN, \text{is invertible (since} \quad M \text{and} \quad N \quad \text{are invertible). Hence} \quad T \stackrel{a.a.s}{\sim} Q \quad \text{which proves transitivity.} \]

**Corollary 3.3:** If \( T \in B(H) \) and \( S \in B(H) \) are projection operators such that \( T \quad \text{is} \quad A \quad \text{almost similar} \)
to \( S \) then \( T \) is similar to \( S \). Moreover, \( \sigma_p(T) = \sigma_p(S) \).

**Proof:** By definition of \( A - \text{almost similarity} \) there exists an \( A \)-invertible operator \( N \) such that

\[ T^{[s]} T = N^{-1}(S^{[s]}S)N \quad \ldots \ldots \quad (1) \]

and

\[ T^{[s]} + T = N^{-1}(S^{[s]} + S)N \quad \ldots \ldots \quad (2). \]

From (1) using the definition of \( \quad A \)-Self adjoint of an operator we have, \( A^{-1}T^*AT = N^{-1}[A^{-1}S^*AS]N \), that is \( A^{-1}T^*TA = N^{-1}[A^{-1}S^*SA]N \) (by [10, corollary 3.14]) where \( AT = TA \) and \( AS = SA \) respectively. It follows that \( A^{-1}T^2A = N^{-1}[A^{-1}S^2A]N \) (since are projection operators) \( i.e. \quad A^{-1}TA = N^{-1}[A^{-1}SA]N \quad \text{i.e.,} \quad A^{-1}AT = N^{-1}[A^{-1}AS]N \) (by [10, corollary 3.14]) \( i.e. \quad T = N^{-1}SN \) and so \( T \sim S \).

In like manner, from (2) \( A^{-1}T^*A + T = N^{-1}[A^{-1}S^*A + S]N = N^{-1}[A^{-1}S^*A]N + N^{-1}SN \), that is \( A^{-1}TA + T = N^{-1}[A^{-1}SA]N + N^{-1}SN \) i.e \( A^{-1}AT + T = N^{-1}[A^{-1}AS]N + N^{-1}SN \) (by [10, corollary 3.14]), that is \( T + T = N^{-1}(S + S)N \) i.e \( 2T = N^{-1}(2S)N \Rightarrow T = N^{-1}SN \) and so \( T \sim S \). But similar operators have the same point spectrum. Hence, \( \sigma_p(T) = \sigma_p(S) \) as required.

**Remark 3.4:**

a) The above corollary gives a condition under which \( A - \text{almost similarity} \Rightarrow \text{Similarity} \) of operators.

b) Conditions imposed on operators \( S \) and \( T \) so that they have the same spectrum is that they should both be projections, that is \( S = S^*; T = T^* \) and \( S^2 = S; T^2 = T \).

**A-SKEW ADJOINT AND A-NORMAL OPERATORS.**

In this section we outline some properties of the Lie algebra \( L_A \) of \( A \)-skew-adjoint operators. We need the following basic definitions:

**Definition 4.1:** A Lie algebra is a vector space \( L \) over some field \( F \) together with a binary operation \([\quad , \quad ] : L \times L \rightarrow L \) called the Lie bracket such that

1) \([\quad , \quad ]\) is bilinear that is \([ax + by, z] = a[x, y] + b[y, z] \) and
\[ [z, ax + by] = a[z, x] + b[z, y] \forall a, b \in \mathbb{F} \text{ and } x, y, z \in \mathbb{L} \]
2) \[ [x, x] = 0 \text{ or } [x, y] = -[y, x] \forall x, y \in \mathbb{L} \]
3) \[ [x, [y, z]] + [y, [z, x]] + [z, [x, y]] = 0 \forall x, y, z \in \mathbb{L} \]. This is called the Jacobi identity.

**Example 4.2:** Let \( \mathbb{V} \) be a vector space over a field \( \mathbb{F} \). Let \( \mathbb{L} = \text{End}_{\mathbb{F}} \mathbb{V} \), i.e., the endomorphism of the vector space \( \mathbb{V} \) over the field \( \mathbb{F} \), that is linear maps from \( \mathbb{V} \) to \( \mathbb{V} \). Alternatively, we may take (for finite dimensional \( \mathbb{V} \)) the set of all \( n \times n \) matrices (operators). As usual, define on \( \mathbb{L} \):
\[
[A, B] = AB - BA, \quad \forall A, B \in \text{End}_{\mathbb{F}} \mathbb{V}.
\]

Note that if \( \mathbb{V} \) is n-dimensional, then \( \text{End}_{\mathbb{F}} \mathbb{V} \) is \( n^2 \)-dimensional vector space over \( \mathbb{F} \). This Lie algebra is called a Linear Lie algebra over \( \mathbb{F} \).

Another example of a Lie algebra could be the ordinary vectors in three dimensions. They form a three dimensional vector space over a field \( \mathbb{R} \). Define \([a, b] = a \times b\) to be the usual vector cross product.

Then, by computation we see that
\[
[a, a] = a \times a = 0, \quad [a, b] = -[b, a] = a \times b \quad \text{and}
\]
\[ a \times (b \times c) + b \times (c \times a) + c \times (a \times c) = 0 \quad a, b, c \in \mathbb{L}. \]

**Remark 4.3:** We denote by
1) The Lie \( \mathbb{L}_A \) of \( A - \text{skew-adjoint} \) operators is the set \( \mathbb{L}_A = \{ T \in B(H) : T^*[r] = -T \} \).
2) The Jordan algebra \( \mathbb{J}_A \) of \( A - \text{self adjoint} \) operators is the set \( \mathbb{J}_A = \{ T \in B(H) : T^*[r] = T \} \).

Note that just like the Lie algebra \( \mathbb{L}_A, \mathbb{J}_A \) is an \( \mathbb{R} \)-linear subspace. That is, it is closed under real linear combinations. (See more results of this class of operators in [2] and [10].)

**Remark 4.4:** For \( A \)-self adjoint and \( A \)-skew-adjoint operators, multiplication is not preserved at all. We also note that every \( T \in B(H) \) admits a Cartesian decomposition \( T = \text{Re}T + i\text{Im}T \), where \( \text{Re}T = \frac{1}{2}(T + T^*) \) and \( \text{Im}T = \frac{1}{2}(T - T^*) \). It is also noted that if \( T \) is \( A \)-skew-adjoint, then its adjoint \( T^* \) is also \( A \)-skew-adjoint.

We state the following without proof.

**Theorem 4.5 [10]:** \( T \in B(H) \) is skew-adjoint if \( \text{Re}T = 0 \).

**Theorem 4.6 [10]:** Every skew-adjoint operator \( T \) is \( A \)-skew-adjoint.

**Corollary 4.7 [10]:** If \( T \in B(H) \) is \( A \)-skew-adjoint, then \( T \) is skew-adjoint if and only if \( [T, A] = 0 \).

**Remark 4.8:** The above corollary is a condition which guarantees an \( A \)-skew-adjoint to be skew-adjoint. But \( T \in B(H) \) admits a Cartesian decomposition as illustrated in **Remark 4.4:** It is clear that this operator \( T \in B(H) \) is skew-adjoint if \( \text{Re}T = 0 \). We now give some general results for an \( A \)-skew-adjoint operator \( T \in B(H) \) that follow immediately from this remark:

**Theorem 4.9:** \( T \in B(H) \) is \( A \)-skew-adjoint if \( \text{Re}T = 0 \).

**Proof:** Every \( T \in B(H) \) is a linear combination of self adjoint operators, that is \( T = T_1 + iT_2 \). But \( T \in B(H) \) is \( A \)-skew-adjoint and so \( T^*[r] = -T \), that is
\[
T^* = -AT^{-1}A^{-1} = -A(T_1 + iT_2)A^{-1} = -AT_1A^{-1} - iT_2A^{-1}. \]
By the above remark, \( T \in B(H) \) is \( A \)-skew-adjoint implies that \( T \in B(H) \) is skew-adjoint if and only if \( AT = TA \) that is \( [T, A] = 0 \).
Thus $T^* = -T_1 AA^{-1} - i T_2 AA^{-1} = -T_1 - i T_2$.

But $T^* = (T_1 + iT_2)^* = T_1 - iT_1$ (since $T_1$ and $T_2$ are commuting self-adjoint operators). That is $T_1 - iT_1 = -T_1 - iT_1$. Validity of this equality is guaranteed if and only if $T_1 = 0$ which is $ReT = 0$.

**Theorem 4.10:** Let $A$ be a symmetry. If $T$ is $A$-skew-adjoint, then $T^*$ is $A$-skew-adjoint.

**Proof:** By definition, $T$ is $A$-skew-adjoint means $T = -A^{-1} T^* A$, that is $T^{[2]} = -T$ and so $T^* = -ATA^{-1}$. Taking adjoints on both sides of this equation gives

$$(T^*)^* = (-ATA^{-1})^* = A^* T^* (A^{-1})^*$$

i.e. $T = -A^{-1} T^* (A^{-1})^{-1}$. (Since $A$ is a symmetry)

i.e. $T = -A^{-1} T^* A$ (or equivalently $T = -T^{[2]}$). Therefore $T^*$ is $A$-skew-adjoint as required.

**Proposition 4.11 [10]:** Every skew-adjoint operator $T \in B(H)$ is normal.

**Proof:** (See [10]).

**Proposition 4.12:** Let $T \in B(H)$ be an $A$-skew-adjoint such that $[T, A] = 0$. Then $T$ is normal.

**Proof:** By definition, $T^* = -ATA^{-1}$. We check whether $T$ and $T^*$ commute, that is $T^* T = -ATA^{-1} T = -TAA^{-1} T$ (since $[T, A] = 0$) i.e. $T^* T = -T^2$.

Similarly $TT^* = -ATA^{-1} = -TTAA^{-1} = -T^2$. From the right hand side of these two equations, we see that $[T, T^*] = 0$. Therefore $T$ is normal.

**Corollary 4.13:** Let $T \in B(H)$ be an $A$-skew-adjoint such that $[T, A] = 0$. Then $T$ is $A$-normal.

**Proof:** Given $T \in B(H)$ an $A$-skew-adjoint, then $T^* = -ATA^{-1}$. It is sufficient enough to show that $[T^{[2]}, T] = 0$. But $A$-normal means $A^{-1} T^* A T = T A^{-1} T^* A$. Since $T$ is $A$-skew-adjoint, replacing $T^* = -ATA^{-1}$ in this equation yields

$-A^{-1} ATA^{-1} T^* = -ATA^{-1} T = -TAA^{-1} A$, i.e. $-T^2 = -T^2 \iff T^2 = T^2$.

This means that $[T^{[2]}, T] = 0$, so $T$ is $A$-normal as required.

**Theorem 4.14:** Suppose $T$ and $S$ are commuting $A$-skew-adjoint operators. Then $T^*$ and $S^*$ commute.

**Proof:** We have $T^* = -ATA^{-1}$ and $S^* = -ASA^{-1}$. In addition, the operators $S$ and $T$ are also commuting, that is $ST = TS = 0$. We have to establish that $[T^*, S^*] = 0$.

Thus,

$$\begin{align*}
(ST - TS)^* &= T^* S^* - S^* T^* \\
&= -ATA^{-1} (-ASA^{-1}) - (-ASA^{-1}) (-ATA^{-1}) \\
&= ATA^{-1} ASA^{-1} - ASA^{-1} ATA^{-1} \\
&= ATSA^{-1} - ASTA^{-1} = A(TS - AST)A^{-1} = 0.
\end{align*}$$

From this we conclude that $T^*$ and $S^*$ commute, that is $[T^*, S^*] = 0$.

**Remark 4.15:** For an operator $T \in B(H)$ which is both $A$-skew-adjoint and $A$-unitary, its spectrum can be found from its Eigen values. A quick computation shows that $T + T^{-1} = 0$. Thus for any $0 \neq x \in H$, we have that

$0 = ((T + T^{-1}) x, x) = \langle Tx, x \rangle + \langle T^{-1} x, x \rangle = \langle \lambda x, x \rangle + \langle \frac{1}{\lambda} x, x \rangle = \lambda (x, x) + \frac{1}{\lambda} (x, x)$

$= (\lambda^2 + 1)(x, x) = 0$, that is $\lambda^2 + 1 = 0$ i.e. $\lambda = \pm i$.

From this result we see that $\sigma(T) \subseteq \{i, -i\}$.

Note also that if $T$ is $A$-self-adjoint, then $T$ and $T^*$ are similar and hence have the same spectrum. However, this is not always the case for an $A$-normal operator. This is illustrated in the example below.

**Example 4.16:** Consider $T$ to be a diagonal operator $\{\omega_i\}$. Denote the adjoint of $T$ by $T^* = \{\omega_i\}$. Without loss of generality, let $T = \begin{bmatrix} 0 & 1 \\ 0 & i \end{bmatrix}$, clearly, $\sigma(T) = \{i, -i\}$ and
Let $A = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$. So $A$ and $T$ are not similar although $T$ being normal implies that $A$ is normal. Let $T = T_1 + iT_2$ be a decomposition $T$, where $T_1$ and $T_2$ are commuting $A$-self-adjoint operators. Then $T$ is $A$-normal.

**Proof:** (See [10]).

**Theorem 4.17** [10]: Let $T = T_1 + iT_2$ be a decomposition $T$, where $T_1$ and $T_2$ are commuting $A$-self-adjoint operators. Then $T$ is $A$-normal.

Proof: (See [10]).

**Theorem 4.18**: Let $T = T_1 + iT_2$ be a decomposition $T$, where $T_1$ and $T_2$ are commuting $A$-self-adjoint operators. Then $T$ is $A$-binormal.

Proof: Given $T = T_1 + iT_2$, by the definition of the adjoint of an operator we have that $T^* = T_1^* - iT_2^*$. It suffices to show that $[T^{[1]} T, TT^{[4]}] = 0$ i.e. $[T^{[1]} T](TT^{[4]}) = (TT^{[4]})(T^{[1]} T)$.

Now $(T^{[1]} T)(TT^{[4]}) = (A^{-1} T^* A T)(TA^{-1} T^* A) = [(A^{-1} (T_1^* + iT_2^*) A)(T_1 + iT_2)][(T_1 + iT_2)](A^{-1} (T_1^* + iT_2^*) A)$

But $T^* = AT A^{-1}$. It then follows that

$$(T^{[1]} T)(TT^{[4]})
= [A^{-1} (AT_1 A^{-1} - iAT_2 A^{-1}) A](T_1 + iT_2) = [(T_1 + iT_2)](A^{-1} (AT_1 A^{-1} - iAT_2 A^{-1}) A)
= (T_1^2 + T_2^2)(T_1 + iT_2)$. In like manner, $(TT^{[4]})(T^{[1]} T) = (T_1^2 + T_2^2)(T_1 + iT_2)$. Therefore $T$ is $A$-binormal.

**Remark 4.19:** In view of the above theorem we can deduce that if $T$ is a decomposition such that $T = T_1 + iT_2$ where $T_1$ and $T_2$ are $A$-self-adjoint operators, then $T$ is normal. (This follows from Theorem 3.13 and Corollary 3.14 [10]). A quick computation shows that $T^* = T_1 - iT_2$, that is $T = (T_1 - iT_2)(T_1 + iT_2)$. We show that $T^* = T_1 - iT_2$, i.e. $(T^* T)(T^* T) = (T^{[1]} T)(TT^{[4]}) = (TT^{[4]})(T^{[1]} T)$. By [10, Corollary 4.3, $T$ commutes with $A$ and so $(T^* T)(TT^{*}) = (T^* T)(TT^{*}) = (TT)(T^* T) = T^4 = (TT)(T^* T)$. We conclude that $T$ is $A$-binormal.

**Proposition 4.20** [10]: Every skew-adjoint operator $T \in B(H)$ is binormal.

Proof: (See [10]).

**Example 4.21**: We define on the function Hilbert space $L^2[a,b]$ a differential operator by $Tf = \frac{df}{dx}$ and show that it is skew-adjoint. Using integration by parts, we have $\langle Tf, g \rangle = \int_a^b f(x)g'(x)dx = \int_a^b f(x)g(x)dx = \int_a^b \frac{dg}{dx} f(x)dx = \int_a^b f(x)g(x)dx = \langle f, -Tg \rangle$. This clearly shows that $T^* = -T$ is a skew-adjoint operator.

**Proposition 4.22**: Every $A$-skew-adjoint operator $T \in B(H)$ is binormal.

Proof: Let $T$ be $A$-skew-adjoint. Then $T^{[1]} = -T$, that is $T^* = -AT A^{-1}$. We show that $[T^* T, TT^*] = 0$ i.e. $(T^* T)(TT^*) = (TT^*)(T^* T)$.

$(T^* T)(TT^*) = (-AT A^{-1} T)(TTA^{-1}) = (ATA^{-1} T)(TATA^{-1})$. By [10, Corollary 4.3, $T$ commutes with $A$ and so $(T^* T)(TT^*) = (TAA^{-1} T)(TTAA^{-1}) = (TT)(TT) = T^4 = (TT)(T^* T)$. We conclude that $T \in B(H)$ is binormal.

**Corollary 4.23**: Every $A$-skew-adjoint operator $T \in B(H)$ is $A$-binormal.

Proof: If $T$ be $A$-skew-adjoint, then $T^{[1]} = -T$. A simple calculation shows that $[T^{[1]} T, TT^{[1]}] = 0$. 

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Remark 4.24: It is well known by earlier results that every skew-adjoint operator $T$ is $A$-skew-adjoint (see [10]). In view of this and the corollary above, it can also be deduced that every skew-adjoint operator $T \in B(H)$ is $A$-binormal.

5. Some Results on $A$-self adjoint and $A$-skew-adjoint operators.

In what follows, we investigate the relationship between $A$-self adjoint and $A$-skew-adjoint operators. We know that every normal operator is quasinormal and every quasinormal operator is binormal. Using results in Theorem 3.9 [10] and Proposition 4.4[10] we establish some common behaviour of $A$-self adjoint and skew adjoint operators. It is also well known that every part of a skew adjoint is skew adjoint and so every part of a skew-adjoint operator is normal. Thus a skew adjoint operator has no completely non-normal part.

Proposition 5.1[10]: Let $T$ be an $A$-skew adjoint operator. Then $T^n$ is $A$-self adjoint for even values of $n \in N$ and $T^n$ is $(−A)$-skew adjoint for odd values of $n \in N$.

Remark 5.2: We can simply interpret this proposition as follows: that if $T$ is $A$-skew adjoint, then $T^n$ is $(−1)^n A$-self adjoint. That is to say that $T^n$ is $A$-skew adjoint for odd values of $n \in N$ and $T^n$ is $A$-adjoint for even values of $n$, which can also be extended to polynomials. The Lie Algebra $\mathbf{L}_A$ is closed under all odd degree polynomials over a field $\mathbf{F}$, while the Jordan Algebra $\mathbf{J}_A$ is closed under all polynomials over $\mathbf{F}$.

The following proposition now provides a characterization of an $A$-skew adjoint operator:

Proposition 5.3: Suppose $Q = TA$, where $A$ is invertible and self-adjoint, then $T$ is skew adjoint if and only if $Q$ is $A$-skew adjoint.

Proof: Let $T$ be skew-adjoint and $Q = TA$ with $A$ invertible and self-adjoint. Then $AQA^{-1} = ATAA^{-1} = AT = −AT = −Q^*$, that is $Q$ is $A$-skew adjoint.

Conversely, let $Q$ be $A$-skew adjoint with $Q = TA$, then $T = QA^{-1}$ and so $T^* = A^{-1}Q^* = A^{-1}(−QA^{-1}) = −QA^{-1} = −T$ that is $T$ a skew-adjoint operator and this completes the proof.

Remark 5.4: The converse of the above proposition gives a more general property of an $A$-skew adjoint operator. It is also worth noting that the Lie Algebra $\mathbf{L}_A$ is a linear space but it is not closed under multiplication. Nonetheless, $\mathbf{L}_A$ is closed under the Lie bracket $[T_1, T_2] = T_1T_2 - T_2T_1$.

Question: Is there any relationship between the Lie Algebra $\mathbf{L}_A$ and the Jordan Algebra $\mathbf{J}_A$? A possible answer to this question can be summarised in the following propositions:

Proposition 5.5: Let $T_1$ and $T_2$ be commuting $A$-skew adjoint linear operators. Then the product $T_1T_2$ is $A$-self-adjoint.

Proof: By definition $T_1, T_2 \in \mathbf{L}_A$ means that $T_1^* = −AT_1A^{-1}$ and $T_2^* = −AT_2A^{-1}$.

Since $[T_1, T_2] = 0$, we have $(T_1T_2)^* = T_2^*T_1^* = −AT_2A^{-1}(−AT_1A^{-1}) = AT_2T_1A^{-1} = AT_1T_2A^{-1}$. This proves that $T_1T_2$ is $A$-self-adjoint.

Proposition 5.6: Let $T_1$ be $A$-skew adjoint and $T_2$ be $A$-self-adjoint. If $T_1$ and $T_2$ commute, then $T_1T_2$ is $A$-skew adjoint.

Proof: Given that $T_1$ is $A$-skew adjoint and $T_2$ is $A$-self-adjoint then $(T_1T_2)^* = T_2^*T_1^* = −AT_2A^{-1}(−AT_1A^{-1}) = −AT_2T_1A^{-1}$. But $T_1$ and $T_2$ are commuting and so $−AT_2T_1A^{-1} = −AT_1T_2A^{-1}$. It follows that $(T_1T_2)^* = −AT_1T_2A^{-1}$. This shows that $T_1T_2$ is $A$-skew adjoint as required.

Corollary 5.7: Let $T \in B(H)$ is an $A$-skew adjoint. Then
Thus, we see (as an example) that 

The following class inclusions also hold: 

\[ \text{Self-adjoint} \subset \text{Normal} \subset A\text{-Normal} \]

From the above corollary, we evidently see the equality of spectra and this is indeed a necessary condition for \( A\)-skew-adjointness of an operator. As an example, let us consider the backward shift operator \( T : l^2 \to l^2 \), defined by \( T(x_1, x_2, x_3, \ldots) = (x_2, x_3, x_4, \ldots) \) that is never \( A\)-skew-adjoint. Its adjoint (the unilateral shift) is defined by \( T^*(x_1, x_2, x_3, \ldots) = (0, x_1, x_2, \ldots) \). We see (as an infinite matrix) that every \( \lambda \in \mathbb{C} \) with \(|\lambda| < 1\) (open unit disc centred at the origin) is in \( \sigma_p(T) \) and that \( \sigma_p(T^*) = \emptyset \). Also, \( \{ \lambda \in \mathbb{C} : |\lambda| < 1 \} \subseteq \sigma_p(T^*) \). Hence \( T \) is not \( A\)-skew adjoint (for any \( A \) with the required properties: that it should self-adjoint and invertible) because the necessary condition for \( A\)-skew-adjointness is not satisfied (equality of spectra of \( T \) and \( T^* \)) i.e. \( \sigma(T) \neq \sigma(T^*) \). (See a similar result on \( A\)-self-adjointness Corollary 3.8, pp59 [2]).

This operator, namely, the backward shift operator \( T : l^2 \to l^2 \) is an example of an operator that is neither in the class of the Jordan algebra of \( A\)-self-adjoint nor the Lie algebra of the \( A\)-skew adjoint operators. However we should also note that there exist non-zero operators that are skew-adjoint and \( A\)-self-adjoint. This is illustrated in the example that follow:

**Example 5.9:** Let \( T = \begin{pmatrix} -i & 0 \\ 0 & i \end{pmatrix} \) and \( A = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \). Then a quick computation shows that \( T \) is both \( A\)-self-adjoint (that is \( T^* = \overline{AT} = \overline{AT}^{-1} \) and skew-adjoint (i.e. \( T^* = -T \)). In view of this we see can the only operator satisfying both conditions for \( A\)-self-adjointness and \( A\)-skew-adjointness is the zero operator.

**CONCLUSION**

From the preceding results, it is clearly evident that \( A\)-self-adjoint, \( A\)-skew-adjoint and \( A\)-unitary operators are special cases of \( A\)-normal operators. We also note that the class of \( A\)-self-adjoint operators contains some self-adjoint operators, some skew-adjoint operators and some which are neither of these categories. We have given the backward shift operator as an example of such an operator. That there exist operators which are skew-adjoint and \( A\)-self-adjoint but not \( A\)-skew-adjoint. There is no class inclusion between \( A\)-self-adjoint and \( A\)-skew-adjoint operators. However, zero is the only operator that can satisfy this inclusion. The following class inclusions also hold:

- Symmetry \( \subseteq \) Unitary \( \subseteq \) Normal \( \subseteq A\)-Normal
- Symmetry \( \subseteq \) Self-adjoint \( \subseteq \) Normal \( \subseteq A\)-Normal

In addition the intersection of the class of self-adjoint and unitary operators yields a symmetry, i.e. \( \{ \text{Self-adjoint} \} \cap \{ \text{Unitary}\} = \{ \text{Symmetry} \} \).

Just like \( A\)-self-adjoint operators, the spectrum of an \( A\)-skew-adjoint operator \( -T \) and the adjoint operator \( T^* \) is equivalent, that is \( \sigma(T) = \sigma(-T^*) \).

Finally, it has also been established that \( A\)-almost similarity is an equivalence relation just like other equivalences like unitary and almost similarity on a Hilbert space. \( A\)-almost similar operators have equal spectra if they are projection operators.

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Yeung Y.H, Li C.K and L. Rodman, on \( H \)-unitary and Block Toeplitz \( H \)-normal operators, \( H \)-unitary and Lorentz matrices: A review, Preprint.
ABSTRACT
The aim of the study was to investigate genderlect in the use of swear words in the six social networks in the Meru speech community. Sample was drawn from the following social network groups: boys’ groups, girls’ groups, men’s groups and women’s groups using judgmental sampling method. The difference theory by Deborah Tannen studied the analysis of the data. The study found out that boys and men use more swear words than girls and women in Kimeru. These differences are informed by different socialization of both males and females in the Meru culture. Women have been instructed in the proper ways of talking just as they have been instructed in the proper ways of dressing, in the use of cosmetics, and in other “feminine” kinds of behavior. Men have been instructed in “masculine” behaviour.

Keywords: Genderlect, Swear words, Socialization, Masculine, Feminine, Behavior

INTRODUCTION
The theoretical basis of language variation is the premise that language varies and these variation patterns across social variables gender being one of them. Gender is a biological category that distinguishes males and females. The focus in gender studies is genderlect which refers to differences in language of both men and women for example, In Living Language (p.222), George Keith and John Shuttleworth record suggestions that: women - talk more than men, talk too much, are more polite, are indecisive/hesitant, complain and nag, ask more questions, support each other, are more co-operative, whereas men - swear more, don't talk about emotions, talk about sport more, talk about women and machines in the same way, insult each other frequently, are competitive in conversation, dominate conversation, speak with more authority, give more commands, interrupt more. It is from this background that the study by Mikwa (2017) focused on genderlect in the use of swear words in Kimeru language. Swear words refer to Kimeru terms that are used to swear, such as to express strong anger or frustration.

Statement of the problem
Numerous studies have been conducted in Kimeru but none had been done on genderlect in the use of swear words, therefore; the study filled that gap.

Objectives of the study
The study had four objectives but this paper is based on the first and second objectives of the study namely: to identify the swear words used by different social networks groups in Kimeru and to find out gender differences in the use of swear words in Kimeru

Theoretical Framework
Difference is an approach of equality, differentiating men and women as belonging to different 'sub-cultures' as they have been socialized to do so since childhood. This then results in the varying communicative styles of men and women. Deborah Tannen is a major advocate of this position Tannen compares gender differences in language to cultural differences. Comparing conversational goals, she argues that men tend to use a "report style", aiming to communicate factual information, whereas women more often use a "rapport style", which is more concerned with building and maintaining relationships.
Materials and Methods
Judgemental sampling method was used to select respondents for the study. It underlying principle involves identifying in advance the ‘type’ of speakers to be studied and then seeking a quota of speakers who fit the specified categories as Milroy (1987:26) observes. A total number of three contact people were used each from the three pre-specified social network groups. The identified subjects introduced the researcher to the members of their social network groups. Therefore, the researcher was able to get three informants per each social network group who were interviewed by way of word list discussion topics which were tape recorded to elicit data for the study. Milroy (1987:26) notes that sociolinguistics samples that are very large amount to unnecessarily large data and necessitate much time in analysis, but may not yield different results (cf Kebeya 1997, Muthwii 1994 and Trudgill 1974), Mikwa (2008) also observes that it is no longer necessary to work with large samples for studies in speech communication because sampling procedures have improved greatly. Thus, in the study, data was got from three pre-specified social network groups in Meru. Each group had three male members and three female members therefore the total population was eighteen informants.

The data consisted of tape recorded spontaneous speech using the difference theory technique. The data collected was sorted out into social network groups using the process of data reduction and interpretation as per the swear word list discussion topics provided. Then the data for each discussion word list topic was represented in a table alongside the social network groups. The information on genderlect on the use of swear words per social network groups were expressed in percentages. The tables and figures were used to express the scores of genderlect on use of swear words knowledge per social network group using tables. Data was presented in extracts from transcribed texts. The genderlect on the use of swear words knowledge that varied according to Pre-specified social network groups were identified and a statistical evaluation method was used to analyse them showing the variability of this knowledge across the social network groups.

Therefore, the study adopted quantitative and qualitative approaches to data analysis. The analysis of scores obtained from the variation of the knowledge of genderlect on the use of swear words across social network groups generated numerical data which called for quantitative analysis. Every word on genderlect on the use of swear words that varied alongside gender depending on the word lists topics of discussion was assigned one point and the total points for every group of informants was converted into percentages and the informants were stratified using these percentages. The percentages were found by dividing 100% by the total number of words on genderlect on the use of swear words per word list discussion topic and multiplying the answer by the words scored by the respective social network groups. This translates in mathematical representation thus:

Total number of swear words per word list discussion topic x 100
Swear words scored by the respective social network groups

Where there was no variation a score of zero was awarded

Analysis of Data as per the words list Discussion Topics
The informants were given swear words lists discussion topics namely: Kimeru swear words that they use when annoyed or frustrated. The spontaneous speech of the informants was tape recorded during the interview sessions. The knowledge of genderlect on the use of swear words varied across the social network groups as illustrated in the data below:
A1) Boys and girls aged between 9 years- 13 years. These respondents were in their upper primary school level of their education. They were given a list of swear words and asked to identify the ones they used when annoyed by their peers during their past time activities. They identified swear words and their scores were as captured on the table below.
The provided swear words were:

Ita naria /ita naria/ go there!
Kia /kia/ fool!
Washumbura /wafumbura/ don’t disturb me
Wamburia/wamburia/ don’t ask me
Aibu eku /aibu eku/ shame on you

Their scores were presented as shown on the table below.

<table>
<thead>
<tr>
<th>Speakers</th>
<th>Gender</th>
<th>Points</th>
<th>Variance</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Males</td>
<td>5/5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>2/5</td>
<td>3</td>
<td>60</td>
</tr>
</tbody>
</table>

KEY: A1 Boys and girls (9-13) years swear words scores

The table shows that the scores for boys and girls (9-13) years where the scores for boys are higher than the scores for girls meaning that boys used more swear words in their conversation than girls where boys preferred conflict to compromise and girls preferred compromise to conflict. This is represented graphically as follows:

Graph 1.1 shows that males have a 0% variance while females have 60% variance meaning males use swear words more than females. KEY: M Males; F Females

A2) Youths aged between 14 years - 18 years
These were boys and girls in their secondary school level of education. They were asked the same question that the boys and girls of (9-13) years were asked. The provided swear words and their scores were as shown on below.

Nkai/nkai/ testicles
Kuru /kuru/ dog
Ntigiri /ntigiri/ donkey
Kia/kia/ fool
Ntaka /ntaka/ rubbish

Their scores were as shown on the table below.
Table 2.1 Youths (14-18) years swear words scores

<table>
<thead>
<tr>
<th>Speakers</th>
<th>Gender</th>
<th>Points</th>
<th>Variance</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>Males</td>
<td>5/5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>1/5</td>
<td>4</td>
<td>80</td>
</tr>
</tbody>
</table>

KEY: A2 Youths (14-18) years

The table shows that the scores for boys and girls aged (14-18) years where the scores for boys are higher than the scores for girls meaning that boys used more swear words in their conversation than girls. Where boys preferred conflict to compromise and girls preferred compromise to conflict. This was captured graphically as follows.

Graph 2.1 Youths (14-18) years swear words scores

Graph 2.1 shows that males have 0% variance while females have 80% variance meaning males use more swear words than females. KEY: M Males, F Females

A3) Speakers above 18 years

These were speakers who were through with their secondary school education. They were asked the same question that the other speakers above were asked. The provided words list and their scores were as shown on the table below. The swear words that they were given are as shown below.

Table 3.1 Speakers above 18 years swear words scores

<table>
<thead>
<tr>
<th>Speakers</th>
<th>Gender</th>
<th>Points</th>
<th>Variance</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3</td>
<td>Males</td>
<td>5/5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>1/5</td>
<td>4</td>
<td>80</td>
</tr>
</tbody>
</table>

KEY: A3 Speakers above 18 years old
The table shows that the scores for speakers above 18 years old where the scores for males are higher than the scores for females meaning that boys used more swear words in their conversation than girls. Where males preferred conflict to compromise and females preferred compromise to conflict. This was represented graphically as follows:

\[ \begin{array}{c|c|c}
  \hline
  & M & F \\
  \hline
  1 & 0\% & 0\% \\
  2 & 0\% & 0\% \\
  3 & 80\% & 80\% \\
  4 & & \\
  \hline
\end{array} \]

Graph 3.1 Graphical representation of speakers above 18 years old swear words scores

Graph 3.1 shows that the male have 0% variance while females have 80% variance meaning males use more swear words than females. KEY: M Males, F Females

**CONCLUSION**

Genderlect in the use of swear words is as a result of difference in socialization of males and females in the Meru culture where females more than males prefer compromises to conflicts when annoyed hence using less swear words than their males counterparts.

**ACKNOWLEDGEMENTS**

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**LITERATURE CITED**


Jennifer Coats. (1986), Women, Men and Language Longman London
ABSTRACT
Women and environmental issues cannot be fully divorced since time of memorial. This is because they have direct contact with the natural resources like land, water forest and fuel, mostly in rural areas, which dominate over 80% of Kenyan population. Women are also responsible for using these natural resources for their daily basic needs. This has resulted to pollution, soil erosion, deforestation and negative changes of climate situation in the country. Today, women groups have made great sacrifice to conserve their environment in which they live. This study examined the roles of women groups in environmental conservation, a survey of Muchui women’s group in Nkando village, Buuri sub-County, Meru County. This study applied a descriptive survey design which focused on 50 members of Muchui women’s group and the sample was selected randomly. Data was collected using close ended and open ended questions. The study was guided by objectives such as community forestry, water harvesting, composting and environmental education as environmental conservation parameters. The study found out that Muchui women group engage in community forestry and water harvesting is an individual activity and it enhances irrigation which in turn helps conserve the environment. Environmental education is also done by all members to the community and composting of manure is done on individual basis. The study concludes that community forestry has a great impact on the environmental conservation. The study also concludes that environmental education is very important to all the people and need to be encouraged by all stakeholders. Lastly manure composting is crucial to all members of the group. The study recommends that the same roles should be replicated to and by other women groups for widespread environmental conservation. The government should also empower women groups and encourage them to be role models in environmental conservation.

Keywords: Natural resources, Women, Community forestry, Composting, Environmental education

INTRODUCTION
Gender roles in Kenya put women in direct contact with natural resources such as forests, water, land and wildlife. They utilize and conserve these resources to supply basic needs for their families. Therefore conservation of natural resources in rural areas cannot be done without the involvement and training of women. They need to be educated on the values, management and sustainability of natural resources as alternative sources of livelihood. But to have success, they must only be appreciated as invisible land managers, but must benefit from relevant incentives in their cultural roles. It is common knowledge in rural Kenya that women (and not men) are indeed the (invisible) managers of natural resources. These resources include land, water, forests and wildlife (Michiels, and Nete. 2013). Most rural women are comparatively poor and uneducated. Most of them do not hold a monthly paying job and therefore are commonly referred to as housewives. But these women are great sustainers of rural micro-economic activities. However nowhere is their impact and activities more significant as their indigenous knowledge of, and management of natural resources such as land, water, forests and wildlife. They are crucial because their traditional gender roles bring them in direct contact with these natural resources, and their survival and that of their families depend directly in exploiting and harnessing supplies from these natural resources (Stoddart, and Mark 2011).

To many poor rural farmers, especially women, nature sustains society because they use the natural resources to feed their families. This sustainability is crucial to them if they have to sustain livelihoods off
these resources. Thus when the world environmental protection and conservation policies advocate for protection without any form of use, while ignoring rural women, they become the greatest victims of such a policy (Mann and Susan 2011). Women constitute a large percentage (over half) of the rural population. Women are socially more burdened in rural Kenya. Their activities range from family economic activities to running of homes and rural development projects. They are also a more appropriate group to target for cultural and social changes. Their activities in development and family care put them in the central position regarding impacts to land and other natural resources (MacGregor, 2006).

Impact on environment is a direct consequence of economic and social factors. Chief of these factors is population size, and growth rate. Destruction of forests, riparian habitats and other sensitive areas arise mostly from increase of population. To be able to control population, improve rural development, and to protect natural resources, the role of women is critical. Rural Kenya is among the areas with the highest population size growth rates, while the natural resources {Wildlife, Forests, Wetlands, Land, Water and fisheries} are decreasing. This paper will discuss the role of women and their impacts on these critical natural resources. This information is important for decisions on which gender is the relevant target group for education and mobilization concerning rural environmental issues. Such knowledge is also important for national planning and policy formulations concerning the use of land and natural resources in the country. (Gaard, and Greta 2011).

Women in rural areas are more linked with natural resource use and conservation than men. Their traditional gender roles bring them in daily contact with natural resources such as land, water, forest and wildlife. They have to use these resources because they are often poor and their livelihood most depends on these resources. When these resources are exploited and ruined, women suffer most. If they are widely used sustainably women benefit most. Most women want to learn and to be recognized for what they really are: managers of natural resources (Stoddart, and Mark 2011).

Any government and non –government efforts to conserve should therefore appreciate and recognize the central role of women as they have diverse indigenous knowledge in the use and exploitation of natural resources whether it is to provide food, shelter, traditional medicines or for other purposes. They are therefore an appropriate target group if wildlife will persist in dispersal areas, if tropical forests and other natural forest parches are to remain uncleared in favour of agriculture, if watersheds and catchments are to be conserved for adequate provision of clean water, if wetlands are to be considered useful for ecological processes and biodiversity and not considered as waste lands, and if land as a resource is to be used sustainably and not turned into degraded wasteland (Laura 2012).

The Muchui Women’s Group is a group of 90 women, whom 50 of the members have been active since 1994 and is registered with the social services. This group is based in Nkando village, Buuri sub-county, Meru County. Buuri is on the leeward side of Mount Kenya experiences low to medium rainfall, ranging from a low of 200 mm to amounts as high as 2,000 mm of rainfall in a year and the poverty index is at sixty percent (60%). (GOK, 2008). The land is fertile, volcanic in origin, and will support a wide variety of crops when rainfall is available. However this area lies in an extremely drought prone area, meaning there is often water shortages.

The Muchui Women’s Self-Help Group approached Farmers Helping Farmers in 1997 to seek support who supported them with 4600 litre water tank each for rain water harvesting and also establishment of small tree nursery in each of the members home. The group also established a central nursery where they raised tree seedlings for sale as well as for planting in their farms. The agreement is each member should plant at least 100 tree seedlings in her farm in the long rains and bring remaining seedlings to the central seedling where they are sold to the community.
LITERATURE REVIEW

Woman and land cultivation

Land provides many basic needs in rural societies, the main one being food. The main activity of rural women is in production of food for their families. In all Kenyan cultures, when one talks of food, whether in production, processing or marketing, they have in mind these activities as cultural roles of women. On most farms in villages, you will find women providing over 80% of labour directly in food production. This activity is major among other chores like fuel-wood collection, pole-wood for construction, fetching of water for domestic use, cooking and feeding of the family, and treatment of common rural ailments (Ralte and Lalrinawmi. 2012). Women therefore come directly in contact with land in their effort to produce food. When soils do not yield enough crops, because of exhaustion, it is women to deal with modification of farming practices like provision of local manure to replenish the soil. When there is destruction of soil cover that causes soil erosion, except where there is government paid work it’s usually women who do the terracing or develop other strategies be they enlightened or naïve. In most cases, men are either passive or absent. This discussion reveals that conservation and wise use of rural land is mostly the domain of women. Their traditional activities skills and knowledge are crucial in understanding why lands deteriorate or remain viable, while it is becoming increasingly important to protect soils from erosion, and degradation. A lot of natural biodiversity and change of ecologies also result when land is misused (Doverspike and Nicole 2012). Of main concern are the spread of desertification and loss of biodiversity because of intensive, indiscriminate and careless use of land. Many women of the world have sustainably used their land, but the increase of rural population and the competition of market economies on the global scene is compromising this sustainability. It is crucial that women are taught to use farming and other compatible land use approaches for biodiversity and ecological conservation. The common problems related to use of land in the face increasing human population and diminishing land resources, and free market economy competition, are deforestation, overstocking, soil and water pollution (Mann and Susan 2011).

One of the greatest factors working against women is land tenure system. In many cultures, land is passed on to men and not women. Most rural are traditionally registered to men and women can do nothing in increasing fragmentation for sale or other activities. Even though they are the ones that deal with production off the land, its fate is entirely a male issue. There are cases when subsistence food crops are diminishing and major cash crops increasing. Women are involved mostly in provision of food, and when little and poor land is available for subsistence crops, they are forced to work more harder or go long distances to reach scattered parcels of land to farm for domestic food crop use. Therefore land tenure systems and legal structures actually marginalize women when in-fact they are the most affected and real invisible land managers in Kenya (Doverspike and Nicole 2012).

From natural resource conservation point of view, it is increasingly becoming important to allow conservation of natural resources such as forests and wildlife as a form of land use. The current danger is over emphasis of agriculture over other forms of land use. The result has been an ever-increasing clearance of forests and other natural vegetation habitats for agriculture including watershed and wetland virgin forests and catchment areas all over the country are being cleared to produce domestic or cash crops while wetlands have fallen prey as vegetable production areas in the dry seasons. With Kenya being a signatory to international treaties committing her to conservation of environment and natural resources, there is a great need to devise practical incentives that are aimed at women, particularly in meeting their gender roles and elevating poverty, so that they can accept and appreciate setting apart land for forests, wildlife and others as an important land use. There is need for focused campaign and help for women with the aim of legitimizing conservation as a form of land use in rural areas. This is the only way conservation will be possible. Furthermore, there is need to encourage land use practices that are compatible with conservation, such as agro-forestry and proper farming practices and land ethics (Taylor & Francis. 2017).
Women and water harvesting

Issues concerning management and conservation of water resources are of great importance in Kenya now. With increasing human pressure on land, riparian areas and wetlands, areas, which were normally sparsely populated, are now settled. There is therefore an increasing concern on impacts particularly on current and future provision of clean water as well as of conservation of wetlands as habitats for wetland related biodiversity. Women are the main collectors and users of water in rural Kenya. They have to decide where to collect water, how to draw, transport and store it, how much water to draw, how many sources of water to exploit and for what purposes {drinking, kitchen and other domestic use}. In some cases where women can afford tanks, rain- water becomes a major source for drinking and other domestic use. In most areas, especially dry areas, women still depend on wells, springs, streams and rivers for water supply (MacGregor, 2006).

In this case, practices that compromise water from streams, underground and rivers directly affect the welfare of women. To have a steady supply of water in streams and rivers, all catchment and riparian vegetation need to be conserved. This ensures that the hydrological cycle to continue, with feedbacks that involve evaporation, condensation, rain and runoffs. Stream and river sources should be conserved, as would be a cold source. This means that all agricultural practices {as they involve deforestation and replacement of natural vegetation} need to be discouraged in riparian and catchment areas. Draining of wetlands or farming them for agricultural practices {such as planting of rice} should be discouraged if they will affect water quality, Quantity, distribution and supply. Women should be educated in the importance of conserving wetlands, riparian zones and catchment areas to ensure clean and reliable water supply for their current domestic use and future supplies. With increasing number of women groups and their unique self-help projects, clean water availability and access is becoming the biggest item on women related-projects (Vakoch and Douglas 2012).

Women and community forestry

Community forestry was initially defined, by FAO, as “any situation which intimately involves local people in a forestry activity. It embraces a spectrum of situations ranging from woodlots in areas which are short of wood and other forest products for local needs, through the growing of trees at the farm level to provide cash crops and the processing of forest products at the household, artisan or small industry level to generate income, to the activities of forest dwelling communities” (FAO 1978). Thus, community forestry was perceived as encompassing activities by individual households, women and men farmers and other people, as well as those involving a community as a whole. Such activities commonly enter widely into rural life and have always done so. It is therefore pertinent to start by asking why there was the sudden and intense interest in these linkages between people and trees in the middle and latter part of the 1970s - and equally why it had not occurred earlier (Doverspike and Nicole 2012).

Apart from maintaining atmospheric balance, protection and maintenance of water sheds, protection of soils and water, and in providing habitats for endemic and rare forest related biodiversity, forests are important to women particularly in supplying fuel wood. Women use forests to supplement fuel and food sources from own land e.g. fuel wood {as trees planted on farms and other agro-forestry projects are owned by men}, nuts and fibres, wild fruits, vegetables, tubers, honey and wild bush meat. Forests are also used for cultural and spiritual purposes and in provision of medicinal plants, which cater for most rural healthcare. In the past, before it became illegal to graze in natural forests, this was a popular use. Women care for livestock and this ban has meant that women spend time elsewhere looking for fodder or grazing on roadsides. Therefore, women have used forest products intimately and their conservation is tightly linked with their activities and gender roles (Doverspike and Nicole 2012).

Since tropical forests hold some of the world’s largest and unique biological resources, they are of great concern and interest to conservation organizations and governments. Tropical forests are disappearing
very fast and forest biodiversity seriously threatened. The close association of women and forests as rural managers and users has brought women to the forefront of tropical forest conservation (LaRosa and Patricia. 2013). Organized women groups are now fighting against deforestation especially where their user’s rights are threatened. Women are also becoming very active in a forestation program (than men) and traditional farming is now being modified to incorporate agro-forestry in an effort to bring resources (such as fuel wood) out of the forest to farms closer to homes where sustainable use can well be practiced. In fact a lot of women groups run tree seedling nurseries for income generally as well as own farm planting (Green Belt Movement 2016).

Hundreds of millions of people across Africa, Asia, and Latin America depend on forests for their livelihoods and culture. Around the world, forest communities are at risk of losing their homes to settlers, cattle ranchers, illegal loggers, and companies. These activities not only devastate the communities who depend on forests for their livelihoods and culture, but also contribute to global climate change by removing community forests as carbon sinks and emitting carbon dioxide (CO₂). A new report by WRI and the Rights and Resources Initiative, to be released on July 24th, shows governments can meet their climate change mitigation targets by protecting community forest rights. We caught up with the report’s lead author, Caleb Stevens, to find out why community forests are so important both for human rights and for curbing climate change (Caleb 2016).

Community forests are lands held collectively by either rural or indigenous communities based on a shared history, language, culture, or lineage. In contrast to individual private property, most community forest lands are governed by customary rights, rules, and institutions that pre-date most modern governments, and continue to adapt to changing circumstances. Customary rights govern community forest land in ways that support local cultures and livelihoods. Many forest communities clear small areas of forest for subsistence agriculture or husbandry, but the forest is able to regenerate and continues to provide numerous benefits in the form of food, building materials, medicines, and many other products and services. While customary forest rights, rules, and institutions vary, many community members have inheritable rights to part of the community’s forest land to support their families. The remaining forest is held as common property of the community—called “forest commons”—with community rules governing access and use. For example, community members may collect firewood from the forest commons. In many cases, rules also mandate that community forest land cannot be sold. Hundreds of millions of people across Africa, Asia, and Latin America use and depend on vast forest areas for their livelihoods and culture. For these rural communities and indigenous peoples, the forest is a critical source of water, timber, wildlife, and identity. Forest resources lie at the heart of their social, political, and economic life as the primary source of livelihood, nutrition, and employment. These fundamental assets are a basis for security and, for many forest communities, are culturally and spiritually significant. (Doverspike and Nicole 2012).

Many countries’ laws do not legally recognize communities’ customary rights to their forest. This leaves forest communities especially vulnerable to losing their forest land to companies, developers, and other interests. Some governments acknowledge only limited use rights so communities can provide for their basic needs, such as in the Democratic Republic of the Congo. Other countries’ laws formally allow for legal recognition of customary forest rights, but the legal documents necessary for communities to exercise their rights are not issued, as in Indonesia. Even when governments do legally recognize customary forest rights, they often only respect rights over forests that are subject to active, visible use by communities. This leaves much of the forest vulnerable to deforestation because the government considers the forest idle, vacant, and available for commercial use (Green Belt Movement 2016).

Year after year, governments are allocating large areas of forest land for use by commercial logging, oil palm, mining, and other economic interests. In the process, governments grant commercial operators the de facto right to deforest, as the approved allocations of forest land often lead to massive clear-cutting and
conversion of forests to non-forest uses. As a consequence, a community may permanently lose its forest without any consultation in some cases; people are even subjected to intimidation or manipulation. These actions not only hurt forest communities, deforestation contributes to climate change. By working with communities to strengthen their forest rights, rather than undermining them, governments can ensure numerous sustainable development benefits. Strong community forest rights help communities protect their forests, reducing CO₂ emissions from deforestation and improving forest health. Strong forest rights also provide communities with secure access to forest products for housing, medicine, and other local uses as well as income from the sale of timber and non-timber forest products (Gaard, and Greta 2011).

Governments, civil society, and donors are working to strengthen community forest rights in many countries. While necessary interventions vary based on context, this commonly requires action on multiple fronts, including: Legal recognition and protection for communities’ customary forest rights; Enforcement of community forest rights by mapping and registering community forests, and expelling illegal loggers and settlers; Provide technical assistance and training to forest communities to improve sustainable forest management and access to markets, among other things; Engage forest communities on developments and other investments affecting their forests; and Compensate communities for the environmental services they provide as effective managers of their forests (Taylor & Francis. 2017).

METHODOLOGY

Research Design
The study adopted descriptive research design. A descriptive study is undertaken in order to ascertain and be able to describe the characteristics of the variable of interest in a situation (Sekaran, 2006). The goal is to offer a profile of the phenomena of interest from a specific perspective. It is restricted to fact-finding and may result in the formulation of important principles of knowledge and solutions to significant problems. It is more than collection of data and it involves measure, classification, analysis and interpretation. The descriptive design is faster and comparatively low cost methods that adequately help answer the research questions (Chandrant 2004). Orodho (2003) defines descriptive design as a method of collecting information by administering a questionnaire to a sample of individuals.

Target Population
The survey covered 50 members of muchui women’s group. According to data from the Muchui women’s group 50 active members are register and operate in Michaka village, Buuri sub-County, Meru County.

Sample Design and Sample size
The simple random sampling was used to select 15 members of muchui women’s group from the target population. This method of sampling was appropriate because the population of study was known and easy to locate and carry out the survey. According to Mugenda (2003) researchers need to determine the required sample size for studies. Mugenda states that a sample size of between 10% and 30% is adequate. Also the rule of the thumb should be used to obtain as a big a sample as possible.

Data Collection Instruments
Since the number of elements in the population was not large, the interview and questionnaires methods were used to collect data. The questions were designed in such a way as to elicit answers to all pertinent issues in order to provide solution(s) to the research problem. The questions were both structured and unstructured questions.

Pilot Study
A pilot study was conducted using the questionnaire on 3 senior members of the group before the main survey. The purpose of pilot testing was to establish the accuracy and appropriateness of the research design and instrumentation and therefore enhance face validity. The content validity of the research and
treatment instrument was evaluated through the actual administration of the pilot group. After the pilot study the main survey followed.

**Reliability**
Reliability of the questionnaire was evaluated through administration of the said instrument to the pilot group. A construct composite reliability co-efficient (Cronbach alpha) of 0.6 and above was considered adequate for this study.

**Data Analysis**
Both quantitative and qualitative techniques were used. The data from the questionnaires was coded and the response on each item put into specific main themes. It also involves checking for completeness in relation to research questions. The words and phrases were categorized based on research objectives. Data were tabulated in form of frequency tables and percentage. The data obtained from the research instruments was analyzed by use of descriptive statistics (frequencies and percentages, means and standard deviations) as well as inferential statistics (correlations and one away analysis and regression of variables).

**Privacy and ethics**
Due to sensitivity of some information collected, the researcher held a moral obligation to treat the information with utmost secrecy. The researcher reassured the respondents of use and confidentiality of the information given. The study ensured that the confidentiality of the respondent was observed whereby they were requested not to fill their names in the questionnaire form. In addition, no respondent was forced to give the responses.

**FINDINGS**
The study found out that Muchui women group engage in community forestry were they established a trees nursery, sell seedling among members and even other members of the public. The study also found that members have the group land where they practice community forestry. Water harvesting is done by Muchui women group as a group collective activity. Every member is provided with water harvesting equipment and installed on individual compound. The study found that the harvested water is used for domestic use and kitchen garden irrigation. Environmental education is also done to all members and members of public frequently. Lastly the study found that composting of manure is done on individual basis and is a group initiative activity where every member is bound to participate.

**CONCLUSION**
The study concludes that community forestry has a great impact on the environmental conservation. It prevents soil erosion and blocks the wind which carries away the fertile soil. Also water harvesting enhances farm irrigation which in turn conserve environment to the members and general public. The study also concludes that environmental education is very important to all the people and need to be encourages by all stakeholders in various industries. Lastly manure composting is crucial to all members of the group to promote farming activities of members and for commercial purpose.

**RECOMMENDATION**
The study recommends that the same women group roles should be replicated to and by other women groups for widespread environmental conservation in Meru County and in the nation at large. The county and national governments should also empower women in groups and encourage them to be a role model in environmental conservation. Lastly the environmental conservation should be collective activities for all member of public. Therefore current and potential leaders and managers in various sectors of the economy should contribute most of their effort in spreading and propagating environmental education to all stakeholders.
REFERENCES
INFLUENCE OF GENDER ON SELECTED PERSONALITY FACTORS: IMPLICATIONS FOR PERSONALITY AND CAREER COUNSELING AMONG SECONDARY SCHOOL STUDENTS IN CHUKA SUB-COUNTY

Riungu, Elosy Nyambura and Kinyua, Susan Muthoni
Department of Education, Chuka University P. O. Box 109- 60400 Chuka
Corresponding author: elosynyambura14@gmail.com

ABSTRACT
This study sought to determine the influence of gender on personality factors of introversion, extroversion, self-concept, self-esteem and shyness among secondary school students in Chuka sub-county, Kenya. The study employed descriptive survey research design on a population of 941 form three secondary school students. A sample size of 260 respondents was selected by use of stratified sampling and proportionate sampling techniques. A self-report personality inventory was used to collect the desired data. Validity of the questionnaires was ensured through expert opinion of the University supervisors while reliability was ascertained through a pilot study whose findings yielded an acceptable split half internal reliability coefficient of 0.85. The findings of the study indicated no significant gender differences in personality factors of introversion, extroversion, self-concept, self-esteem and shyness among secondary school students. Therefore, when counseling secondary school students, school counselors may need to overlook gender stereotypes suggesting that boys are more extroverted, better in self-concept and self-esteem as well as more bold compared to girls.

Keywords: Personality, Introversion, Extroversion, Self-concept, Self-esteem

INTRODUCTION
Several psychologists look at personality formation differently. Personality refers to a person’s general style of interacting with the world, especially with other people; whether outgoing, excitable or placid, conscientious or careless, kind among others (Gray, 2002). A basic assumption of personality concept is that people do differ from one another in styles of behavior; ways that are relatively least consistent across time and place. Jest and Gregory point out that a personality trait may be unique, common to some group, or shared by an entire species, but the pattern is different for each individual. Research has shown that different personalities tend to have distinct preferences in choice of career (Inkule, 2004). Individuals tend to pursue careers that are fulfilling. Nevertheless, being in a career doesn’t necessarily mean that it is fulfilling because many people have no concept of the work and skills involved in a chosen career (Hentz, 1995). This is because the best match is a career in which the major tasks of the work are those that a person enjoys doing.

According to Inkule (2004), a career assessment can help an individual identify and better articulate personal interests, values and skills in relation to career choice. In this respect, career counselors often administer career assessments to help individuals focus their search on careers that closely match their unique personal profile. Career counselors assess people’s interests, personality, values and skills to assist in exploration of career options. Professionals involved in career counseling have hundreds of tools at their disposal to help identify possible matches between who their clients are and what they might succeed at in terms of work (Wingfield, 2003). Variables thought to be important in occupational choice range from whether one is a people person to whether a work environment brings out the best in a worker (Hentz, 1995). Within the range of acceptable jobs, workers tend to choose those that satisfy their basic values because when personality matches the job, satisfaction is high and work is performed well (Galvin, 2004). It is common knowledge that the way people perform in their careers greatly depends on their personal interests in what they are doing. So when people are forced into careers they are not interested in, it should not be surprising when they turn out to be poor performers (Lerner & Taylor, 1999).

Gender stereotypes in personality and career choice are common in which case men are perceived as being strong-willed and destined for certain careers requiring use of muscle and strength (Inkule, 2004).
Gender is the significance a society attaches to the biological categories of male and female in regard to attitudes and activities that a society links to each (Stark, 2004). Gender is a dimension of social organization, shaping how people interact with others and even how they think about themselves. Further, Archer and Cressy (2000) found out that gender involves hierarchy, placing men and women in different positions in terms of power, wealth and other resources. Global comparisons reveal that societies vary widely in defining tasks as either masculine or feminine. However, both genders are physically capable of learning to cook and make clothes or to weld and fly airplanes but these functions are generally assigned to women and men respectively (Schaefer, 2003). According to Wayne (2004), males and females are understood by culture to have different attributes and to be suited for different social roles. Tillie (2007) suggests that women’s career development presents issues absent from the same kinds of strict career choices made by most men. This is because women’s career choices are often determined by powerful social and cultural forces that shape decisions in accordance with frequent false assumptions in regard to women’s needs, abilities and aspirations. In addition, women at the top end of the career spectrum are faced with the pressures to conform to traditional stereotypes as well as those pursuing career paths that require less education and training are just as much the victims of societal attitudes that may cause them to accept less than fulfilling positions.

Objective
The objective of this study was to determine the influence of gender on personality factors of introversion and extroversion, self-concept, self-esteem and shyness among secondary school students in Chuka sub-county.

RESEARCH METHODOLOGY
Descriptive survey research design was adapted for this study in which case the study variables were not manipulated in any way. Instead, the study findings were reported as they existed in the field. The study population was 941 form three students from 12 secondary schools in Chuka Sub-county. Stratified sampling technique was used to obtain a sample of 260 students from the study population. A self-report personality inventory was used to collect the desired data. The opinion of university supervisors were sought for validation of the research instruments whose reliability was ascertained by use of split-half method. A reliability co-efficient of 0.85 was obtained. The research permit was granted by the National Commission for Science, Technology and Innovation. The collected data was analyzed by use of percentages, frequencies and chi-square test statistics with the aid of SPSS version 15. The data results are presented in tables.

RESULTS AND DISCUSSION
Information on gender of respondents was sought and the data analysis results are presented in Table 1.

Table 1: Distribution of Respondents by Gender and School Category

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th></th>
<th>Female</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percentage</td>
<td>Frequency</td>
<td>Percentage</td>
<td>Frequency</td>
</tr>
<tr>
<td>Boys</td>
<td>60</td>
<td>23</td>
<td>0</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Girls</td>
<td>0</td>
<td>0</td>
<td>65</td>
<td>25</td>
<td>65</td>
</tr>
<tr>
<td>Mixed</td>
<td>70</td>
<td>27</td>
<td>65</td>
<td>25</td>
<td>135</td>
</tr>
<tr>
<td>Total</td>
<td>130</td>
<td>50</td>
<td>130</td>
<td>50</td>
<td>260</td>
</tr>
</tbody>
</table>

The results in Table 1 reveal that there were an equal number of male and female respondents. However, there were more girls than boys from single gender schools but more boys than girls from mixed gender schools. The study sought to test at alpha 0.05 level of significance that there were no statistically significant gender differences in personality factors of introversion and extroversion, self-concept, self-esteem and shyness among secondary school students with the aim of aiding school counselors in
designing efficient personality and career counseling strategies. A chi-square test was carried out to determine gender differences. The information in Table 2 was generated from the analysis.

Table 2: Chi-square Test on Influence of Gender on Selected Personality Factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Chi-square value</th>
<th>Df</th>
<th>P-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introversion</td>
<td>1.458</td>
<td>4</td>
<td>0.692</td>
<td>P&lt;0.05&lt;sub&gt;ns&lt;/sub&gt;</td>
</tr>
<tr>
<td>Extroversion</td>
<td>1.458</td>
<td>4</td>
<td>0.692</td>
<td>P&lt;0.05&lt;sub&gt;ns&lt;/sub&gt;</td>
</tr>
<tr>
<td>Self-concept</td>
<td>0.821</td>
<td>2</td>
<td>0.663</td>
<td>P&lt;0.05&lt;sub&gt;ns&lt;/sub&gt;</td>
</tr>
<tr>
<td>Shyness</td>
<td>0.017</td>
<td>2</td>
<td>0.992</td>
<td>ns</td>
</tr>
<tr>
<td>Self-esteem</td>
<td>0.165</td>
<td>2</td>
<td>0.921</td>
<td>P&lt;0.05&lt;sub&gt;ns&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

Key: ns - not significant at alpha 0.05

An examination of results in Table 2 reveals that gender differences in personality factors of introversion, extroversion, self-concept, self-esteem and shyness were not significantly significant at alpha 0.005. Therefore, the null hypothesis was rejected meaning gender had no influence on the selected personality factors among secondary school students. Further, frequencies and percentages analysis of the responses were determined to ascertain the chi-square results.

The respondents answered a personality test on introversion and extroversion. Information in Table 3 represents frequency and percentage distribution of responses by gender.

Table 3: Frequency and Percentage Distribution of Students’ Scores of Influence of Gender and Extroversion

<table>
<thead>
<tr>
<th>Score</th>
<th>Trait Frequency</th>
<th>Trait Percentage</th>
<th>Boys Frequency</th>
<th>Boys Percentage</th>
<th>Girls Frequency</th>
<th>Girls Percentage</th>
<th>Total Frequency</th>
<th>Total Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-20</td>
<td>Very Introverted</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-17</td>
<td>Slightly Introverted</td>
<td>17</td>
<td>7</td>
<td>14</td>
<td>5</td>
<td>31</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>9-11</td>
<td>Average</td>
<td>62</td>
<td>24</td>
<td>63</td>
<td>24</td>
<td>125</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>3-8</td>
<td>Slightly Extroverted</td>
<td>48</td>
<td>18</td>
<td>52</td>
<td>20</td>
<td>100</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>130</td>
<td>50</td>
<td>130</td>
<td>50</td>
<td>260</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

The results in Table 3 indicate that more boys (3) than girls (1) were very introverted. Similarly, more boys (17) than girls (14) were slightly introverted. Contrary, more girls (63) were average in the introversion/ extroversion trait. In addition, more girls (52) than boys (48) were slightly extroverted. The differences in percentages for influence of gender on introversion and extroversion are not significant meaning that gender had no influence on the personality trait. This confirms the chi-square test results in Table 2 implying that boys and girls are equally introverted and extroverted.

To determine self-concept of the respondents, a personality test was taken in the study. The results in Table 4 represent frequency and percentage distribution of respondents’ scores by gender.

Table 4: Frequency and Percentage Distribution of Students’ Scores of Gender and Self-concept

<table>
<thead>
<tr>
<th>Score</th>
<th>Trait Frequency</th>
<th>Trait Percentage</th>
<th>Boys Frequency</th>
<th>Boys Percentage</th>
<th>Girls Frequency</th>
<th>Girls Percentage</th>
<th>Total Frequency</th>
<th>Total Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-10</td>
<td>High self-concept</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>6-8</td>
<td>Average</td>
<td>102</td>
<td>39</td>
<td>99</td>
<td>38</td>
<td>201</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>0-5</td>
<td>Low self-concept</td>
<td>26</td>
<td>10</td>
<td>28</td>
<td>11</td>
<td>54</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>130</td>
<td>50</td>
<td>130</td>
<td>50</td>
<td>260</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
As indicated in Table 4, there were more boys (102) than girls with average self-concept. Girls were more in the categories of high and low self-concept with a difference on 1 and 2 frequencies respectively. This difference in percentages is not significant as indicated by the chi-square results in Table 2. This means that both boys and girls experience similar levels of self-concept. The study respondents answered a personality test on self-esteem. The results of data analysis presented in Table 5 displays frequency and percentage distribution of respondents’ scores by gender. This analysis was carried out to determine the influence of respondents’ gender on self-esteem.

Table 5: Frequency Distribution and Percentage of Students’ Scores of Gender and Self-esteem

<table>
<thead>
<tr>
<th>Score Trait</th>
<th>Boys Frequency</th>
<th>Boys Percentage</th>
<th>Girls Frequency</th>
<th>Girls Percentage</th>
<th>Total Frequency</th>
<th>Total Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low self-esteem</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Average</td>
<td>95</td>
<td>36</td>
<td>96</td>
<td>37</td>
<td>191</td>
<td>73</td>
</tr>
<tr>
<td>High self-esteem</td>
<td>30</td>
<td>12</td>
<td>28</td>
<td>11</td>
<td>58</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>130</td>
<td>50</td>
<td>130</td>
<td>50</td>
<td>260</td>
<td>100</td>
</tr>
</tbody>
</table>

Information in Table 5 reveals that there were slightly more girls (6 and 96) than boys (5 and 95) who had low and average self-esteem respectively. However, there were more boys (30) than girls (28) in the high self-esteem category. The percentage differences in the influence of gender on self-esteem were not significant as indicated by the chi-square results in Table 2. This implies that boys and girls have similar experiences of self-esteem.

The study respondents answered a personality test on shyness. Data analysis was carried out to determine the influence of respondents’ gender on shyness. Information in Table 6 presents frequency and percentage distribution of respondents’ scores by gender.

Table 6: Frequency Distribution and Percentage of Students’ Scores of Gender and Shyness

<table>
<thead>
<tr>
<th>Score Trait</th>
<th>Boys Frequency</th>
<th>Boys Percentage</th>
<th>Girls Frequency</th>
<th>Girls Percentage</th>
<th>Total Frequency</th>
<th>Total Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very shy</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Average</td>
<td>77</td>
<td>29</td>
<td>78</td>
<td>30</td>
<td>155</td>
<td>59</td>
</tr>
<tr>
<td>Slightly shy</td>
<td>49</td>
<td>19</td>
<td>49</td>
<td>19</td>
<td>98</td>
<td>38</td>
</tr>
<tr>
<td>Total</td>
<td>130</td>
<td>50</td>
<td>130</td>
<td>50</td>
<td>260</td>
<td>100</td>
</tr>
</tbody>
</table>

Regarding the personality trait of shyness, more boys (4) than girls (3) were very shy while more girls (78) than boys (77) were average in shyness. The same number of boys and girls (49) were slightly shy. The differences in the percentages for influence of gender on shyness were insignificant as reflected by the chi-square test results in Table 2. This means that can be as shy as the girls.

Although there were slight differences in percentages for influence of gender on selected personality traits, the findings in Table 2 reveals that the differences were not statistically significant for the personality factors of introversion and extroversion, self-concept, self-esteem and shyness. In line with findings, Rubeinstein (2005) suggests that there is no significant influence of gender on extroversion. Contrary, Kling, Hyde, Showers and Buswell (1999) point out that men are more assertive whereas women are slightly more extroverted and more anxious. This may explain the reason behind slight gender variations in the personality factor of introversion, extroversion among secondary school students. School counselors may overlook introversion and extroversion gender stereotypes when dealing with personality and career issues among secondary school students.
The findings in Table 2 disclose that self-concept was not related to gender. The statistically insignificant gender variations revealed by the frequency and percentage analysis in Table 4 were attributed to the emphasis on guidance and counseling of students on matters of self-concept in secondary schools within the country. Supporting these results, Rubeinstein (2005) who examined the role of gender in self-concept concluded that there was no correlation between gender and self-concept. This means that both boys and girls seeking therapeutic services may be treated the same with regard to self-concept issues.

Although there were no statistically significant gender differences in the personality trait of self-esteem, boys tended to exhibit slightly higher self-esteem than girls. Wingfield (2003) suggests that self-esteem of males is slightly higher than that of females through most of the lifespan. However, Buss and Bandura (2003) purport that boys and girls may or may not have different personalities depending on the circumstances encountered in relation to character, thought and habits formation. In support, Kling, Hyde, Showers and Buswell (1999) argue that male participants scored slightly higher on standardized measures of self-esteem noted in Table 5 were too slight to be worth any attention meaning that gender did not contribute to the self-esteem of an individual.

The chi-square results in Table 2 reveal that shyness tended to be independent of gender. This meant that in spite of the statistically insignificant differences in frequencies and percentages indicated in Table 6, both boys and girls in secondary schools equally felt shy. According to Buss (2002), gender is unrelated to shyness because shyness is a personal problem and nearly everyone has felt shy in a certain situation regardless of gender. In addition, Busy and Bandura (2003) suggest that shyness is relative to the environment and circumstances one encounters irrespective of gender. For example, a girl may be shy in the presence of boys but very bold when interacting with other girls. Since personality was found to be independent of gender, both boys and girls in secondary schools do not require gender specific personality and career counseling. Instead, more emphasis on aptitude and interest is needed irrespective of gender.

CONCLUSION AND RECOMMENDATIONS

Male secondary school students need not be generalized as being extroverted, having positive self-concept, displaying high self-esteem and being bold. Female students are all not introverted, do not all display a negative self-concept and low self-esteem, nor are they all shy. Any student, male or female may portray any level of introversion, self-concept, self-esteem and shyness in varying situations.

The search for a career that matches an individual’s personality among secondary school students need not be influenced by gender. Both boys and girls may pursue any line of profession as long as their personality, aptitudes and interests are appropriate.

Based on the findings of this study, school counselors need not necessarily consider gender stereotypes when dealing with personality issues of students with regard to introversion and extroversion, self-concept, self-esteem and shyness.

REFERENCES


ABSTRACT
Invasive alien species are regarded as one of the largest threats to ecosystem processes and services that are vital to human well-being as well as to biodiversity loss across the globe. Challenges of invasion are linked to extra cost of management, reduced ecosystem productivity, increased threat to health and reduced utilities from natural resources. In Kenya, a large number of invasive cacti have been introduced and have subsequently naturalized in the arid and semi-arid areas. This is due to their ability to survive well in dry periods, compete well in disturbed conditions, have low levels of parasites and have a high reproductive potential. *Opuntia* Mill (prickly pear/cactus pear) is the largest genus with a high number of invasive species that have a wide range of geographical distribution. Its invasion in Kenya is mainly attributed to changes in land use and the subsequent degradation. However, management strategies are mostly addressed at a global perspective with minimal investigation at the national level, where local livelihoods are directly affected by the invasion. This review presents the current status of *Opuntia* invasions in Kenya and their successful management. It covers: pathways of introduction and spread, species distribution, utilization, invaded areas, the effectiveness of control measures and the effectiveness of regulations. It is intended to inform development interventions to reduce the negative impacts of invasions on ecosystems, biodiversity, economy and rural livelihoods while preserving potential benefits.

**Keywords:** Cactus, Biodiversity, Biological invasions, Invasive alien species, Rural livelihoods
The Convention on Biological Diversity (CBD) defines a pathway as being any human mediated means that allows the entry or spread of an alien species within a region or beyond (CBD, 2014). Invasive species can be introduced intentionally usually for some benefits (e.g. use in biological production systems, landscaping and ornamental purposes) or unintentionally through transport, trade, travel or tourism (Hulme et al. 2008; Claire, 2000). Identifying these pathways provide information to reduce the rates of unintentional introductions and for developing interventions for monitoring and management (Hulme, 2009). However, the status of the pathways of introduction of Opuntia species in Kenya has not been assessed. Assessing this information will not only inform the development policies and management strategies but will be important when evaluating the effectiveness of pathway related control measures. Hulme et al., (2008) recognized three main pathways of invasion; (i) importation of a commodity, (ii) arrival of a transport vector and (iii) spread from a neighbouring region. This was further developed by the CBD, which requires countries to identify, prioritize and manage their pathways of introduction through six main categories: release in nature, escape from confinement, transport – contaminant, transport – stowaway, and spread through a corridor or unaided (CBD, 2014).

In Kenya, more than 80% of the country is arid and semi-arid lands (ASALs) - the rangelands where constraining environmental conditions provide limited options for sustainable land use other than livestock rearing. They contribute significantly to livestock production and wildlife conservation. However, a large number of cactus species have been introduced and their subsequent establishment and spread have had devastating effects on people and livelihoods (Strum et al., 2015). The early reason for introduction was for use as a hedge. One of the genus, Opuntia Mill (Prickly pear), native to America, is among the most widely introduced, cultivated and invasive species in the genus. It has however become invasive around the world including Australia, Europe and many African countries (Novoa et al., 2015). The species is a perennial, spiny shrub that produces large number of seeds which are dispersed by myriads of animals over long distances (Foxcroft et al., 2011). Besides sexual reproduction, the species form dense thickets through vegetative reproduction that hinder the growth of potential competitors (Foxcroft et al., 2011). In addition, the species undergoes phenotypic plasticity and genetic differentiation that enable it to adapt to different environments (Novoa et al., 2015). Such trait facilitates its spreading and colonization in new areas.

The current distribution of Opuntia in Kenya is fundamentally being changed by human activities and little attempt has been made to assess the status of each species in terms of invasion. Additionally, few studies have been done on the general status of invasive species in East Africa (e.g. Obiri, 2011; Gichua et al., 2013) but with little evaluation of the taxa according to genera and the potential risks they have on the local ecosystem and livelihoods. As a result, a broad national assessment of the pathways of invasion for each species is vital for formulation of appropriate control strategies. This may uncover new patterns, processes and risks that can be used to improve the existing management strategies (Novoa et al., 2015). So far six species of Opuntia have been identified namely; O. stricta, O. monacantha, O. ficus-indica, O. engelmannii, O. microdasys and O. elatior. They are the among the most widespread and abundant invasive plant species in the arid and semi-arid regions of Kenya. This paper therefore explores their national status of invasions and in particular, (i) to compile a list of Opuntia species present in Kenya and determine the current invaded areas, (ii) to identify the pathways of introduction and risks, (iii) benefits and traits related with invasiveness and (iv) effectiveness of
regulations, and (v) effectiveness of control measures. The information is intended to inform development interventions to reduce the negative impacts of invasions on ecosystems, biodiversity, economy and the rural livelihoods.

**RESEARCH METHODOLOGY**

**Description of cactus**

Cactus (plural: cacti) belongs to family Cactaceae. They are a group of trees or shrubs of different shapes, sizes and growth forms and often with clusters of spines that arise from modified axillary buds called areoles (Novoa et al., 2014). The stems (pads) are of varied lengths and widths and generally flattened (Pinkava, 2003). This variation in growth form is a trait that is strongly associated with invasiveness and is brought about by the ability to reproduce sexually and asexually (Anderson, 2011). About 1600 species are recognized worldwide. Most have become invasive due to their ability to survive well in dry periods, compete well in disturbed conditions, have low levels of parasites and have a high reproductive potential both sexually and asexually (Zimmermann et al., 2009). Among them is *Opuntia* Mill., that mainly grows in the arid and semiarid zones (Fig. 1). It is the largest genus of Cactaceae with more than 360 species with a range of geographic distribution (Segura et al., 2006). However, description of these species is generally difficult because of variation in phenotypes and the existence of numerous hybrids (Ochoa, 2003). The genus includes a group of species with edible fruits hence commonly known as prickly pear/cactus pear. *Opuntia* species have specialized photosynthetic system known as Crussulacean Acid Metabolism (CAM) with the ability to withstand prolonged drought and high temperatures and are consequently well adapted to arid conditions (Grünwaldt et al., 2015). The flowers range in colour depending on the species, generally bright yellow and bloom once a year (Turner et al. 1995). Filaments are sensitive to contact and bend towards the direction of contact (Grant et al., 1979). Flowers open on a single day or two days consecutively lasting for about 8 hours hence well suited to reducing the risk of poor or no pollination (Bowers, 2004). They are pollinated effectively by bees and beetles (Linsley and MacSwain, 1957; Grant et al., 1979). The fruits are red to reddish purple; vary from pear shaped to almost spherical, with numerous seeds imbedded in the pulp (Parsons and Cuthbertson 2001). In addition, they have a relatively shallow and horizontally spreading root system that utilizes water efficiently (Snyman, 2007). The species produce abundant seeds that are spread by means of mutualistic interactions with both native and alien dispersers including baboons, birds and large mammals (Padró’n et al., 2011). Germination occurs during the rainy season, although seeds can persist in the soil for at least 19 months and probably much longer (Bowers, 2004). Plants reach reproductive maturity at about nine years of age and can live longer than 30 years (Bowers, 1996). The plant also reproduces vegetatively when detached cladodes become rooted in the ground.

![Fig. 1 The habit and fruits of *Opuntia*](image-url)
Species type and distribution
Classification of Opuntia species was based on the classification system by Pinkava (2003) and the Flora of North America (2003). Scientific information and data were gathered from several predetermined resources, including scientific publications, relevant books, online databases, grey literature and expert opinion. Information was also gathered from relevant stakeholders and industry database (e.g. the Global Invasive Species Database, National Museums of Kenya, Centre for Agricultural Biosciences International (CABI), Kenya Wildlife Service, Kenya Forestry Service and the Ministry of Environment and Natural resources). Field guides by Witt (2017) and Henderson (2001) were used to clarify species descriptions and distribution.

Pathways and risk analysis
Key priority pathways were identified according to Hulme et al., (2008) and Convention on Biological Diversity [CBD] (2014). Prioritization of pathways involved ranking them based on their impacts according to the Environmental Impact Classification for Alien Taxa (EICAT) (IUCN, 2017); Blackburn et al., 2014). They were also categorized according to their ecological and their socio-economic impacts as follows: Minimal Concern (MC) - discernible impacts but no effects on individual fitness of native species; Minor (MN) fitness of individuals reduced but no impact on populations; Moderate (MO) - changes to populations but not to community composition; Major (MR) - community changes that are reversible; and Massive (MV) irreversible community changes and extinctions.

Species use
Information on human uses of cacti was extracted from many sources and were classified into the following categories: (i) hedging, (ii) food or fodder, (iii) ornamental, (iv) medicinal, and (v) other uses (e.g. cultural). The proportion of the differences in uses was compared using percentages.

RESULTS AND DISCUSSION
Species type and distribution
Six species of Opuntia are currently recognized in Kenya. These are Opuntia stricta (Australian pest pear), O. monacantha (Drooping prickly pear), O. engelmannii (Cows tongue cactus), O. elatior (Prickly pear), O. ficus-indica (Sweet prickly pear) and Opuntia microdasys (Teddy-bear cactus). They have different origins with the same reasons for introduction as an edible fruit, hedge and ornamental (Table 1). They also share the same traits and are declared as weed in other parts of the world (Walter et al., 2011). They were introduced in the ASALs during the colonial times in the early 1950s but have nevertheless naturalized and in most cases occur in association with each other (Witt, 2017). Areas most invaded are the road sides, disturbed areas, savannah, rocky outcrops and forest edges. Opuntia stricta is among the most widespread in Kenya and also present in the neighbouring countries including Ethiopia, Tanzania and Uganda (Shackelton et al., 2017). The species is among the top 100 of the world’s worst invasive alien species (Lowe et al., 2000). Two varieties are recognized: O. stricta var stricta (Haworth) and O. stricta var dillenii. Opuntia stricta var. stricta is the most widespread and abundant in Laikipia County and Tsavo East National Park with an origin in Dol Dol town in Laikipia County (Shackelton et al., 2017). In Ethiopia, the variety is widespread and abundant in the eastern part where it is associated with O. ficus-indica (Shackelton et al., 2017). The species is also present along the Kenyan coastline with a few infestations near Lake Baringo, growing in association
with *O. elatior* Mill. The species has little benefits and the most problematic in terms of impeding mobility, reducing fodder availability and impacting negatively to human and livestock health (Shackleton *et al.*, 2017).

### Table 1: *Opuntia* species with their origins, reasons for introduction and the areas invaded

<table>
<thead>
<tr>
<th>Species</th>
<th>Origin</th>
<th>Reason for introduction</th>
<th>Invaded areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Opuntia elatior</em></td>
<td>Costa Rica, Panama, Venezuela, Columbia and other Caribbean</td>
<td>Edible fruit, hedge, ornamental</td>
<td>Roadsides, savannah, disturbed areas, rocky outcrops, lowlands and gullies</td>
</tr>
<tr>
<td>2. <em>O. engelmannii</em></td>
<td>Southern and central USA, Mexico</td>
<td>Edible fruit, hedge, ornamental</td>
<td>Roadsides, savannah, disturbed areas, rocky outcrops especially semi-arid regions</td>
</tr>
<tr>
<td>3. <em>O. ficus-indica</em></td>
<td>Mexico</td>
<td>Edible fruit, fodder, hedge, ornamental</td>
<td>Roadsides, savannah, disturbed areas, Arid and semi-arid regions</td>
</tr>
<tr>
<td>4. <em>O. microdasys</em></td>
<td>Northern Mexico</td>
<td>Hedge, ornamental</td>
<td>Disturbed areas</td>
</tr>
<tr>
<td>5. <em>O. monacantha</em></td>
<td>Argentina, Brazil, Paraguay, Uruguay</td>
<td>Edible fruit, fodder, hedge, ornamental</td>
<td>Roadsides, disturbed areas, forest edges, gaps, woodlands and savannah</td>
</tr>
<tr>
<td>6. <em>O. stricta</em></td>
<td>Southern and Eastern USA, Mexico, Caribbean</td>
<td>Hedge, ornamental</td>
<td>Widely invasive from woodlands, wetlands, roadsides, grasslands</td>
</tr>
</tbody>
</table>

*Opuntia ficus-indica* is another serious invasive species that has been blamed for destroying grazing land in the Kenyan and Tanzanian drylands (Obiri, 2011). It is also among the most diverse species in the drylands. *Opuntia engelmannii* has been introduced in Africa and is reported to become naturalized and invasive in South Africa and Kenya (Pasiecznik, 2015). In South Africa, the species is prohibited and must be controlled in all situations (Nel *et al.*, 2004) while in Kenya it has not yet been declared a weed but has invaded the northern rangelands of Laikipia County (Pasiecznik, 2015). It starts as a minor weed in localized areas but later explodes in abundance causing invasions in wider areas (Walter *et al.*, 2011). In addition, the species is fast-growing and forms impenetrable spiny thickets over a wide area overwhelming native vegetation and preventing free movement of people, animals and wildlife (Pasiecznik, 2015). *Opuntia monacantha* has a widespread distribution in Kenya but not particularly common. It is scattered in Laikipia, Baringo, along the coast and Narok. It is also naturalized in other parts of the world, including Australia, South Africa and south-eastern USA. The species is reported as a problem by spreading rapidly especially on degraded rangelands, disturbed areas and agricultural land (Pasiecznik, 2013). The species is listed in the IUCN Red List in the category of least concern (IUCN, 2013).

**Reasons for introduction**
The main reason for introduction of *Opuntia* in Kenya is the use as a hedge and for ornamental purposes. In contrast, only *O. ficus-indica* is used as fodder during the dry season while *O.
*stricta* is used to heal wounds. The use for ornamental purposes is part of the horticultural trade worldwide. This is an important driver of introductions with several attributes associated with attractiveness such as brightly coloured fleshy fruits that attract a wide range of dispersers (Richardson and Rejmanek, 2011). However, this trade continues and should therefore be regulated and monitored to prevent further spread and future invasions.

**Pathways and risk analysis**

In this study, two major pathways of introduction of *Opuntia* into new areas are identified: (i) intentional introduction as a commodity but escapes unintentionally, and (ii) unintentional introduction through natural dispersal. The escape is from garden especially through garden throw-outs (Hodkinson and Thompson, 1994) while in dispersal it is through vegetative reproduction (Zimmermann et al., 2009), floods (Parendes and Jones, 2000) and rapid dispersal of seeds by various vectors (Foxcroft et al., 2011). Another potential pathway is through transportation of habitat material such as soil from the infested areas to new areas. A study by Witt et al. (2017) in the Serengeti-Mara ecosystem of East Africa revealed that more than 80% of alien plants were intentionally introduced with 24% having established naturalized populations within the boundaries and spreading rapidly in areas far away from human settlement, hence posing a major threat to biodiversity and tourism. *Opuntia stricta* was among the six species that posed the highest risks. Many invasion opportunities also occur or follow disturbances, which are largely caused by human activities and subsequently open opportunities for invasive trees and shrubs to exploit (Davis et al., 2000). Based on the impact category, four of the species; *Opuntia stricta*, *O. ficus-indica*, *O. engelmannii* and *O. monacantha* were regarded of major concern where plant community changes although reversible, while *O. elatior* and *O. macrodastys* were regarded of moderate concern where there are changes to populations but not to community composition. However, if no actions are made in controlling these species, they might cause massive irreversible community changes and extinctions.

**Regulations to prevent introduction of invasive plant species in Kenya**

In Kenya, there are several laws governing the management of invasive species which are largely implemented through the National Environmental Management Authority (NEMA). Despite these laws and institutions, the invasion of plant species continues to be a threat and key contributor to environmental degradation in the ASALs as a result of movement of plant materials (Obiri, 2011). Nevertheless, this can be prevented by constricting pathways, intercepting movements at borders and assessing risk for intentional imports (Simberloff 2009). Unintentional introduction of any invasive plant into Kenya is prevented by subjecting any plant material for importation to strict specified conditions as regulated by the Kenya Plant Health Inspectorate Service (KEPHIS). Quarantine restrictions are based on pest risk analysis and existing scientific knowledge on the distribution, biology and pests of the plant (Kedera and Kuria, 2003). Facilitation of the import and export of plant materials is done through the issuance of import permits and phytosanitary certificates. Any infested or infected plants or plant products are subjected to treatment or destruction. Inspections are carried out at the entry points (sea ports, international airport and borders). The border control points are located where there is a risk of entry and most are in the southern (Namanga, Taveta, Lungalunga and Mombasa) and western (Malaba, Busia and Eldoret) borders of Kenya because there is considerable trade and movement of plant materials between Kenya and Uganda and Tanzania (Kedera and Kuria, 2003). For Intentional introduction of alien species in Kenya, the regulations are under authority of the
Kenya Standing Technical Committee on Imports and Exports (KSTCIE), which is a body that approves importation of restricted and new materials into the country. KEPHIS is the secretariat to the committee and facilitates the process of risk assessment before introduction of live organisms. These include live biological controls, bio-fertilizers, bio-stimulants, organic fertilizers, their products and other regulated articles. The committee operates under the Plant Protection Act (Cap 324) of the laws of Kenya. First, a risk assessment is carried out as part of the authorization process and once it is complete, the products approved for introduction are referred to relevant research institutions for efficacy or registration. Authorization of an introduction is accompanied by conditions such as containment requirements, monitoring procedures, preparation of mitigation plans. Monitoring to detect new invasive species involve several institutions such as the Kenya Agricultural and Livestock Research Institute (KALRO), the International Centre of Insect Physiology and Ecology (ICIPE) and KEPHIS.

Effective control measures
The most applied methods of managing *Opuntia* are a combination of chopping, burying and burning. Mechanical and manual methods are preferred in managing invasion of woody species because they are target specific and economical (Rai *et al.*, 2012). However, they can be labour-intensive in large-scale infestations and the disturbed areas may encourage reinvasion (DiTomaso, 2000). Herbicides on the other hand improve the effectiveness of chopping. However, use of herbicides alone is very ineffective. Mixing different herbicides to increase efficacy is also applied but is also not successful since the plant regenerates after some time. This is a major draw-back in the use of herbicides where populations are replenished from soil-stored seeds (Foxcroft *et al.*, 2001). Besides, herbicides are very expensive, do not provide long-term effects and can lead to replacement of sensitive species as well as resistance after continuous use (DiTomaso, 2000). However, use of bio-control is regarded as cost-effective with two effective natural enemies of *Opuntia; Cactoblastis cactorum* Berg, and *Dactylopius opuntiae* Costa (Zimmermann and Moran, 1991). The latter was introduced in a pilot project in Laikipia, Kenya and has shown that bio-control is possible for this species (Dyck, 2017). However, bio-control species may become invasive and negatively impact non-targeted species (McLeod, 2004). Besides, removal of invasive plant species by any of the above mentioned methods may open niches for other invasion unless followed by rehabilitation (Masters and Sheley, 2001; Strum *et al.*, 2015). Nonetheless, instead of relying on a single control method, successful management of invasive alien species requires an integrated approach that uses multiple control methods to prevent reinvansion and improve ecosystems.

CONCLUSION
Six species of *Opuntia* have been identified and are among the most invasive species in Kenya and the world at large. Their main use as ornamentals and hedge has created pathways for introduction and therefore, many invasion events are expected in the future. There is therefore need to regulate this use with greater efforts to screen pathways that bring unintended introductions.

REFERENCES


ASSESSING LAND DEGRADATION ALONG MUTONGA RIVER CANYON FROM SATELLITE IMAGES USING SOIL ADJUSTED VEGETATION INDEX

Kibetu Dickson Kinoti, Department of Arts and Humanities, Chuka University, P. O. Box 109-60400, Chuka

ABSTRACT
Mutonga River canyon forms an important social economic strip spanning about 8km East and West along upper Mutonga River Bridge. The 8km strip is an area of dense human activities comprising of quarry stone mining and settlements. The canyon contains extensive stone mining sites as well as a permanent river serving the communities of Meru County in the upstream and Tharaka-Nithi County in the downstream respectively. Uncontrolled quarrying along the canyon’s river bank has resulted to geomorphic failures in the recent past leading to fatal landslides in 2002 and 2010. To assess the extent and effects of these mining activities on the canyon’s slope stability, satellite images of years 2010 and 2016 were comparatively used. The severity of degradation was then assessed using Soil Adjusted Vegetation Index (SAVI). Calculated vegetation cover threshold values across the two epochs were taken as indicators of degradation. The study revealed that the strip along Mutonga river Canyon has undergone massive de vegetation and slope destabilization. Soil creep from the quarry sites has also resettled into the water course way reducing the river depth, benthic life and degrading river water quality.

Keywords: SAVI, Satellite Image, Canyon, Degradation, Quarry

INTRODUCTION
Land degradation is an increasing global environmental challenge especially in developing countries. Due to reliance on environment goods for livelihood, land degradation is common in high potential as well as arid and semi-arid lands of Kenya. In this study land degradation is the removal of vegetation or any cover on the earth’s surface. Bare land is one of the most important and typical land covers all over the world (Hui et al, 2017). Quarry and related activities have been singled as human endeavours irreversibly impacting on the canyon’s slope instability, water quality and riverine vegetation loss. Quarrying activities have expanded in the last five years along Mutonga river canyon. This stretch is an important limestone quarry site with over 60 percent of supplied quarry building stones within Meru and Tharaka-Nithi counties sourced from this belt. Increased stone mining has been witnessed in this area with the entry of local and international stone machine quarry companies. Notably, the introduction of stone dressing machines has brought competition to the traditional quarries. Dense concentration of stone quarrying related activities has encroached on the escarpments, riverine vegetation and natural lands along the stretch. Conversion of natural land into loose surface may have negative impacts on riverine ecosystem and related hydrological characteristics. Reported impacts of geomorphic failure have in the recent past resulted to fatal landslides claiming the life of quarry workers. Land degradation is now common along this stretch due to excavation and dumping of quarry wastes. Although few studies on environmental related impacts have been done, none has incorporated remote sensing images or approaches to explore the spatial and temporal impacts of the expanding quarry activities. The study sought to bridge this conceptual gap by assessing the spatial and temporal dynamics of quarrying related land degradation impacts on the canyon’s slope retreat and water course way morphology.

To achieve this goal Soil Adjusted Vegetation Index (SAVI) was used to highlight vegetation features and their spatial distribution within the area of interest. Vegetation cover was taken as a proxy to land degradation since quarry sites are often cleared of plant cover for excavation. This exposes the underlying surface to human activities. Although SAVI is one of the many
vegetation indices applied to get vegetation information from satellite imagery, its advantage over the Normalised Difference Vegetation Index (NDVI) is that it works well when used in areas with low plant cover (Jensen, 2000; Ray 2006). It is for this reason it was chosen since quarry sites often have little plant cover to that found in many urban areas.

The objective of this study was to assess the extent and effect of quarry activities on canyon’s slope stability and hydrological characteristics of river Mutonga. The likely conditional effects on the surrounding of any natural land may include increased surface run-off, pollution and reduced water quality (Melesse et al, 2007). To assess the spatial and temporal aspects of land degradation, remote sensing based SAVI index calculated through rationing of the near infrared and red bands of multi-dated land sat images were used. The results were then validated through field ground truth sampling of the selected quarry sites.

MATERIALS AND METHODS

Data sets

Landsat image data dated 11\textsuperscript{th} July 2009 and 2\textsuperscript{nd} February 2015 respectively were used. 30M resolution TM sensor image bands of spectral ranges (0.63–0.69\textmu m) and (0.78–0.90\textmu m) corresponding to red and near infrared bands were used in calculating Soil Adjusted Vegetation Index.

Soil Adjusted Vegetation Index (SAVI)

SAVI is an enhanced remote sensing index which applies wavelengths of 0.65 \textmu m and 0.83 \textmu m (R and NIR bands). It can better map areas with low plant cover preferentially those with less than 15 percent vegetation cover. This is because Soil Adjusted Vegetation Index (SAVI) is sensitive in detecting vegetation in the low plant-covered areas compared to the Normalised Difference Vegetation Index due to fact that it largely uses the increased data dynamic ranges making discrimination of vegetation easier. In this case SAVI was calculated using equation proposed by Huete, 1988 as;

\[
SAVI = \frac{(NIR-Red) \times (1+L)}{(NIR+Red+L)}
\]

In this equation, L is a correction factor whose value range 0 to 1; where 0 is used for areas with very high vegetation densities and 1 for those with very low vegetation densities respectively.

Normalised Difference Built-Up Index (NDBI)

Settlement was identified as one of the other key land use and human activity along the Mutonga canyon stretch. The slope tops are covered with built up areas linearly aligned along roads leading to the quarries. The NDBI index used was based on the equation proposed by Zha \textit{et al}, (2003);

\[
NDBI = \frac{MIR-NIR}{MIR+NIR}
\]

The normalised difference built up index uses Near Infra Red band of range 0.76-0.90\textmu m and the Mid Infra Red band of 2.08-2.35 \textmu m spectral wavelengths. The two spectral wavelength range are used because built up areas reflect more in the two bands than others.

2.4 Assessing dynamics of Degradation based on SAVI and NDBI indices

To quantify the spatial extent of exposed bare land, the study applied SAVI and normalised difference built-up index (NDBI) results comparatively. The study area’s changes introduced by the increased human activities can best be analysed using specialised indices.
2.5 Accuracy Assessment
To assess the accuracy of the resultant products, difference between index based and supervised classification results were verified using the area ratio and match rate formulas. The formula has applied by Hui et al, 2017 in the accuracy assessment of their index based map products for Wuhan city, China were modified for this study. The original formulas modified to include the area ratio and match rates for SAVI and NDBI images as used by Hui et al is as shown below:

\[ Ra = \frac{Ba}{Br} \]

\[ Rm = \frac{(Ba \cdot Br)}{Br} \text{ or } Rm = \frac{(Ba \cdot Br)}{Ba} \]

Where \( Ba \) indicates the bare land in the automatic mapping result, while \( Br \) represents the bare land in the supervised classification result.

FINDINGS AND DISCUSSION

3.1 Geomorphic slope stability Dynamics
The stretch has witnessed extensive excavation especially on the western arm where more quarrying activities have been observed. The SAVI based images from the two time series showed a substantial decrease in plant cover across the time considered. This was associated with increased on set of quarry site between 2009 and 2017. The western arm compared of the canyon had intense quarry activities compared to the eastern edge. Encroachment towards the mainland by the miners has seen the slope of the quarry escarpment retreat and drop sharply towards the canyon floor. The major cause of slope failure was disturbance introduced by quarrying activities, haulage trucks and related human activities. Manual quarry sites exhibited massive slope retreats with steep sided concave escarpments observed compared to the mechanized quarries. Notable was the effects of human settlement and farming on the slope top with also catalyzed vegetation loss and exposed soil cover.
Spatial-temporal Hydrological Characteristics of Mutonga River

To assess characteristics of Mutonga river water spatially through the time frame considered, modified normalised digital water index was used. The index mapped open water appearance across the ten year revealing variations in water quality. The river’s water characteristics considered in this study were clarity (turbidity) and depth of the water course across the 8 km stretch. The indexed image showed how the quality of water had deteriorated due to soil creep from the overhanging quarry cliffs and sediment loadings from the quarry banks. The depth of the water course was decreasing with time and the banks narrowing from encroached sediment loads. This was attributed to human activities associated with quarry related activities.

CONCLUSION
The observed land degradation along the canyon has been accelerated by human activities associated with quarrying activities. The remote sense image based spatial-temporal analysis of soil and vegetation cover loss shown the degradation varied considerably across the stretch. That land rehabilitation and control of quarrying activities is essential to address the raising concerns of micro-environmental degradation along the stretch.

REFERENCES
ABSTRACT
Loss of vegetation land-cover has directly been linked to global warming, loss of biodiversity and environmental sinks besides declining environmental productivity. The incumbent study focused on assessing the key drivers of deforestation and its implications on rural households’ wellbeing in Kenya. The study was carried out in Mua hills of Machakos County. The study envisioned that by identifying the key drivers of deforestation, and its subsequent implications, context-specific measures would be developed to reduce further deforestation and promote long-term sustainable environmental productivity. The study research design employed a case study on both the quantitative and qualitative data. The sample of the study was the population of Mua hills and the respondents were farmers, the forester in charge of Mua Hills, the county government and a surveyor. The research helped identify the agents of deforestation, activities taken by the dwellers and the strategies employed by Kenya Forest Service to help the communities improve their livelihoods. The findings were that agriculture which is at 55% is the main agent causing deforestation and the other agents of deforestation were human settlement and charcoal burning. The conclusion of the research was that deforestation has both negativity; climate change and water pollution and positivity; employment to the societies. I recommend that Sensitization on farmer education. Farmers should be well educated on policies governing the forest area, the use of sustainable forest management and the best livelihood based approaches

Keywords: land degradation, dryland-forestry, deforestation, rural household livelihoods.

INTRODUCTION
Forests are important for protecting ecological diversity, regulating climate patterns and acting as carbon sinks. They are the basis of water catchment areas in the world. Deforestation can be defined as the permanent removal of tree so that land can be converted to non-forest use (Chakravarty, Ghosh, Suresh, Dey, & Shukla, 2012). Deforestation has adverse impacts on bio-sequestration of atmospheric greenhouse gases bringing about global warming. Deforestation is generally caused by overpopulation, inequitable distribution of wealth and power, and also urbanisation. Impacts of deforestation include environmental, economic and also social factors. Deforestation has a crucial role in both mitigating against and adapting to climate change. The strategies that are employed by the local communities should help in sustainable forest management. The worlds’ tropical forests have been reducing at a high rate annually. It is noted that deforestation can cause loss of livelihoods through the loss of assets. Kenyan forests are rapidly declining due to pressure from increased population and other land uses. Deforestation has so many social effects on our society. Its’ impacts not only affects us humans but also plants, animals and the surrounding to adapt in order to survive such situations. When forests are depleted, indigenous people who consider forests as their primary habitats are rendered homeless. The people living in these forests are forced to move while their surroundings are being altered. Social conflicts and struggles over land are usually as a result of the lost land by the people through deforestation. Mua Hills is a rich site with water catchment areas, favourable climate for cash crops and can sustain livelihoods. People should be educated more on the issues dealing with deforestation in order to understand and lean towards favourable land practises. With this background, the study sought to show the drivers of deforestation and its implications on the livelihoods of the rural households in the study area. According to (Tidan, 2013) the main factors causing deforestation have their roots in different sectors and as a result, the effects produced are also varied across global, national and local boundaries. The increased population growth and densities and urbanisation are key factors that are exerting immeasurable pressure on forest resources in major towns and cities in developing countries. This study evaluated the evident causes and consequences of
deforestation on the rural level in Kenya. The study further appraised the benefits and the effects of deforestation and strategies deployed for sustainable forest management.

MATERIALS AND METHODS
The Study Area
The study was carried out in the Famous Mua Hills environs. Mua hills is found in Machakos County in Kenya. Mua hills has an area of 182.20 km\(^2\) which is made up of several hills hence the name. The area has a population of 25,573 people and approximately 6157 households. It has a rainfall range of 500 – 1000 mm annually and an average temperature range of 15 - 25.5°C. Soils in the area consist of different types: Black cotton soil, a mixture of black cotton and red soils, sandy soil and purely red soil. The area has both exotic and indigenous tree species. Mua area is under a rapid vegetation cover loss due to human settlement. The hills act as a major catchment area supplying the Maruba dam and due to deforestation in these hills, a lot of silt is being deposited in the dam.

Methods
This research aimed at assessing the relationship between deforestation and livelihoods patterns. A case study approach was adopted during the study because of its suitability. The tools of data collection include image representation, structured interviewing, self-administered questionnaires and observation. Data from this study was obtained from both primary and secondary sources. The data acquired was both qualitative and quantitative. The primary data was gathered directly from the field from satellite imagery and stakeholders like farmers and the local communities. This type of data was collected using a combination of interview guides and structured questionnaire. The secondary data which is also an important aspect was sourced from books and publications of various scholars related to deforestation and rural livelihoods.

Interviews were used for the key informants. They were mostly used to identify the sources of livelihoods on forest communities in Mua Hills and used to examine the extent in which deforestation has affected the livelihood patterns in the study area. Questionnaires were also used for the individual views of heads of households regarding the research questions. They were conducted under the supervision due to the inability of effective reading or writing by some people. This was used to identify the agents and activities causing deforestation in Mua hills. According to (Mohammed, 2014), a sample is a representative measure of a population examined so as to gain statistical information of the whole hence denoting the process of getting the research unit of the target population. A simplified formula is provided by (Yamane & Taro, 1967) to calculate sample sizes.

\[ N = \frac{N}{1+N(e)^2} \]

\( n \) is the Sample size

\( N \) is the population size and

\( e \) is the level of precision (95% confidence level)

The sample size to be interviewed was:

\[ n= \frac{25573}{1+25573(0.5)^2} \]

\( n= 394 \) respondents.

Thus 12-13 respondents were sampled within 30 clusters

RESULTS AND DISCUSSION
Activities by the dwellers
- Cash crop and subsistence farming. Agriculture is the main income generating activities in the hills. They plant maize, beans, coffee- in the colder areas of the hills. Some farmers do this for small scale and large scale businesses.
- Charcoal burning. This is seen to be done by most of the youth in the area for faster income.
Strategies adopted by KFS Machakos to help the communities around Mua hills
- IVEMWA project was established and has been running for two years. The main aim of this project was to establish tree nurseries to serve Mua and Iveti hills.
- The Kenya Forest Service staff have an extension staff which holds Barazas, Administration meetings with the chief and the communities to help encourage then on proper Agricultural practices.
- Kenya Forest Service has been planning to establish a Community Forest Association to encourage the communities around the hills to plant trees best suited for charcoal burning production with short rotation ages. This is to try and eradicate the cutting of the important species in the hill.

Agents of Deforestation in Mua Hills
- Charcoal burning
- Human settlement
- Agriculture

Extent of Deforestation
It was evident that there is a lot of forest cover loss in Kenya and worldwide, more so the communities around Mua Hills were of no exemption. As (K. & Asathana, 2012) says, confirms there is a lot of forest cover change in the tropics. Many respondents confirmed that Agriculture and human settlement are the key causes of deforestation in Mua Hills.

Occupation and Income
It was necessary to identify major practises undertaken by the dwellers for income generation. Majority of the dwellers fall broadly rely on Agriculture and casual employment as main source of income. It is noted that 55% practice Agriculture, 30% are under casual employment and the rest 15% do wood and charcoal selling. Many of the young able men are employed in the saw mills around the area and a few sell charcoal.

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farming</td>
<td>11</td>
<td>55.0</td>
</tr>
<tr>
<td>Sale of wood or charcoal</td>
<td>3</td>
<td>15.0</td>
</tr>
<tr>
<td>Casual employment</td>
<td>6</td>
<td>30.0</td>
</tr>
</tbody>
</table>

Education level of respondents
It can be noted that most respondents have acquired up the secondary level of education and can read and write English. This concurs with the age of the respondents in that, the majority who practice agriculture fall under 30 to over 50. The rest are majorly in sells of wood and charcoal.

<table>
<thead>
<tr>
<th>Education level of respondent</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>6</td>
<td>30.0</td>
</tr>
<tr>
<td>Secondary</td>
<td>9</td>
<td>45.0</td>
</tr>
<tr>
<td>Technical</td>
<td>3</td>
<td>15.0</td>
</tr>
<tr>
<td>College/ University</td>
<td>2</td>
<td>10.0</td>
</tr>
</tbody>
</table>
Relationship with the household head
This was used to identify the marital status of the respondents. It was seen that majority of the respondents which is 60% was either widows, widowers or married and 20% are married and the later 20% were children who are single. This was considered to determine the extent of household income and the number of dependents. Majority of the families had up to 4 dependants. The single have a lesser number of dependants compared to the married or widows.

<table>
<thead>
<tr>
<th>Relationship to the household head</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self</td>
<td>12</td>
<td>60.0</td>
</tr>
<tr>
<td>Spouse</td>
<td>4</td>
<td>20.0</td>
</tr>
<tr>
<td>Child</td>
<td>4</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Age
Majority of the respondents were between 30 and 50 years and it is also evident that they are the main group practicing Agriculture.

<table>
<thead>
<tr>
<th>Age of respondent</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-30</td>
<td>5</td>
<td>25.0</td>
</tr>
<tr>
<td>30-40</td>
<td>6</td>
<td>30.0</td>
</tr>
<tr>
<td>40-50</td>
<td>3</td>
<td>15.0</td>
</tr>
<tr>
<td>&gt;50</td>
<td>6</td>
<td>30.0</td>
</tr>
</tbody>
</table>

Permits and Resources obtained from the Hill
It was evident that the respondents obtain a lot of resources from the hill, the main product being timber and poles at 35%. It was also noted that a few of these products required a permit to be harvested since 75% of the respondents said that they got no permit for the resources harvesting.

<table>
<thead>
<tr>
<th>What goods require a permit</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicinal herbs</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>Grazing</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>Bee keeping</td>
<td>1</td>
<td>5.0</td>
</tr>
<tr>
<td>Timber/ Poles</td>
<td>2</td>
<td>10.0</td>
</tr>
<tr>
<td>N/A</td>
<td>15</td>
<td>75.0</td>
</tr>
</tbody>
</table>

Objective 1: Main activities causing deforestation in Mua Hills

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farming</td>
<td>55</td>
</tr>
<tr>
<td>Sale of wood/ Charcoal burning</td>
<td>15</td>
</tr>
<tr>
<td>Casual employment</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Agriculture is the main activity that is practiced by the dwellers. Due to the household dependency, majority of the people in Mua tend to depend mostly in Agriculture because crops take a shorter time to mature and it is a faster way to generate income.

**Objective 2: Agents of deforestation in Mua Hills**
- Charcoal burning. Logging of trees and producing charcoal is the main activity that is practised by the youth in the area.
- Human settlement. Many people are buying land and cutting down the trees for the purposes of creating homes and businesses.
- Agriculture. Farming is the key driver of deforestation. The clearing of forested land for agricultural purposes is caused by the dependency in the households. This drives the people to clear more land so as to sustain their families.

**Objective 3: The effects of deforestation in Mua Hills**
- Water pollution. The water in Maruba dam has been pollutes by the silt deposited in the dam during heavy rains.
- Soil erosion. Since there is less vegetation in most parts of Mua hills, a lot of soil has been eroded over time and has been deposited in the seasonal rivers and Maruba dam.
- Climate change.

**Objective 4: best strategies deployed to and by the local communities for sustainable forest management**
- IVEMWA project was established and has been running for two years. The main aim of this project was to establish tree nurseries to serve Mua and Iveti hills. This project empowers the women of the community to practice sustainable forest management.
- The Kenya Forest Service staff have an extension staff which holds Barazas, Administration meetings with the chief and the communities to help encourage them on proper Agricultural practices.
- Kenya Forest Service has been planning to establish a Community Forest Association to encourage the communities around the hills to plant trees best suited for charcoal burning production with short rotation ages. This is to try and eradicate the cutting of the important species in the hill.

**ACKNOWLEDGEMENT**
Special thanks to the Almighty for His guidance through this work. I am highly indebted to my supervisors Mrs. Anne Wekesa and Mr Oscar Kisaka for their insightful comments and putting clarity to this work. I also appreciate Mr. Simon and Mrs. Esther Mwanthi from KFS Machakos for helping me with my data collection and those who provided me the possibility to come up with this research.

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RICHNESS AND ABUNDANCE OF BUTTERFLIES IN KIANG’ONDU FOREST AND THE LOCAL COMMUNITY ATTITUDES TOWARDS BUTTERFLIES

Mutuka, Moses Kitili and Njeru, Justin Mugendi
Department of Environmental Studies, Chuka University P. O. Box 109, Chuka
Correspondence: mosesmutuku7@gmail.com 0724 614 655; jusmugendi@gmail.com 0724 412 930

ABSTRACT
Butterflies are among the most popular insects that are extensively studied to determine both the status of their populations and as an indicator of ecosystem health. In this study, an assessment of species richness, diversity, abundance and distribution of butterfly species Kiang’ondu Forest and surrounding farmlands was conducted between May and June, 2017. Restricted search; transect, open searches, and opportunistic sighting methods were used to obtain data. A social-ecological survey to determine local community’s knowledge about butterfly conservation in the area was carried out using self-administered questionnaires. A total of 49 butterfly species were recorded. The most abundant was Pieris rapae. The distribution of butterfly species varied significantly in different habitat types. Pieris rapae and Borbo sirena in the families of Pieridae and Hesperiidae respectively were widely distributed. Species richness also varied depending on habitat type. The highest species richness of butterfly species was in the forest and forest edge with 20 and 15 respectively. Species diversity was highest in the forest (H’ 3.29) and edge (H’ 2.46). The lowest species diversity was in farmlands (H’ 2.30). All the respondents were aware of butterflies in the forest and in their farms. Majority of the respondents (85%) felt that the presence of butterflies in their farms benefitted the community by pollinating their crops in addition to adding beauty to the environment (67%). They also felt that butterflies were important to the future generations (9%) and are indicators of clean environment (9%) and hence the need to conserve the Kiang’ondu Forest. A total of 83% got firewood, charcoal, and building materials from the forest. There is need to promote conservation awareness campaigns and strengthen law enforcement to curb illegalities.

Keywords: Butterflies, diversity, Mt. Kenya, threats, attitudes, local community

INTRODUCTION
Insects are by far the most species-rich group of animals, representing over 20% of terrestrial biodiversity. Contrary to most other groups of insects, butterflies (Lepidoptera) are the chosen study species, being among the most popular, well documented, and easy to recognize insect groups (De Heer et al. 2002). According to Daniels, (2003) these insects are extremely short-lived for an average life of about two weeks, and face many challenges on a constant battle for survival; only one out of every hundred eggs survives to become an adult and once fully developed, butterflies are prey for various birds, small mammals, lizards, frogs, toads, spiders, and other insects. Yet, in the small amount of time they are alive, butterflies play critical ecosystem roles as important pollinators of nectar and pollen for both wild and cultivated plant species (Ehrlich, 2003; Proctor et al. 1996). Throughout the world, scientists monitor butterflies extensively to determine both the status of butterfly populations and as an indicator of ecosystem health (Thomas, 2002). In this regard, entomologists believe that the greatest threats to butterflies (and other insect-pollinators) are habitat destruction and land use change (Ecological Society of America 2008). This makes it important to monitor pollinator activity in anthropogenic landscapes as we rely on them for so much in our daily lives.

As species are lost at an increasingly high rate from both outside and within protected areas in Africa, Ehrenfeld, (1976) argues that it has become important to establish baseline data on species’ abundances and distributions to which future surveys and conservation efforts can be related, and according to Caro et al. (1998) historically, in East Africa, there has been less attention given to smaller animal taxa in most protected areas and, until very recently, surveys have focused on large mammals. Nonetheless, it is increasingly recognized that smaller species are important for ecological and conservation monitoring because some are particularly sensitive to environmental pollution and changes in habitat structure, (e.g. Houlanhan et al., 2000; MacNally et al., 2004; Stuart et al., 2004). For example Daily and Ehrlich,
(1992); Hamer_ et al. (2003) illustrates that some tropical butterflies show changes in species composition in response to selective logging, and that would be unlikely to affect ungulates or carnivores to the same degree. The indicator properties of butterflies in regards to species richness have been demonstrated in East Africa and have been used in nationwide conservation planning (Howard_ et al., 1998).

There are about 18000 species of butterflies described globally, in Africa there are about 3200 species and about 900 of these occur in Kenya, of which Kakamega area host about 487 species (Larsen 1991, Kuhne 2008). Despite all these knowledge on the butterflies ecological role and social cultural values attached to them, less is known about the butterflies in Kenya. The study will help the conservationist in reaching sound decision on matters pertaining conservation of butterfly species in Kiang’ondu Forest Station and Kenya at large. In this study, an assessment of species richness, diversity, abundance and distribution of butterfly species of Kiang’ondu Forest and surrounding farmlands of the Eastern Mt. Kenya Forest.

MATERIALS AND METHODS

Study Site
Tharaka-Nithi County is one of the 47 counties of Kenya located in former Eastern province. The county borders Meru County to the Northeastern, Kitui County to the South East, and Embu County to the south. It covers an area of 2409Km$^2$ and has a population of 362,330 as of census 2009(Kenya National Bureau of Statistics). Males comprise 48% while females make up 22% of the total population according to Kenya National Population and Housing Census of 2009 (KNBS, 2009). Kiang’odu forest which forms the study site is part of Mt. Kenya located at the foot of Mt. Kenya location of Chuka_Igamba-ngo’mbie sub-county Tharaka-Nithi County. It covers a large area under a live fence of electric wire fencing.

Research Design
Sampling was carried out in four sampling sites that’s forested habitat, riverine habitat, forest edges and surrounding farmlands. This study included a total of three transect counts at each habitat type for four days in a week for six weeks in the month of May and June 2017. During each site visit, walked at a constant pace of 22 m/min (Soga and Koike 2012) along a 20 m transect line recording all the species and individuals of each species seen within the 2.2 m radius (Kitahara and Sei 2001; Pollard 1977). Binoculars and a camera would be used when appropriate to identify butterflies (Kitahara & Watanabe 2003). Distance from one transect to another was fixed at 300 m. No attempt were made to count butterflies flying high above the recorder (6 m and above), so that species that habitually fly in the canopy would be recorded only when they were at ground level (Pollard & Yates 1993). All butterflies that were not positively identified in the field were captured using a sweep net, photographed and stored in a butterfly envelope carrier for later identification. Specimens were identified using the Butterflies of Kenya guide book by Larsen (1996) and also from the help of entomologists from Chuka University Entomology Lab. during data collection in order to eliminate obvious biases or influences from outside variables (Pollard 1977). Lepidoptera flight activity is closely related to thermal effects, such as, calm conditions with high temperatures and solar radiation (Dennis_ et al. 2006). Equally, butterflies are less active in cooler, cloudier, windier weather (Dennis 2004). Accordingly, fieldwork took place between 08:00 and 14:00 local time, with a temperature above 17$^\circ$C, and without rain or strong wind (Ohwaki_ et al.2007; Erin Josephitis, 2014).

Data Collection
Restricted Search (Transect) the transect protocol involved a walk in a fixed path at a constant pace. Butterflies were identified within a prescribed distance from the path that was 2.2 meters on either side of the path and also when the butterflies are seen in front of, or above. (I.e. no backtracking). Open Searches also sometimes referred to as “checklist searches “, was intended to focus on the presence and abundance of butterflies in Kiang’ondu Forest Station. Freely searched out places where butterflies typically would breed or congregate, and lastly Opportunistic Sightings or incidental sighting, are butterfly sighting that
are not part of a formal identification. For example these were the butterflies species that were encountered after conducting the restricted search (transect) or Open search methods.

Questionnaire administration, a total of 30 questionnaires were administered in to the community around the Kiang’ondu Forest Station. Only one person in every third house along the designated roads and/or paths was permitted to participate in the interview. The purpose of the interview was explained and if the person was willing to participate, the interview proceeded. In cases where there was nobody in the homestead or the person is below 10 years, moved to the next homestead. Each interview lasted 20-30 minutes and conducted them assisted by my fellow student who had good knowledge of the area. Interviews were conducted in Swahili and Meru depending upon the respondent’s preference. Each interview was to take the form of a conversation, structured around a written questionnaire consisting of general and specific questions.

**Species richness and evenness**
Species richness was represented as the sum of different species at each habitat type. Species evenness was measured using the Shannon equitability index for each site, as shown below: Evenness (Eh) = H / ln (S), where H = Shannon’s wiener diversity index, and S = Species richness

**Species diversity**
Species diversity was measured using the Shannon Wiener Index (Rasingam & Parthasarathy 2009). The Shannon Wiener Index has an emphasis on richness and is sensitive to rare cover types. The equation for the Shannon Wiener Index for each habitat type is shown below. Shannon-Wiener Index Diversity, (H’) was used to calculate diversity of species in various habitats.

\[ H’ = - \sum (pi \ln pi) \]

Where H’ is the Index of species diversity, s is the number of butterflies, \( pi \) is the proportion of the total sample belonging to the, \( i \)-th species and \( \ln \) is the natural logarithm. Species richness was assumed as the total number of species encountered.

**Abundance of species**
Total butterfly abundance was calculated as the sum population of all component species at each habitat type. A relative abundance of butterfly species in various habitats was calculated as the ratio of the number of species found in each habitat and the total number of species recorded in all study habitats. A relative abundance of butterflies between species was calculated as the ratio number of each species and the total number of all species recorded.

**Distribution of species**
The distribution of species recorded as presence or absence of species in a particular habitat.
A rank-abundance curve was plotted to illustrate the comparisons of abundance, richness, and evenness between habitat types.

**The local community’s knowledge and attitude towards butterflies**
To analyze the data on local knowledge and attitude, the responses were entered verbatim into Microsoft Excel spreadsheets. Repeated-similar answers were categorized and tallied. To identify correlations in the responses, the use Pearson chi-squared (\( \chi^2 \)) was applied in the analysis using SPSS 16.0 software.

**RESULTS**
During 24 days of sampling throughout the 6-weeks of month of May and June, 498 individual butterflies were identified using restricted search (transect), open searches, and opportunistic sightings that comprised 49 species. These came from five families. A species accumulation curve plotted against days spent in the field showed that the number of species captured each day of sampling was still rising at the
end of the study period (Figure 2). There were far more species of Papilionidae (12 species) and far fewer species of Hesperidae (seven species) that were observed.

![Species Accumulative curve showing the number of butterfly species identified against days in the field, (49 species)](image)

**Figure 4**

**Diversity index of butterflies in KFS**

Butterfly species diversity differed among habitats. The highest species diversity of butterflies was recorded in forest ($H'=3.29$), followed by edges ($H'=2.46$) and the lowest in farmlands (2.30) (table 1). All in all, no significant variation of species diversity of butterflies was detected among habitats. (SS=2.893209, DF=3, P=0.962229)

<table>
<thead>
<tr>
<th>Habits</th>
<th>Forest</th>
<th>Edges</th>
<th>Farmlands</th>
<th>Riverine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species richness</td>
<td>27</td>
<td>12</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Evenness</td>
<td>1.00</td>
<td>0.91</td>
<td>0.93</td>
<td>0.91</td>
</tr>
<tr>
<td>Shannon-Wiener diversity ($H'$)</td>
<td>3.29</td>
<td>2.46</td>
<td>2.30</td>
<td>2.40</td>
</tr>
</tbody>
</table>

**Relative abundance of butterfly species in KFS**

A total of 498 butterfly individuals, were recorded during the study. The abundance differed among species and habitats. To illustrate this, *Pierisrapae* (14.86%) was the most abundant species followed by *Acerosplotzi* and *Coliaslecto* with 4.82% (Appendix 2). Nonetheless, two species *Andronymus Caesar* and *Acraea cerasa* were the least abundant species with 0.40 and 0.20 respectively. The highest abundance of butterfly species among habitats were recorded in forest (22.22%), followed by Edges (30.61) and the lowest abundant species of butterflies were recorded in Farmlands.
DISCUSSION, CONCLUSION AND RECOMMENDATION

Lepidopteran Species Richness and Diversity

Kenya is a mega Lepidoptera country with diverse habitats including tropical montane rainforest, afro-alpine moorland, riparian forest, grassland, woodland and semi-arid wooded savannah. About 900 species of butterflies (Larsen 1991 and Kuhne 2008) have been recorded in the country, and of these 34 butterfly species are endemic. Until now, no published butterfly records were available for the Kiang’ondu Forest Station. However, the current study recorded 49 species of butterflies in different habitats in Kiang’ondu Forest Station.

High butterfly diversity and absolute species richness were recorded at forest and edges. The habitat heterogeneity at the forest and edge could be effective in offering habitat requirements for both adult butterflies and their developmental stages. High floral resources abundance in this habitats could have also contributed to the high butterfly diversity. A positive relationship is known to exist between butterfly diversity and floral abundance (Steffan-Dewenter and Tscharntke, 1997). Butterfly diversity was significantly higher at the forest and edge than riverine and farmland. This shows that a greater proportion of butterfly species of Kiang’ondu Forest Station could be restricted to the forest and forest edge with limited foraging ranges between the two habitats. Probably, the forest and forest edge provide specific habitat requirements for diverse butterfly species in the area. Butterflies are known to exhibit specific habitat requirements, namely adequate numbers of a single or a few host-plants for oviposition, nectar-source plants, or even more cryptic resources ranging from mutualistic dependencies to pools of standing water for critical minerals (Baz and Antonio, 1992). Many of these butterflies in the forest could be specialised to inhabit the forest understory and feed on other food sources other than flowers. The food resources could be restricted in the forest and within the narrow range of forest edge. This concept highlights the significance of the forest in the conservation of butterflies.

Abundance and Distribution

This results was caused by the rain effect on the habitats which made the forest habitat be more diverse with different species of plants and water ponds which attract the butterfly species in large groups than in the other habitats, thus leading to forest habitat having a large number abundance followed by edge, riverine and farmland.
*Pieris rapae* was the most abundant butterfly species recorded and most individuals were encountered in edges followed by farmland. Its dominance is probably attributed to its preferred habitats, almost any type of open space. According to Bartlett and McLeod (2017), *P. rapae* lives in almost all habitat type and this is evident in this study as all the habitats had relatively a good abundance of the *P. rapae* that is forest, edge, farmland, and riverine had an abundance of 16, 22, 21, 12 number of species respectively.

**The local community’s knowledge and attitude towards butterflies.**

Most of the people living in Mukung’o, Mutupe and Kariokoo appreciated the fact that natural resources belong to them and it is their duty to protect them. Such a perception will enhance conservation of the region’s natural resources by not depleting them to levels which might deny access by future generations. In Mukung’o and Kariokoo however, a considerable number of respondents believe that natural resources belong to the government and it is the responsibility of the government to protect them. With most of these area’s respondents being small scale farmers, this lack of a sense of responsibility to protecting the forest endangers the same critical ecosystem their livelihood is dependent on.

The study of butterfly’s species in Kiang’ondo Forest Station shows that there are relatively high number of butterfly’s species that’s is 49 species. More species of Lepidoptera are expected as the study was undertaken during wet season when the resources (e.g. food) were widely distributed. However, the species diversity, abundance, and distribution are a temporal and spatial phenomenon. The diverse species richness of Lepidoptera in Kiang’ondo Forest Station is attributed to habitat heterogeneity which allows species to occupy different habitat type to meet basic species ecological needs. Differences in species richness, diversity, abundance and distribution among habitats are mainly influenced by different species requirement such as changes in climatic condition, life forms, host plant, food availability and presences of microhabitats in Kiang’ondo Forest Station. Conclusively, the study serves as a baseline data for future studies in and outside Kiang’ondo Forest Station at large, notably on the distribution, abundance and diversity of Lepidoptera. Future studies should focus on early, long rains and dry seasons to come up with a complete species diversity, abundance and distribution of Lepidoptera found in Kiang’ondo Forest Station. Further, the forest managements should encourage the communities around to practice butterfly farming as way of economic value and tourism sector as well.

**REFERENCES**


ABSTRACT
The study was conducted to determine the distribution and abundance of reptiles and amphibians in the forest and the adjacent farmlands in Kakunga-Mukangu region of the Kakamega Forest National Reserve, and also to determine the attitudes of the local community towards conservation of herpetofaunal species. Data was collected between January and April 2017 using standardized general search and seize, drift fence and pitfall trapping methods. In addition, a socio-ecological survey was carried to determine attitudes and perceptions of the local communities towards reptiles and amphibians using questionnaires that were administered using a combination of systematic and simple-random sampling techniques. A total of 134 individuals were recorded including seven species of reptiles and five species of amphibians under 8 genera (Phrynobatrachus, Trachylepis, Hemidactylus, Lygosoma, Adolfus, Bufo, Rana, Naja) were recorded. Trachylepis megalura was the most abundant species of reptile and Phrynobatrachus natalensis as was the most abundant species of amphibian. Secondary forests in the study area had the highest number of species (9) while primary forests recorded the most number of individuals (40). A significant number of the herpetofauna were also recorded in the farmlands. Results for the socio-ecological survey showed that all the respondents were aware of at least one species of reptile and amphibian. These species of animals had little or no direct benefit to members of the community. Majority of the respondents believed that the herpetofauna were dangerous and thus no conservation efforts were put in place by the respondents to conserve them. As a result, the herpetofauna were exposed to conflicts which the community, a situation that they believed was the major reason for their decline. Recommendations were made suggesting that effective awareness should be enhanced to educate the local community on the ecological importance of herpetofauna, protection of their critical habitats and management of boundary vegetation along their croplands.

Keywords: Herpetofauna, diversity, local community, attitude, benefits, threats

INTRODUCTION
Biodiversity has an extreme importance in supporting life on Earth, which includes thriving human activities such as medical practices and food production (Urbina-Cardona 2008). The substantial decline in herpetofaunal abundance and diversity is now a well-known fact between conservation biologists. The Global Amphibian Assessment and the Global Reptile Assessment have expressed serious warning in regards to recent, alarming statistics (Urbina-Cardona 2008). Worldwide, 32.5% and 22% of amphibian and reptile species, respectively, are endangered (Canavero et al., 2010), and current trends suggest even more species could become threatened in the near future. Furthermore, most forests in Africa remain unexplored for herpetofauna and given the rampant rate of forest destruction and insecurity, there is the potential of many species of reptiles and amphibians disappearing before they have been documented.

The concern about the loss of reptiles and amphibians is justified on the grounds that worldwide, amphibians are crucially important in their ecosystems. The general ecological importance lies in their being predators; acting as primary and secondary carnivores on insects some of which are crop pests or disease vectors (Jena, et al., 2013; Behangana, 2004). The ecological effects for their decline cannot be taken for granted because evidence to date suggests that amphibians decline will have large-scale and long lasting ecosystem level effects, including changes in the global algal community structure and primary production, altered organic matter dynamics, changes in other consumers such as aquatic insects and riparian predators, and reduced energy transfers between streams and riparian habitats (McCallum 2007; Schneider et al. 2001).
In East Africa, most of the forests and forest fragments remain partly explored. These forests include the Eastern Arc Mountains (Kifcon, 1995; Howell, 1993) and a number forests associated with the Guinea-Congolian forest such as Budongo, Bwamba, Kibale, Bwindi, Mbira and Mt. Elgon in Uganda (Vonesh, 2001) and the Kakamega Forest in western Kenya in which Wagner & Böhme, (2007) provides an annotated checklist of reptiles and amphibians found in the forest. Kakamega forest is the easternmost part of the Guinea-Congolian tropical rainforest system (Clausnitzer, 2005) and has a very large diversity and zoogeographical value.

A number of on reptiles and amphibians in Kakamega Forest and other parts of Kenya has been done, (for example Wagner & Böhme, 2007; Böhme et al., 2005; Wagner & Schmitz 2006). However, in order to provide conservationists data for defining priorities for conservation it is necessary to obtain basic information on the diversity and community of forest amphibians and reptiles (Wagner & Böhme, 2007). It is also of great importance to provide information about the level of knowledge and the attitude of the local communities about the reptiles and amphibians that are being conserved. This because, the attitude towards wild animals has been shown to greatly influence the support given by the public and various decision-making bodies to the preservation of the species (Ceriaco, 2012).

The aim of the present paper is to provide additional information about the diversity and abundance of reptiles and amphibians in Kakamega Forest and in particular the northern part of the forest. In additional, the study focuses on unveiling the level of knowledge of the local community and reptiles and amphibians and also gauge their attitudes towards conservation of the species in the area. The present study documented the herpetofaunal diversity around Kakamega Forest, but also determined the knowledge and the attitudes of the local community towards herpetofauna with the aim of providing data that can be used in developing conservation strategies for the reptiles and amphibians in Kakamega Forest.

METHODOLOGY
Kakamega Forest is situated in the Kakamega District near Kakamega town in the Western Province of Kenya. The forest extends from 0°10' and 0°21 N to 34°47’ and 34°58’E, covering an area of 240 km$^2$, of which only 44.55 km$^2$ are protected by law (Wagner & Böhme, 2007; Mitchell, 2004). It is Kenya’s only tropical rain forest and is said to be Kenya’s last remnant of Guineo-Congolian rain forest that once spanned the continent. The area receives an average of 1200mm to 1700mm of rain per year. The heaviest rainfall is experienced in April and May with a slightly drier June and a second peak roughly in August to September (short rains). January to February are the driest months. Temperature is fairly constant throughout the year, ranging between 20°C to 30°C.

Figure. 1: Location of Kakamega Forest. (Source: Farwig, Braun, & Böhning-Gaese, 2008).
The present study was conducted between January and April 2017. Counting of amphibians and reptiles was done using timed species count method. The method entails quietly walking and intensively searching within all possible herpetofaunal microhabitats such as under leaves, debris, decomposing tree stumps and logs, on tree, shrubs, bushes and wetlands. Trapping using a linear drift fence of 5m long with bucket pitfalls at both ends was also used to collect data on specimen. (Separate bucket pitfalls were strategically placed to collect specimen for recording. The drift fence and pitfalls were subjected to regular checking. Due to the available resources, only one trap station was established in every habitat type. Traps were checked daily shortly after sunrise (between 6:00am and 7:00 am) and late in the evening (between 6:00 pm and 7:00 pm). The abundance of reptiles and amphibians were expressed in terms of the number of individuals observed. The transect method as described by Heyer et al., (1994) was employed to sample localities within each vegetation communities in the area. In each study site, a 200m transect in rectangular form was established starting from a random point with a width of 2m on either sides of the transect lines. Visits were made on each transect daily. The sites were sampled in a random rotational sequence in order to minimize bias. For each species encountered, the scientific name, sex and life stage will be recorded. Linear drift fence of 5m were placed randomly at each habitat type with bucket pitfalls of ten liters at both ends of the drift fence. Two separate pitfall traps were also placed strategically at 50m intervals purposely for specimen collection. The positions of the drift fence and pitfall traps were changed every two weeks.

The general search method involved walking on a prescribed habitat looking for and studying the behavior of herps. It was conducted twice in a day with the preferred time being in the midmorning and late afternoon since herps are usually active at this time due to the warm temperatures. Each study time took thirty minutes. Visual encounter surveys along transects was also employed. Transects were mainly established along trails and rivers, in order to minimize human disturbance. Surveys were conducted during the day. As much distance as possible was covered during each performed transect. Individuals that were encountered incidentally on the transect route were also recorded and transects were visited at least 24 hours before surveying the same transect for a second time. Species were identified and documented by taking the specimen with a photograph for later confirmation of species identity. Additionally, the weather at the time of collection was recorded along with time, microhabitat type and behavior of the herp. Questionnaires and personal interviews were used to collect data from randomly selected individuals. A total of sixty questionnaires were administered. The interviews and questionnaires focused on gathering basic information on the attitudes, perceptions and knowledge of the locals on reptiles and amphibians and their opinions on measures to conserve them.

RESULTS

Diversity, distribution and abundance
The species encountered differed in terms of abundance in different habitat types in the study area (Table 1). Lizards had the highest abundance and snakes had the least. Chameleons and tortoises were not encountered during the study period. A total of 14 individuals were recorded.

Table 1: Abundance and distribution of reptiles and amphibians in major in Kakamega Forest

<table>
<thead>
<tr>
<th>Animal species</th>
<th>Primary forest</th>
<th>Secondary forest</th>
<th>Forest edges</th>
<th>Glades</th>
<th>Near water/wetland</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Striped skinks</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>12</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Jackson's forest lizards</td>
<td>3</td>
<td>1</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Tropical house geckos</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Brook's geckos</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Variable skinks</td>
<td>9</td>
<td>4</td>
<td>3</td>
<td>15</td>
<td>1</td>
<td>32</td>
</tr>
<tr>
<td>Peter's writhing skink</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Frogs</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Toads</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Forest cobra</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Proceedings of the Fourth International Research Conference
Relative Distribution
As shown in figure in Table 2, the highest abundance of snakes and chameleons was found in the forested areas whereas most of the lizards, frogs and tortoises were found within the built up areas. Other habitat types included a combination of rocks and houses, farms and rivers, farms and houses, rocks and farms, houses and forests, rocks and forests, rivers and houses and rocks and rivers.

<table>
<thead>
<tr>
<th>Species</th>
<th>Building</th>
<th>Forest</th>
<th>Farm</th>
<th>On Rocks</th>
<th>River</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>Snakes</td>
<td>0</td>
<td>0.00</td>
<td>47</td>
<td>79.66</td>
<td>5</td>
<td>8.47</td>
<td>4</td>
</tr>
<tr>
<td>Lizards</td>
<td>32</td>
<td>51.61</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>22</td>
</tr>
<tr>
<td>Frogs</td>
<td>32</td>
<td>52.46</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>21</td>
</tr>
<tr>
<td>Tortoise</td>
<td>12</td>
<td>54.55</td>
<td>9</td>
<td>40.91</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
</tr>
<tr>
<td>Chameleon</td>
<td>0</td>
<td>0.00</td>
<td>29</td>
<td>87.88</td>
<td>3</td>
<td>9.09</td>
<td>11</td>
</tr>
</tbody>
</table>

Diversity
Table 3: The diversity of species in different habitats calculated using Shannon Weiner Index

<table>
<thead>
<tr>
<th>Animal species</th>
<th>Primary forest</th>
<th>Secondary forest</th>
<th>Glades</th>
<th>Forest edges</th>
<th>Near water habitats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Striped skinks</td>
<td>0.08</td>
<td>1.17</td>
<td>1.69</td>
<td>1.17</td>
<td>0.00</td>
</tr>
<tr>
<td>Jackson's forest lizards</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.82</td>
<td>0.01</td>
</tr>
<tr>
<td>Tropical house geckos</td>
<td>0.08</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Brook's geckos</td>
<td>0.21</td>
<td>0.04</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Variable skinks</td>
<td>0.46</td>
<td>0.10</td>
<td>3.30</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>Peter's writhing skink</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Frogs</td>
<td>0.08</td>
<td>0.04</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Toads</td>
<td>0.02</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>5.06</td>
</tr>
<tr>
<td>Forest cobra</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Knowledge and attitudes the local community about herpetofauna in Kakamega Forest
All the respondents were aware of the presence of reptiles and amphibians in the area. As shown in figure 2, most of the respondents revealed that they were knowledgeable about snakes, lizards and frogs that are present in Kakamega Forest. These differences were statistically significant (snake $\chi^2 = 50.581; df =1; p = 0.000$, and frogs $\chi^2 = 58.065; df =1; p = 0.000$). Although not statistically significant ($\chi^2=5.226; df=1; p=0.611$), majority of respondents claimed that they were not aware of presence of tortoises in the area.

Threats facing reptiles and amphibians
Table 4 below shows the contribution of the indigenous people toward the possible threats that have contributed to the decline of reptiles and amphibians. The results showed that their killing and harassment by man is the major threat. These groups of animals are believed to have no direct benefit to man, and at the same time dangerous without any proof (except for some snakes). This has resulted to the animals being harassed by man whenever encountered. The respondents’ records also showed that habitat deterioration, deforestation, drought and climate change were also the contributing factors for the decline of reptiles and amphibians in the area.
Attitudes towards conservation

Table 4: Relationships between the perception of herpetofaunal species being dangerous and the attitude towards its conservation

<table>
<thead>
<tr>
<th>Animal</th>
<th>$\chi^2$</th>
<th>Df</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snakes</td>
<td>62.217</td>
<td>4</td>
<td>0.000</td>
</tr>
<tr>
<td>Lizards</td>
<td>0.96</td>
<td>1</td>
<td>0.757</td>
</tr>
<tr>
<td>Frogs</td>
<td>63.060</td>
<td>4</td>
<td>0.000</td>
</tr>
<tr>
<td>Tortoises</td>
<td>62.000</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>Chameleons</td>
<td>76.427</td>
<td>4</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 5: showing the results of the respondents on the threats facing reptiles and amphibians

<table>
<thead>
<tr>
<th>Type of threat</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunting/killing/harassment</td>
<td>48</td>
</tr>
<tr>
<td>Habitat deteriorations/deforestation</td>
<td>17</td>
</tr>
<tr>
<td>Drought/climate change</td>
<td>18</td>
</tr>
<tr>
<td>Negative attitude/perception towards them</td>
<td>2</td>
</tr>
<tr>
<td>Forest fires</td>
<td>3</td>
</tr>
<tr>
<td>Environmental and habitat pollution</td>
<td>2</td>
</tr>
<tr>
<td>Over exploitation</td>
<td>1</td>
</tr>
</tbody>
</table>

Conservation measures towards protecting reptiles and amphibians

Table 5 below shows the different conservation measures that should be put in place to ensure effective protection of reptiles and amphibians as per the respondents. Majority suggested that more protected areas should be established such as special herpetofaunal parks as this would reduce the conflicts between them and man. A good number of the respondents also stressed on the importance of public education and protection of their habitats.
Table 9: showing conservation measures towards protecting herpetofauna

<table>
<thead>
<tr>
<th>Conservation mechanism</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness creation</td>
<td>19</td>
</tr>
<tr>
<td>Enforcement of laws and policies</td>
<td>3</td>
</tr>
<tr>
<td>Afforestation</td>
<td>11</td>
</tr>
<tr>
<td>Protection of wetlands and other habitats</td>
<td>15</td>
</tr>
<tr>
<td>Mitigating pollution</td>
<td>3</td>
</tr>
<tr>
<td>Establishment of new protected areas/sanctuaries/herpes parks/orphanages and other conservation areas</td>
<td>33</td>
</tr>
<tr>
<td>Local people to participate in their conservation</td>
<td>3</td>
</tr>
</tbody>
</table>

DISCUSSION

Diversity, Distribution and Abundance

The study was able to document seven species of reptiles and five species of amphibians. *Trachylepis megalura* was recorded as the most abundant species of reptile and *Phrynobatrachus natalensis* as the most abundant species of amphibians. As reported by Tsetan (2011), the data was able to support the fact that diversity in ecology has better potential which gives support to numerous reptile species. The conversion of natural habitats for agriculture, human settlements and other developments that leads to the fragmentation of natural habitats has contributed to the land use change resulting to the decline of herps in some locations since these species cannot migrate. These supports the findings of (Lajmanovich *et al.* 2003; Storfer 2003; Young *et al.* 2004; Gardner *et al.* 2007b) and (Cushman 2006; Parris 2006).

This study did not aim to report any of the studied unit as the most or least significant, rather it aimed to gather baseline data on the herpetofauna. A low number of amphibians and reptiles was recorded from the protected mixed habitats despite the forest providing favorable conditions for their survival by the availability different microhabitats such as springs, swamps, glades, primary and secondary forests. The study did not find a significant impact of grazing on the herpetofauna while Fabricius *et al.* (2003) reported that snakes and lizards are more abundant in communal grazing area. From the information gathered by the questionnaires on the population trends of herps in the study area, agricultural activities such as farming near forested areas and creation of farms in areas that were originally occupied by bushes near the forest are the major causes of decline in the population numbers of herps.

The most abundant species was found to be the striped skink while the least abundant species was found to be snakes (only one forest cobra was encountered during the entire period of data collection). Variable skinks were the most abundant in the primary forest, toads were the least abundant and no snakes were recorded. In the secondary forest and forest edges, striped skinks were the most abundant species. Variable skinks were the most abundant species in glades while toads were the most abundant species near aquatic habitats. Primary forest habitats recorded the highest diversity of herps.

Awareness of herps in the study area

All the respondents were aware that there were different species of amphibians and reptiles in the study area. Every respondent had interacted with snakes, lizards and frogs while only a few had interacted with chameleons and tortoises as shown in figure 2. The percentage knowledge on the different species is an indicator that lizards are the most abundant species of herps in the area, followed by frogs, then snakes, then chameleons and tortoises are the least abundant.
Attitudes and perceptions towards herpes
The respondents’ reports showed that snakes, frogs, tortoises and chameleons are dangerous at varying degrees as shown in the graph above. Lizards were considered the most non dangerous species of herpes in the area, though there was only proof of snakes being dangerous. In as much as some of these animals were considered by the community to be dangerous, they still recognize them as important aspect of the forest ecosystem and saw the need of the animals being conserved.

Threats and conservation measures
According to the respondents, killings, habitat deterioration and climate change were found to be the leading causes of herpetofaunal population decline. However, majority suggested that effective education awareness and protection of their habitats would help in conserving these species. Encounter of these animals made them to be harassed either by chasing them away or killing them because they are just believed to be dangerous in one way or another, they had no direct benefit to man, others were like snakes and chameleons were believed to be used for witchcraft purposes.

CONCLUSION
This study provides the first insight into the attitudes and perceptions of the indigenous people on the conservation of herpetofauna in Kakamega Forest. The study was carried out with the objective of contributing to our knowledge about the diversity of herpetofauna in Kakamega Forest and more importantly a background information about the awareness status and the attitude of the local community towards the herpetofaunal species in the area. It would be really encouraging if future studies will show a positive attitude of conserving herpetofauna by the indigenous people as this would raise hopes for recovery of the threatened, endangered and rare species of herpes. Based on the findings from this study, therefore, there is need to promote awareness programmes to educate the local people on the ecological importance of herpetofauna and promote their conservation both locally and nationally.

REFERENCES
LINKING WATER QUALITY TO SOURCES AT HOUSEHOLD LEVEL AMONG RIPARIAN COMMUNITIES IN UPPER NJORO RIVER CATCHMENT, KENYA


1Egerton University, P. O. Box 536-20115, Egerton
2Jomo Kenyatta University of Agriculture & Technology, P. O. Box 62000 – 00200, Nairobi
3Ministry of Agriculture, Livestock & Fisheries, P. O. Box 34188-00100, Nairobi

E-mail and mobile phone: CM M‘Erimba-merimba2010@gmail.com, 0728543191; SK Muthoka-skaveni@yahoo.com, 0722241854; JM Raude-jmesso@jkuat.ac.ke, 072542689; KO Ouma-kenochieng8477@gmail.com, 0722328316, J Wanjala-wanjalajacqueline@gmail.com; CO Digo-chadscad@yahoo.com; 0723 999602

ABSTRACT
Riparian communities in river catchments worldwide face challenges in sustainable utilization of available natural resources, including surface and ground water. This study examined the spatio-temporal variability in water footprint in the upper Njoro River Catchment [NRC], linking source-and-consumption to domestic water quality trends in wet 2014 and dry 2017 seasons respectively. Sampling was conducted in upper, mid- and lower zone of upper NRC for physico-chemical parameters, nutrients and microbial loads in domestic water from three major sources; River Njoro, Borehole and Rainfall. Generally, in the 2014 wet-season, pH ranged from 6.4-9.0, mean conductivity was relatively high up to 141 µS cm⁻¹ while oxygen and temperature averaged at 6.3 mgL⁻¹ and 19.1°C, respectively. Nitrate-N levels ranged from 0-10.6 mg L⁻¹ and total phosphorus [TP] was highest at 0.68 mg L⁻¹. During the 2017 dry-season, pH, oxygen and temperature values remained within the respective dry-season ranges. However, nitrate-N concentration peaked at 8.1 mg L⁻¹ while TP decreased to 0.4 mg L⁻¹. Seasonally, significant differences in the water parameters, except temperature and ammonium-N, were observed. Two-way ANOVA revealed significant zonal variability of household water pH, conductivity, oxygen, nitrate-N, SRP and TP. Significant differences in all the measured parameters of water from the 3 major sources was also observed. Microbiological density in household water ranged between 0-2 Escherichia coli [EC] and 2-16 Total Coliform [TC] log-cfu/100 ml water respectively in 2014 wet-season. In 2017 dry-season, the respective microbial load proportions increased approximately by a factor of 2.1. There was a significant seasonal variability in EC and TC densities which also differed significantly between mid- and upstream in 2017 [p<0.001]. The overall water quality significantly varied spatio-temporally highlighting critical aspects when designing measures to enhance domestic water safety particularly at household level, with zoning as an important criterion, in river catchments.

Keywords: Microbiological, Nutrients, Riparian, Spatio-Temporal

INTRODUCTION
Riparian communities in river catchments worldwide face challenges of unsustainable utilization of available natural resources including safe drinking-water (WHO, 2011). Incidentally, these communities living in rural and peri-urban informal settlements, are also predominantly characterised by low household low-income while a sizeable population have challenges of sanitation and health facilities. It is estimated that over 780 million people worldwide, mostly in low-income countries, lack access to a portable source of water (WHO/UNICEF, 2013). Consequently, the socio-economic and environmental impacts of unsatisfactory (inadequate, unsafe and inaccessible) supply of water and sanitation services cannot be neglected (Montgomery & Elimelech, 2007; Johnson et al., 2008). Eradication of water-related and waterborne diseases, closely related to satisfactory water supplies (Ashbolt, 2004; Eshelby, 2007), has a direct positive impact on the socio-economic status of an individual, a household, and the community. Several alternatives to overcome unsatisfactory water supply have been implemented (WHO/UNICEF, 2013). However, challenges in potability are still emerging particularly on the physicochemical (Yillia & Kreuzinger, 2009; Nyamangara et al., 2013) and microbial quality (Bessong et al., 2009; Singh et al., 2013; Omondi et al., 2015) aspects of available domestic water. This often results from either direct diffuse or point source contamination of water sources in catchments (Yillia, 2008) or indirectly from conveyance or storage facilities (Macharia et al., 2015).
In Kenya, approximately 27.9% of the population had access to water from water services providers, 37.2% obtained water from un-improved springs, wells and boreholes by 2009. In the same period, over 29% received household water from other unsafe sources including streams, ponds and lakes while 5.9% are supplied water by vendors (NESC/MDP, 2013). It is critical to note that Kenya’s fresh water per capita is on the decline both in quantity and quality. The decline is projected to reach 235 m$^3$ by 2025 unless effective interventions are implemented (NESC/MDP, 2007). Catchment management is one such intervention that will reduce the degradation and ensure better water quality. This can be achieved by monitoring water quality to identify and track the chemical and microbial contamination footprint for different sources of domestic water followed by appropriate interventions. The aim of this study was to link the chemical and microbial quality of domestic water from the major sources in the upper Njoro River Catchment (NRC). Specifically, the objective was to compare the quality of household water at the source and point-of-use spatiotemporally. We then suggested possible interventions, based on the findings, to ensure satisfactory water supplies to the riparian community in the upper NRC.

MATERIALS AND METHODS

Study Area
The Njoro River Catchment (NRC) with approximately 260-280 km$^2$ catchment area is drained by the 40-60 km Njoro River, a highland Kenyan Rift-valley rural stream in south-western part of Kenya in Nakuru County. The catchment lies between latitudes 0º 17′ S, 0º 32′ S and 035º 50′ E, 036º 05′ E (Figure 1). River Njoro originates from the Eastern Mau escarpment (~2800 m a.s.l) flowing through the predominantly agro-ecological zone, with a mosaic of rapidly expanding rural and peri-urban settlements, into Lake Nakuru (~1700 m a.s.l) (Shivoga, 2001). The Little Shuru tributary, a permanent stream, in the upper catchment flows through the densely populated upper-zone NRC Beeston area characterised by inadequate safe water and sanitation facilities (Mokaya et al., 2004) to join Njoro River mid-zone at 2293 m a.s.l (M’Erimba et al., 2014). Rainfall (600–1800 mm p.a.) in the NRC is typical bimodal characterised by a long-wet season (May-September) and short-wet period (November-December) annually (Mathooko & Kariuki, 2000; Macharia et al., 2015) although the pattern has become irregular with the current regional effects of climate change.

Figure 6: The upper Njoro River Catchment with the sampling locations across the upper (Nessuit, Beeston), middle (Njokerio, Ngóndu) and lower (KALRO, Kariobangi) zones

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**Sampling Design: Site, Source and Household selection**

The sampling design was based on the methods developed by UNICEF/WHO for rapid assessment of drinking-water quality (RADWQ) (Howard & Bartram, 2003; WHO, 2011). Cluster sampling method was used followed by random selection of households within each cluster. Cluster sampling was preferred to account for the spatial variability of the water quality indicators in the NRC. The target stratum included households randomly selected in the peri-urban and rural settlements in each cluster across the upper, mid- and lower zones within the upper NRC. Approximately 160 households with children aged 0.5–below 5 years were selected according to Bartlett et al. (2001) for survey sampling. The age bracket was selected primarily to assist in monitoring the impact of water, sanitation and hygiene on the nutritional and health status of the children as a proxy measure of community nutrition and health well-being. Details of the findings on the upper NRC community nutrition and health status are however, outside the scope of this paper and therefore documented separately.

**Water Sampling and Field measurements**

Household domestic water was sampled once over a 6-week period in each season across the three zones, from the point-of-use (POU) and storage/sources, for both microbial and physico-chemical analyses. Triplicate water samples were collected aseptically from storage points and/or POU into sterilised 200-mℓ bottles for microbial analysis and also separately into acid-washed, pre-rinsed 500-mℓ plastics bottles for physico-chemical tests respectively. *In-situ* measurements using multi-probe HACH (Model HQ-40d) portable meters included pH, conductivity, temperature and dissolved oxygen (DO). The GPS locations of the households and water points was taken using a hand-held GPS (GARMIN® *e-trex* legend) unit. The samples were transported in ice-cooled boxes at 4 °C and analysed at Egerton University, Department of Biological Sciences, Limnology laboratory.

**Physico-chemical Analysis**

Standard APHA (2005) analytical procedures were followed for total suspended solids (TSS), nitrite-N (NO₂-N), nitrate-N (NO₃-N), ammonium-N (NH₄-N), soluble reactive phosphorus (SRP) and total phosphorus (TP). The TSS was determined gravimetrically. Samples were filtered through Whatman rinsed GF/C glass fibre filters (0.6-0.7 μm; 47 mm). Filtered samples were used to analyze NO₂-N, NO₃-N, NH₄-N and SRP. The Sulfanilamide acid method was used to determine NO₂-N. The Sodium salicylate method was used for NO₃-N while the phenol-hypochlorite method was used for NH₄-N. SRP was analyzed with the Ascorbic-acid method. For TP, 25-mℓ unfiltered sample was digested with 12 g potassium peroxidisulphate for 90 minutes and the digestate analysed as indicated above for SRP.

**Enumeration of *Escherichia coli* and Total Coliforms**

Water samples for microbial analysis were processed within 6 hours of collection. The membrane-filtration technique was used to detect EC and TC bacteria (APHA, 2005). Ten-fold serial dilutions were made for each sample used to test for total coliforms (TC) and *Escherichia coli* (EC). The dilutions were triplicated and drained through sterile membrane filters (0.45 μm; 47 mm) with a vacuum pump. The filters were then incubated on Chromocult Coliform Agar (ISO 6222, OXOID) in sterilised disposable plastic plates at 37 °C for 24 hrs. Pink to red colonies and blue colonies were counted for TC and EC respectively. Plates with countable colonies between 20 and 200 were selected for enumeration. To determine microbial density, colony numbers were reported as log-colony forming units (cfu) per 100 mℓ.

**Statistical Analysis**

Statistical analyses were conducted in SPSS version 21 (IBM, 2012). All physico-chemical and microbiological data were tested for normality of distribution using the Kolmogrov-Smirnov test where all except pH, DO and temperature, were non-normally distributed and bacterial counts generally positively skewed. The data was log₁₀(x+1) transformed and significant mean differences tested using *t*-test and multivariate analysis at p < 0.05 significance level coupled with Tukey LSD *post-hoc* testing.

Hierarchical Cluster Analysis was conducted to identify location relationships based on the predominant household water quality in NRC. The ‘between-group linkage’ clustering was adopted and the degree of
association determined using the ‘squared Euclidian distance’ after ‘z-score standardization’ transformation of the physico-chemical and microbiological variables. A rescaled distance cluster combined (RDCC) > 10 and > 5 for physico-chemical and microbial water quality respectively, on the dendrogram scale was used to identify location-source clusters.

RESULTS
Spatial and Temporal variability in Household Water Quality

Physico-chemical Water Quality

The physical and chemical quality of the major water sources over the dry and wet seasons is summarised in Table 1. The lowest pH (3.3) was in river water while the highest conductivity (565.3 µS cm⁻¹) was from borehole water recorded during the dry 2017 season. Dissolved oxygen (DO) was slightly higher in 2014 wet season (6.2 mg L⁻¹) compared to the dry 2017 period (5.9 mg L⁻¹) although water temperature remained at around 19.0 °C in both seasons. River water recorded the highest content of suspended particulate matter ranging from 5.8 mg TSS L⁻¹ in 2014 to 23.4 mg TSS L⁻¹ in 2017 mid-zone. Significant seasonal differences were observed in all the above parameters (t-test, df=373, p < 0.05) except DO. For instance, conductivity and TSS markedly increased by > 2 folds while the minimum pH decreased by > 45% between 2014 and 2017.

The general increase in mean nutrient levels from 2014 wet to 2017 dry season was also significant (p < 0.05). Nitrate-N increased from 0.7-1.1 mg L⁻¹, nitrite-N from 10.8-19.5 µg L⁻¹, ammonium-N from 235.6-262.8 µg L⁻¹, SRP from 24-32.5 µg L⁻¹ and TP from 66-71.1 µg L⁻¹. Significant temporal variability was also evident in higher nitrate-N, SRP and TP concentrations in the lower zone. Also, noteworthy is the relatively higher nitrate-N levels (0.5-2.1 mg L⁻¹) in borehole water compared to other sources from mid-stream downwards in both seasons (Table 1).

Microbial Quality of Water

Table 2 illustrates mean bacteria indicator densities in different sources of household water both seasonally and spatially. The 2014 wet season was characterised by a general increase in densities up to 5 log units of EC and 2<TC≤6 log units in water from different sources. In contrast, EC densities were up to 6.5 log units while TC log-unit count was more than double (5<TC≤7.2) in 2017. Significant seasonal differences in EC densities was observed (t-test, t=2.2, df=171, p<0.05) and similarly for TC (t-test, t=20.6, df=171, p<0.05). Spatial differences were also evident for EC (ANOVA, F²,167=9.414, p<0.05) and TC (ANOVA, F²,167=4.217, p<0.05). In particular, the mid-zone maintained significantly higher EC and TC densities over the 2014 wet period. The proportion of EC in the water sources in 2014 indicated a high percentage of EC in water in the upper zone (76-85%), mid-zone (76-83%) and downstream (62%). In 2017, there was some overall improvement in the upper (70-72%) and mid-zones (28-60%) but an alarming increase of up to 92% downstream. Specifically, in 2014 the overall aggregate mean %EC proportions in borehole, rain and river water were 57.3, 76.3 and 83.5 respectively. Further, in 2017, the aggregated mean %EC densities oscillated around the 60% mark with borehole water at 63.8%, rain water at 64.2% and river water at 60.8%.

To investigate pollution hotspots in the upper NRC, median densities of EC and TC at different locations in the 3 zones were compared for both seasons (Figure 2). As generally observed, bacteria densities were 1-2 log units lower in 2014. The EC count was 3≤EC<4 and 5<EC<6.5 log units in while TC recorded densities 4<TC<5 and 6<TC<7 log units 2014 and 2017 respectively. In 2014, Njokerio (mid-zone) recorded the highest EC (>3.5 log units) while the lowest EC count (<3.2 log units) was observed in Nessuit (upper zone). The highest TC count (>5.5 log units) was realised downstream (KALRO) although Nessuit water still had the lowest TC densities (< 3 log units). During the dry 2017 period, Ngondu (mid-zone) had the lowest EC counts (<1 log unit) although Njokerio improved being second highest after Kariobangi downstream (>6 log units). The dry season TC densities followed a similar pattern, lowest at
Ngóndu (5.5 log units) and peaked at Kariobangi (>6.5 log units). In general, water sources downstream had higher bacteria densities while the upper zone was less affected.

Table 22: Seasonal and temporal variability in mean values of physico-chemical parameters (except pH, given in range) of household water during the two sampling periods. SE = standard error. (--) = data not available.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Season: Wet - 2014</th>
<th>Upstream</th>
<th>Borehole</th>
<th>[n=14]</th>
<th>6.6-8.6</th>
<th>346.9</th>
<th>5.4</th>
<th>17.0</th>
<th>0.5</th>
<th>0.0</th>
<th>0.8</th>
<th>93.3</th>
<th>15.6</th>
<th>22.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>River</td>
<td>[n=13]</td>
<td>6.4-9.0</td>
<td>223.0</td>
<td>6.9</td>
<td>19.4</td>
<td>0.4</td>
<td>14.6</td>
<td>0.2</td>
<td>0.5</td>
<td>0.2</td>
<td>37.3</td>
<td>3.7</td>
<td>11.9</td>
</tr>
<tr>
<td></td>
<td>Rain</td>
<td>[n=46]</td>
<td>6.7-8.7</td>
<td>18.5</td>
<td>5.8</td>
<td>19.2</td>
<td>0.7</td>
<td>7.5</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>343.4</td>
<td>30.7</td>
<td>43.3</td>
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<tr>
<td></td>
<td>SE</td>
<td></td>
<td>0.8</td>
<td>0.1</td>
<td>1.3</td>
<td>1.4</td>
<td>0.1</td>
<td>58.3</td>
<td>6.7</td>
<td>7.0</td>
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</tr>
<tr>
<td>Zone</td>
<td>Season: Dry - 2017</td>
<td>Downstream</td>
<td>Borehole</td>
<td>[n=10]</td>
<td>6.6-8.3</td>
<td>393.3</td>
<td>6.6</td>
<td>20.7</td>
<td>1.9</td>
<td>9</td>
<td>1.5</td>
<td>158.8</td>
<td>31.2</td>
<td>153.2</td>
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<tr>
<td></td>
<td>River</td>
<td>[n=24]</td>
<td>6.5-8.4</td>
<td>100.1</td>
<td>5.4</td>
<td>18.4</td>
<td>0.7</td>
<td>5.6</td>
<td>0.5</td>
<td>128.2</td>
<td>8.4</td>
<td>38.2</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Rain</td>
<td>[(n=24)]</td>
<td>6.9-8.0</td>
<td>450.3</td>
<td>5.4</td>
<td>19.6</td>
<td>0.1</td>
<td>5.2</td>
<td>0.1</td>
<td>15.5</td>
<td>33.5</td>
<td>27.8</td>
<td></td>
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<td></td>
<td>SE</td>
<td></td>
<td>20.7</td>
<td>0.2</td>
<td>0.4</td>
<td>1.8</td>
<td>0.0</td>
<td>2.8</td>
<td>6.7</td>
<td>6.1</td>
<td></td>
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</tr>
<tr>
<td>Zone</td>
<td>Downstream</td>
<td>Borehole</td>
<td>[n=42]</td>
<td>5.6-8.8</td>
<td>565.3</td>
<td>5.6</td>
<td>21.0</td>
<td>4.6</td>
<td>6.6</td>
<td>0.5</td>
<td>48.2</td>
<td>61.0</td>
<td>74.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>River</td>
<td>[n=46]</td>
<td>6.1-8.7</td>
<td>108.9</td>
<td>5.6</td>
<td>19.1</td>
<td>0.6</td>
<td>1.1</td>
<td>0.1</td>
<td>17.3</td>
<td>6.8</td>
<td>7.3</td>
<td></td>
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<td></td>
<td>Rain</td>
<td>[n=40]</td>
<td>25.5</td>
<td>0.2</td>
<td>0.3</td>
<td>0.9</td>
<td>5.3</td>
<td>0.3</td>
<td>45.3</td>
<td>4.2</td>
<td>5.5</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td></td>
<td>115.0</td>
<td>0.1</td>
<td>0.4</td>
<td>6.6</td>
<td>0.2</td>
<td>0.1</td>
<td>25.0</td>
<td>3.6</td>
<td>15.7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Location-specific physico-chemical water quality
Hierarchical cluster analysis of seasonally and spatially-filtered data revealed shifting site-source cluster combinations for each period (Figure 3). In 2014, at a RDCC > 15, the quality of household water from rain and river from each zone was more or less similar and so much more between Nessuit upstream and Kariobangi downstream. These sites in addition to Ngóndu mid-zone and KALRO downstream formed cluster 1. In this cluster, river water quality at Nessuit (upstream) and Kariobangi (downstream) were closest during this season. Cluster 2 comprised rainwater upstream (Beeston) and borehole mid-zone (Njokerio) at RDCC > 20.

Table 23: Mean densities of Escherichia coli (EC) and Total Coliforms (TC) (log cfu. 100 ml⁻¹) in household water from 3 main sources across 3 zones in the upper Njoro River catchment in 2014 and 2017. SE=standard error; MAL = Maximum allowable limit. SE = standard error. (--) = data not available.
### Season: Wet - 2014

<table>
<thead>
<tr>
<th>Zone</th>
<th>Upstream</th>
<th>Midstream</th>
<th>Downstream</th>
<th>[log cfu. 100 ml⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Borehole n=43</td>
<td>Rain n=20</td>
<td>River n=13</td>
<td>n=9</td>
</tr>
<tr>
<td>EC [log cfu. 100 ml⁻¹]</td>
<td>2.98</td>
<td>3.71</td>
<td>3.38</td>
<td>3.01</td>
</tr>
<tr>
<td>SE</td>
<td>0.11</td>
<td>0.12</td>
<td>0.14</td>
<td>0.24</td>
</tr>
<tr>
<td>TC [log cfu. 100 ml⁻¹]</td>
<td>3.89</td>
<td>4.36</td>
<td>4.06</td>
<td>3.95</td>
</tr>
<tr>
<td>SE</td>
<td>0.09</td>
<td>0.09</td>
<td>0.17</td>
<td>0.19</td>
</tr>
<tr>
<td>% EC</td>
<td>76.5</td>
<td>85.2</td>
<td>83.4</td>
<td>76.1</td>
</tr>
</tbody>
</table>

### Season: Dry - 2017

<table>
<thead>
<tr>
<th>Zone</th>
<th>Upstream</th>
<th>Midstream</th>
<th>Downstream</th>
<th>[log cfu. 100 ml⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Borehole n=9</td>
<td>Rain n=8</td>
<td>River -</td>
<td>Borehole n=9</td>
</tr>
<tr>
<td>EC [log cfu. 100 ml⁻¹]</td>
<td>4.52</td>
<td>4.64</td>
<td>-</td>
<td>1.67</td>
</tr>
<tr>
<td>SE</td>
<td>0.87</td>
<td>1.01</td>
<td>-</td>
<td>0.83</td>
</tr>
<tr>
<td>TC [log cfu. 100 ml⁻¹]</td>
<td>6.39</td>
<td>6.43</td>
<td>-</td>
<td>5.80</td>
</tr>
<tr>
<td>SE</td>
<td>0.16</td>
<td>0.11</td>
<td>-</td>
<td>0.24</td>
</tr>
<tr>
<td>% EC</td>
<td>70.8</td>
<td>72.2</td>
<td>-</td>
<td>28.7</td>
</tr>
</tbody>
</table>

Figure 7: Median densities of Escherichia coli (EC) and Total Coliforms (TC) (cfu. 100 ml⁻¹) in household water from different locations in the upper Njoro River catchment during wet-2014 and dry-2017 seasons. Cluster Analysis of Household Water Quality

On the contrary, the dry 2017 season was distinctly characterised by sites clustered on 2 main sources of domestic water. Cluster 1 consisted of three locations extracted from each zone (Nessuit-upstream, Njokerio-midstream and Kariobangi-downstream) with borehole water as the common denominator.
However, Nessuit and Njokerio household water had closer physico-chemical quality in this cluster and overall at RDCC of 2. Alternately, cluster 2 followed the same zonal pattern but with different locations clustered on rainwater, Beeston (upstream) and Ngondu (midstream) exhibiting closer association in household water quality at RDCC of 5 compared to KALRO downstream.

![Figure 8: Wet (2014) and Dry (2017) season dendrograms illustrating the average linkage between locations based on household physico-chemical water quality in the upper Njoro River Catchment.](image)

**Location-specific Microbial Quality of Household Water**

In 2014, Nessuit (upstream) and Ngondu (mid-zone) with rain water sources were the most closely related at RDCC <5 but still clustered together with borehole water sources midstream (Ngondu) and downstream (Kariobangi) at RDCC >5 comprising cluster 1. Hence, in terms of microbial water quality, TC and EC densities in rainwater was similar to borehole sources for most households spatiotemporally in 2014. Household water from River Njoro at Njokerio and Beeston formed cluster 2 at RDCC>5.

During the 2017 dry weather, rain and borehole water sources location at upstream and downstream (KALRO, Beeston and Nessuit) associated closely at RDCC <5. These sites and sources plus Njokerio (Rain) and Ngondu (River) mid-zone, and Kariobangi (borehole) formed cluster 1 at RDCC of 14. Only Ngondu borehole water source comprised cluster 2 at RDCC >5 with the microbial water quality markedly different from the rest of the sites and sources in the upper NRC.

![Figure 9: Wet (2014) and Dry (2017) season dendrograms illustrating the average linkage between locations based on microbial quality of household water in the upper Njoro River Catchment.](image)

**DISCUSSION**

In rural and semi-urban river catchments, most riparian communities derive domestic water for varied sources which caters for multiple uses. In the NRC, domestic water abstracted or harvested from these
sources find uses including drinking, cooking, bathing, laundry, general cleaning and livestock watering (Yillia, 2008). Household water in the upper NRC is mainly derived from three sources viz. harvested rainwater (HRW) particularly during the long May-September and November-December short-wet seasons (Macharia et al., 2015), surface water from the considerably polluted Njoro River (Yillia, 2008) and groundwater from several boreholes. In general, for the three sources, most physico-chemical parameters were within the Kenyan (NEMA, 2006) and international (WHO, 2011) guideline values for domestic water. The results in this study, except for conductivity which unusually higher, concur with previous surveys on the quality of domestic water within NRC (Macharia, 2011; Macharia et al., 2015). Changes in water quality particularly limited oxygen and nutrients is known to affect bacterial densities due to die-offs more so during prolonged storage (Momba & Notshe, 2003). However, other predisposing factors may elevate the proportion of microbial densities during handling, transportation and storage (Wright et al., 2004; Macharia et al., 2015).

Microbial densities in household water were generally higher during the 2014 wet season particularly in river and rainwater compared to the 2017 dry period. Site specific analysis for seasonal variability of microbial quality indicators suggested loading during wet weather. The ambient levels of EC and TC increased significantly during 2014 wet weather in river water up to 83.5% in EC densities. In tropical regions, high intensity rainfall events are usually associated with high surface runoff which erode surface soil carrying debris and contaminants from agricultural catchments into surface water systems (Ouma et al., 2013). This, coupled with inadequate sanitation amenities and widespread livestock grazing in NRC serves as a major pathway of microbial contamination of surface with faecal matter from settlements and farmlands (Crowther et al., 2001; Mokaya et al., 2004; Jenkins, 2008).

Harvested rainwater (HRW) has traditionally been widely considered ‘safe’ for drinking and domestic consumption among rural communities (de Kwaadsteniet et al., 2013). However, in many cases, HRW is unsuitable for drinking prior to treatment (WHO, 2011) since up to 80.3 and 40.9% TC and EC densities have been detected in HRW (Sazakli et al., 2007). In addition, many categories of EC are pathogenically associated with intestinal and extra-intestinal infections (Ahmed et al., 2011a, 2011b). In the current study, %EC densities ranging from 57-84 in 2014 wet season and 60-64 in 2017 dry season are way above the WHO/NEMA zero-limit and still above the proportions documented elsewhere (Sazakli et al., 2007; Ahmed et al., 2011a).

Boreholes have been classified as ‘improved’ water sources under the WHO Joint Monitoring Programme (JMP) classification criteria (WHO/UNICEF, 2013). While it is well known that contamination may occur along the intake-transport-storage-consumption pathway (Bain et al., 2012), the JMP approach fails to account for these factors. In our study, %EC densities of 57 borehole water were lowest in 2014 and not significantly varied from other sources in the 2017 dry season. Noteworthy is the still high microbial densities in borehole outside the maximum allowable limits. Nevertheless, borehole water could be considered as relatively ‘improved’ compared to HRW and river water using the JMP criteria.

The microbial quality of borehole water can be compromised by unhygienic handling practices at the collection point, during transportation and retrieval for domestic use. For instance, Macharia et al. (2015) revealed a significant increase in EC densities in household containers compared to the point-of-collection (borehole). This could also be amplified by the unsanitary conditions in the household including unclean conveying and storage containers. Other critical factors include socio-economics (Macharia, 2011), post-collection water treatment mechanisms (Macharia et al., 2015) and domestic water-sanitation-hygiene (WASH) practices at household level (Jensen et al., 2002).

**CONCLUSION AND RECOMMENDATIONS**

Despite the physico-chemical water quality of household water being within acceptable limits, the microbial quality on the converse was far above the maximum allowable limits for domestic and even
treated wastewater (NEMA, 2006; WHO, 2011). From our study, we observed that household water quality is significantly influenced by the source-conveyance-storage pathway WASH practices at household level. At a spatial scale, water quality deteriorates downstream as well as between the POC and POU. Temporally, there is a higher likelihood of domestic water sources being contaminated during the wet season due to increased transportation of contaminants and vulnerability of these sources to external inputs of water. Therefore, it is paramount that all the above aspects be considered when designing and implementing WASH programmes in river catchments. Significant interventions could involve uninterrupted supply of piped water between POC and POU to eliminate unhygienic handling along the delivery chain. It would also be interesting to track the contaminants along the water supply and distribution networks in household water and determine the existing/potential remedial actions in response to the country’s National Environmental Sanitation and Hygiene Policy embedded in the Vision 2030 (NESC/MDP, 2013).

REFERENCES


MACROINVERTEBRATE SIZE CLASS DRIFT IN TWO KENYAN STREAMS DIFFERING IN THE INTENSITY OF ANTHROPOGENIC DISTURBANCES

M’Erimba, C. M.\textsuperscript{1}, Ouma, K. O.\textsuperscript{1}, Mathoka, S. K.\textsuperscript{1}, Nyaga, D. M.\textsuperscript{2} and Mureithi, P. W.\textsuperscript{1}

\textsuperscript{1}Department of Biological Sciences, Egerton University, P. O. Box 536, Egerton, Kenya
\textsuperscript{2}Department of Environment and Resource Development, Chuka University, P. O. Box 109-60400, Chuka, Kenya

merimba2010@gmail.com, 0728543191; kenochieng@gmail.com, 0722328316; skaveni@yahoo.com, 0722241854; nyagamwenda@yahoo.com, 0726828493; wangariprisca@gmail.com, 0711220000; E-mail: merimba2010@gmail.com

ABSTRACT

Drift is an ecological process prominent in lotic systems where living and dead organic matter is transported downstream by stream currents. Ecologically, it is regarded as a means of dispersal by newly hatched aquatic insect larvae and recovery of denuded spaces in streams after spates. It is also envisaged as a means of minimizing competition and predation. Light, water chemistry and discharge are some of the factors that govern drift. The objective of this study was to investigate macroinvertebrate drift in the Njoro (disturbed) and Ellegirini (relatively undisturbed) Rivers. Two 24 hr samplings were done in February 2012 in both rivers. Two drift samplers (mesh size, 100µm) were used, always maintaining exposure time at 15minutes. Drift densities were significantly higher in the Ellegirini than in the Njoro River (t-value = 7.246, \(P<0.01\)). In both rivers, invertebrates <1mm drifted in significantly high numbers than the >1mm (t-value, \(P<0.01\)). Diurnal and nocturnal <1mm drift densities were statically very highly significant in the Njoro River (\(P<0.001\)) whilst the > 1mm category was comparable (\(P>0.05\)). The opposite was observed in the Ellegirini River where <1mm drift densities differed significantly between the time of the day (\(P<0.001\)) but not with the >1mm (\(P>0.05\)). Chironomidae dominated both during the day and night samples in the Njoro River whereas simulidae and baetidae dominated day and night time drift samples in the Ellegirini River. It is concluded that invertebrate drift more in less disturbed than disturbed streams. Future drift studies should not ignore the <1mm category and also should explore the effect of varying exposure time and mesh size on drift densities.

Keywords: Diurnal, Nocturnal, Drift, Size Class, Rivers, Nets

INTRODUCTION

Streams and rivers are complex systems that are viewed in four dimensions, the lateral, vertical, longitudinal and temporal (Ward, 1989). The longitudinal dimension takes into consideration the flow of water and transport of materials from the source to the mouth. As such, abiotic and biotic characteristic exhibit a predictable pattern in a longitudinal manner (\textit{sensu} Vannote \textit{et al.}, 1980). One of the phenomenon associated with these systems that has elicited considerable interest to stream ecologist is drift. Drift is viewed as a passive downstream transport of stream–dwelling organisms due to their limited swimming ability (Grzbkowska \textit{et al.}, 2004; Thornton, 2008). However, the phenomenon has received little attention especially at the landscape and watershed level studies (Kannoje, \textit{et al.}, 2012).

Brittain and Eikland (1988) reviewed four main types of drift. The first one is catastrophic drift, which is usually associated with flood conditions during which the substrate is physically disturbed by high discharge. Other extreme factors, such as pesticides (Whiles & Wallace, 1995), changes in water temperature (Reisen, 1977) and sediment coring (Bretschko, 1990) can also induce drift. The second type is the behavioural drift usually attributed to different behavioural aspects. For example, animals may be dislodged from the substratum and enter the drift while foraging. They may actively enter the water column, for instance to escape from a predator (active drift). The third category is the distributional drift, which is envisaged as a method of dispersal, especially in the larval stages soon after hatching. A final category, constant drift, also called background drift, is where animals drift in low numbers due to accidental dislodgement from the substrate irrespective of any diurnal periodicity.

Drift is dependent on the changes in light intensity (Haney \textit{et al.}, 1983). Drift densities are higher during the night (nocturnal) than during the day (diurnal) with a major peak occurring shortly after sunset and a minor peak before dawn (Elliot, 1967; Allan, 1978; Palmer, 1992; Waringer, 1992). Studies carried in the
tropics have supported this observation e.g. Hynes (1975), Mathooko & Mavuti (1994). Depending on the drift density, an organism can either be a day or night drifter. Some species within the orders Ephemeroptera, Plecoptera and Diptera usually drift in high numbers during the night than during the day whereas hydracarina and some trichoptera are day drifters (Elliott, 1970; Benke et al., 1991; Thornton, 2008). Similar observations have been made in the tropics by Hynes, (1975) and Mathooko & Mavuti, (1994). Light is known to suppress drift even during the night with full moon (Bishop & Hynes, 1969). Nocturnal drift of stream invertebrates is regarded as an escape adaptation to the optically oriented predators such as fish (Allan, 1978; Mathooko, 1996). Drift pattern has been found to be a periodic in streams lacking fish (e.g. Flecker, 1992).

Drifting invertebrates are derived from the benthos and spend very little time in the water column (Scullion & Sinton, 1983; Palmer, 1992). Bretschko (1990) concludes that the number of drifting individuals depends on the absolute abundance in the sediments and on the severity of the perturbations, as well as its behaviour (escape reaction to perturbations). Among the habitats, riffles produce higher drift densities and biomass than pools (Hansen & Closs, 2007; Leung et al., 2009; Naman et al., 2017). Whereas drift in semi-pristine rivers may closely exhibit diel periodicity in some rivers, in relatively disturbed rivers the case could be different. In Africa, most rivers experience disturbances that are anthropogenic in nature owing to the high demand for water for domestic use. A classic example includes those described by Mathooko (2001) in the Njoro River, Kenya. The aim of this study was to investigate drift under two different conditions; one natural drift in a river that is less frequented by humans and domestic animals (the Ellegirini River) and two, drift from a river that is frequented by man and animals daily (the Njoro River). We hypothesized that drift densities from the two rivers are different.

MATERIALS AND METHODS

Study Rivers

The study was conducted during low flows in 2012 in the middle reaches of two second-order streams in the Kenyan Rift Valley with similar climate, geology and vegetation but differing in the intensity of anthropogenic activities on their banks and streambed (Table 1).

<table>
<thead>
<tr>
<th>Disturbance category</th>
<th>Njoro River</th>
<th>Ellegirini River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laundry</td>
<td>Present (10%)</td>
<td>Absent (0%)</td>
</tr>
<tr>
<td>Deforestation</td>
<td>Present (10%)</td>
<td>Present (5%)</td>
</tr>
<tr>
<td>Livestock watering</td>
<td>Present (25%)</td>
<td>Present (15%)</td>
</tr>
<tr>
<td>Sand harvesting</td>
<td>Present (15%)</td>
<td>Absent (0%)</td>
</tr>
<tr>
<td>Bathing</td>
<td>Present (10%)</td>
<td>Present (5%)</td>
</tr>
<tr>
<td>Water abstraction</td>
<td>Present (30%)</td>
<td>Present (10%)</td>
</tr>
</tbody>
</table>

The Njoro River (Fig.1C) has a catchment of approximately 250 km² (Osano, 2015) straddling between latitude 00°15´S, 00°35´S, and longitude 35°50´E, 36°05´E. It originates from the Mau Hills at about 2880 to about 1750 m a.s.l at the mouth where it discharges into Lake Nakuru, a Rift Valley Soda lake. The river is 55 km in length from the source to the mouth. Little Shuru (its main tributary) joins the river at an altitude of about 2293 m a.s.l. The middle course of the Njoro River is mainly dominated by Syzygium cordatum Hochst Ex Krauss (Mathooko & Kariuki, 2000) and is characterized by typical pool-riffle sequence, with soft substratum and bedrock cataracts in the pool and riffle sections respectively. The river experiences small-scale disturbances on daily basis along the entire length from people and livestock that come for watering (Mathooko, 2001; Yillia et al., 2008a, b).

The Ellegirini River (Fig.1B) has catchment area of about 80 km² (latitude 0°24.27´N to 0°29.2´N; longitude 35°27´E to 35°35´E). The river originates from the Kaptaget Forest at an altitude of about 2580
metres above sea level (m a.s.l) with the main tributary as Naiberi River. The river flows westwards for 27 km to the “Two Rivers Dam”, a man-made pool located at an altitude of about 2175 m a.s.l, which is also fed with discharge from the Endoroto River. The overflow of the Two Rivers Dam becomes the Sosian River whose discharge orientates in a westward direction. *Syzygium cordatum* dominates all other tree species such as *Pittosporum viridiflorum, Euclea spp.* in the middle reaches (M’Erimba et al., 2007, 2014). Physico-chemical characteristics of both rivers are summarized in Table 2.

![Map of Ellegirini and Njoro River study areas showing the study sites](image)

**Figure 1:** Map of Ellegirini and Njoro River study areas showing the study sites

**Table 2:** Physical and chemical variables measured in the Njoro and the Ellegirini Rivers during the study. Bolded values are means ± SE, n = 5

<table>
<thead>
<tr>
<th>Stream variables</th>
<th>Njoro River</th>
<th>Ellegirini River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>14.71 ± 0.95</td>
<td>14.47 ± 0.16</td>
</tr>
<tr>
<td>Conductivity (µs cm⁻¹)</td>
<td>138.94 ± 2.38</td>
<td>46.05 ± 2.69</td>
</tr>
<tr>
<td>Dissolved oxygen (mg l⁻¹)</td>
<td>8.9 ± 1.20</td>
<td>6.62 ± 0.28</td>
</tr>
<tr>
<td>% Oxygen saturation</td>
<td>99.2 ± 18.37</td>
<td>70.46 ± 7.58</td>
</tr>
<tr>
<td>pH</td>
<td>6.84 ± 0.11</td>
<td>6.28 ± 0.16</td>
</tr>
<tr>
<td>Velocity (m s⁻¹)</td>
<td>0.18 ± 0.04</td>
<td>0.21 ± 0.03</td>
</tr>
<tr>
<td>Discharge (m³ s⁻¹)</td>
<td>1.4 ± 1.12</td>
<td>2.75 ± 1.26</td>
</tr>
</tbody>
</table>
**Drift sampling**

Drift sampling commenced on 7th to 8th February 2012 in the Njoro River and 17th to 18th February 2012 in the Ellegirini River. Stream variables were measured prior to drift sampling. Conductivity was measured with a WTW-LF 90 conductivity meter. Dissolved oxygen and percentage saturation were determined using a WTW-OX 192 oxygen meter whereas pH and water temperature were determined using a combined WTW - pH 91 meter. Discharge was computed by determining the mean water velocity at 60% of the total water depth with a flow meter General Oceanics model 2030R along a cross-section in each stream. Two drift samplers were used in this case (65cm x 10cm x 30 cm). They were placed side by side on the first and second sampling dates at suitable points with fairly swift current at the Njoro River midstream (00°22.57’S, 35°56.27’E) and Ellegirini River midstream (00°27.05’N, 035°27.03’E) respectively, and secured to the stream bottom with iron rods. Since the fixing was combined with physical disturbance of hammering, sampling started an hour later (Bretschko, 1990). The flow meters (General Oceanic ‘Flo-mate’, model 2030R) attached to the drift samplers were filled with the stream water for lubrication using a syringe and then adjusted to 60% of the water depth. The samplers’ open ends (mouths) were covered with lids after taking the initial readings from the flow meters. They were then lowered into the water almost simultaneously and the cover (lids) removed. Exposure time was done for 15 minutes for every sample collected to avoid clogging of the nets.

After 15 minutes, the drift sampler mouths were closed, lifted up and hung on the metal rods. Final readings were noted down, drifting material collected in the cup at the rear of the net was removed by hand and kept in well-labeled polyethylene bags, then fixed with 4% formalin. This procedure was repeated almost immediately to collect subsequent samples. Approximately 144 samples were collected from each stream. The samples were then pooled into 2 hourly interval sets over 24-hour period to permit comparison with other drift studies. At the end of sampling, the samples were taken to the laboratory, washed through a series of sieves to remove formalin. Animals were counted under stereomicroscope (mag 400x), enumerated and identified to the lowest level possible and grouped into two categories, the > 1mm and < 1mm-sizes. Drift densities were determined as outlined by Leung *et al.* (2009) by first determining the amount of filtered water (Q, m$^3$s$^{-1}$) by multiplication of the water depth, breadth of sampler and the mean velocity (m s$^{-1}$). To determine drift densities (individuals per m$^3$), individual counts were divided by the total discharge.

**Data Analysis**

SPSS statistical software (version 20) was used in analyzing the data. Parametric test mainly t-test and one-way ANOVA were applied after performing log (x+1) transformation to test the differences in mean drift densities between the rivers as well as between the day and night drift samples as well as among the major macroinvertebrate groups. The null hypothesis (H$_0$) assumed that the mean drift densities were not statistically different among the groups and between the rivers as well as between the day and night samples respectively.

**RESULTS**

**Drift composition**

A total of 13 macroinvertebrate taxa drifted in both rivers. Ephemeroptera and Chironomidae dominated the other taxa at the Njoro River while Diptera mainly Chironomidae and Simuliidae dominated at Ellegirini River. The rest of the invertebrate groups drifted in low numbers including Collembola and ants that were of terrestrial origin. Potamonautidae, Amphipoda and Nematoda occurred only in Ellegirini River while Odonata was observed only in the Njoro River drift samples. Among the Ephemeroptera, genus *Afrocaenis, Baetis, Acanthiops* and *Afronurus* were collected in drift samples in both streams. *Baetis* dominated in the order ephemerotera in both rivers. Among the diptera group, of the 19 genera identified *Rheogricotopus, Polypedilum, and Rheotanytarsus* dominated in both streams. Simulids were mainly indets that were collected in drift samples in both rivers.
Macroinvertebrate drift density trends

Macroinvertebrate drift densities determined over 24 hr period in both rivers were 12.39 ± 0.51 individuals m\(^{-3}\) in the Njoro River and 38.86 ± 3.46 individuals m\(^{-3}\) in the Ellegirini River. The difference between these two values were very highly significant (t = 7.246, d.f. = 149, p < 0.001). In the Ellegirini River, two peaks were observed between 1400-1600hrs and 2000-2200hrs. A decline in drift density was observed from 2200hrs till midday of the following day when the experiment was terminated. A similar trend was observed in the Njoro River (Fig. 2).

Macroinvertebrate drift density trends between the size class greater than 1mm and less than 1mm for both rivers is depicted in Figure 3a. In the Njoro River, a clear difference between the two size classes was only evident during the day between 1200 to 1800hrs and 1000-1200hrs. In the Ellegirini River, the difference in drift density between the two size classes was observed throughout the sampling period over 24 hours. In the Njoro River, individuals that drifted were 5.70 ± 0.28 ind. m\(^{-3}\) in the > 1mm-size category while the < 1mm-size comprised 6.69 ± 0.34. These two values were statistically significant (t = 2.232, d.f. = 142, p < 0.05). In the Ellegirini River, the > 1mm drift densities were 9.16 ± 0.85 indiv. m\(^{-3}\) while the < 1mm-size category comprised 29.70 ± 2.87 indiv. m\(^{-3}\). These two values were statistically very highly significant (t = 6.865, d.f. = 156, p < 0.001).

![Figure 2: Diel drift densities at Ellegirini River and Njoro Rivers. Vertical bars are ± SE, n = 7 for Ellegirini and 6 for Njoro Rivers respectively.](image)

Day and night drift densities

Macroinvertebrate drift densities (pooled data) recorded in the Njoro River during the day was 14.24 ± 0.60 indiv. m\(^{-3}\)) while in the night was 10.65 ± 0.63 indiv. m\(^{-3}\). The difference in mean drift densities between day and night was statistically very highly significant (t = 3.591, d.f. = 70, p < 0.001). In the Ellegirini River the values obtained were 36.56 ± 6.25 and 40.99 ± 3.34 indiv. m\(^{-3}\) during the day and night respectively. Although drift densities in the Ellegirini River were higher during the night than during the day, the difference was not statistically significant (t = 0.637, d.f. = 77, p > 0.05). However, when drift was separated into > 1mm and < 1mm as indicated in Figure 3b in the Njoro River, the > 1mm category did not differ significantly between the mean drift densities collected during the day and night (t-test, p > 0.05). When the < 1mm size class category was considered, the difference in mean drift density
between day and night samples was statistically very highly significant (t-test, p < 0.001). The opposite was observed in the Ellegirini River (Fig. 3b) where the mean drift density in the size class > 1mm differed significantly between the day and night samples (t-test, p < 0.001). The mean drift density in <1mm size class category however, did not differ significantly between the samples collected during the day and night (t-test, p > 0.05).

In the Njoro River, Chironomidae drift densities were significantly higher during the day than during the night. The opposite was observed in the Ellegirini River (Table 3). Simuliidae drifted in significant numbers during the day in the Njoro River than during the night. However, in the Ellegirini River the mean drift densities were the same between day and night samples. Although drift densities in Baetidae did not differ significantly between the sampling times in the Njoro River, this group drifted in significantly high numbers during the night than during the day in the Ellegirini River. There was no difference in drift densities in nematods in both rivers irrespective of the time of the day. When the four groups were compared in the Njoro River during the day, the mean drift densities among the four groups was statistically very highly significant (One-way ANOVA, F(3, 156) = 150.66, p < 0.001). Chironomidae dominated the other three groups in day time samples (Tukey, HSD, α = 0.05) followed by Simuliidae, Baetidae and Nematoda. The same observation was made during the night where Chironomidae dominated the other groups. In the Ellegirini River, the difference in day time drift densities among the groups was statistically very highly significant (one-way ANOVA, F(3, 168) = 17.508, p < 0.001). Simuliidae dominated in drift samples (Tukey-HSD, α = 0.05) followed by Baetidae, Chironomidae and nematode. During the night however, Baetidae drifted in significant numbers in comparison to the other groups (Tukey, HSD, α = 0.05) followed by Simuliidae, Chironomidae and lastly nematodes.

Figure 3: Drift density trends (a) between the size classes in the Njoro and the Ellegirini Rivers over 24hr period. Comparison of mean drift densities between day and night (b) and the size classes in the Njoro and the Ellegirini Rivers. Vertical bars are ± SE, n = 45 for Njoro and 38 for Ellegirini Rivers respectively.
Table 3: Macroinvertebrate drift density (ind.m⁻³) between day and night at both Njoro and Ellegirini Rivers. Bolded values are means ± SE (in parenthesis), n = ranged from 31-40 in Njoro and 37-43 in the Ellegirini Rivers respectively. significance levels for the t-test are denoted by * P < 0.05, **p < 0.01, ***p < 0.001 and n.s = not significant.

<table>
<thead>
<tr>
<th>Group</th>
<th>Day</th>
<th>Night</th>
<th>t-value</th>
<th>Day</th>
<th>Night</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chironomidae</td>
<td>6.594</td>
<td>5.174</td>
<td>2.648*</td>
<td>3.345</td>
<td>5.236</td>
<td>2.671**</td>
</tr>
<tr>
<td></td>
<td>(0.403)</td>
<td>(0.316)</td>
<td></td>
<td>(0.052)</td>
<td>(0.648)</td>
<td></td>
</tr>
<tr>
<td>Simuliidae</td>
<td>5.130</td>
<td>3.271</td>
<td>4.386***</td>
<td>18.574</td>
<td>13.462</td>
<td>1.337ns</td>
</tr>
<tr>
<td></td>
<td>(0.337)</td>
<td>(0.206)</td>
<td></td>
<td>(0.519)</td>
<td>(0.954)</td>
<td></td>
</tr>
<tr>
<td>Baetidae</td>
<td>0.661</td>
<td>0.606</td>
<td>0.599ns</td>
<td>9.044</td>
<td>19.182</td>
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</tr>
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<td></td>
<td>(0.068)</td>
<td>(0.057)</td>
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<td>(0.138)</td>
<td>(1.706)</td>
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<tr>
<td>Nematoda</td>
<td>0.029</td>
<td>0.037</td>
<td>0.890ns</td>
<td>2.014</td>
<td>1.019</td>
<td>1.323ns</td>
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<td></td>
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<td>(0.007)</td>
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<td>(0.103)</td>
<td>(0.144)</td>
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</tr>
</tbody>
</table>

In the Njoro River Chironomidae, Simuliidae and Nematoda drift densities were significantly higher during the day in the size class < 1mm except in Baetidae where drift densities were significantly higher in the size class > 1mm. The same trend was repeated during the night (Table 4). In the reference stream (Ellegirini), the size class < 1mm drifted in significant numbers in all the major taxonomic groups during the day. The same trend was observed during the night except in Baetidae where drift densities in size class > 1mm were significantly higher than the < 1mm. When the size class > 1mm was considered alone, Chironomidae, Simuliidae and Baetidae drift densities did not differ significantly between day and night samples (t-value, p > 0.05) in the Njoro River. Nematodes were only observed in night samples in this size class. In the Ellegirini River, all the groups were represented in this size class both during the day and the night. Simuliidae and Baetidae > 1mm drifted in significant numbers during the day than during the day (p, < 0.001). The other two groups did not differ significantly between the mean drift densities in this size class. When the size class < 1mm was considered, significant differences in mean drift densities were observed between the day and night in Chironomidae and Baetidae in the Njoro River. Drift density were higher during the day than during the night (t-value, p < 0.001) in the Ellegirini River, Chironomidae and Baetidae < 1mm drifted in significant numbers during the day than during the night while Simuliidae and nematodes drifted in significant high numbers during the night than during the day (p, < 0.001) in the same size class.

DISCUSSION

Studies on benthos in the Njoro River started way back in 1994 by Leichtfried and Shivoga, (1995). Subsequent studies focused on organic matter inputs (e.g. Magana, 2001) and anthropogenic disturbances on the banks and within the stream channel (Mathooko, 2001). An in-depth description of the riparian vegetation in the catchment of this river is provided by Mathooko & Kariuki (2000). Njoro (disturbed) and Ellegirini (less disturbed) Rivers are similar in respect to geology, vegetation, land use/land cover except that Njoro River experiences frequent and daily longitudinal anthropogenic disturbances at a small-scale. Ellegirini River, a fast-flowing river, is less disturbed both on banks and streambed and recorded lower conductivity values but higher current velocities and discharge (Tables 1 and 2).

Contrary to our expectation, drift densities were three-fold higher in the Ellegirini River than in the Njoro River. The reference stream recorded higher velocity and discharge than the study stream. Imbert & Perry (2000) observed increased drift densities with increase in discharge in a manipulated experiment where stepwise and abrupt increase in flow caused significant increase in drift. Similar observations were made by Miller & Judson (2014) in Green River, Colorado, USA, where drift increases were proportional to peak magnitude, with drift biomass peaking during the rising limb of the hydrograph and declining prior to the cessation of peak flows. Bretschko (1990) concluded that the number of drifting individuals was a
reflection of the absolute abundance in the sediments. In a separate study, M’Erimba et al. (2014) established that benthic densities in the Ellegirini River were significantly higher than in the Njoro River. This was attributed to the levels of physical disturbances that were intense on the sediment surface of the Njoro River compared to the Ellegirini River. Equally, diversity of invertebrates was higher in the Ellegirini River. Drift in both rivers was dominated by Chironomidae, Simuliidae and Baetidae. Occurrence of the three families in high numbers in drift observed in this study is consistent with other studies e.g. Bass (2004) and Kennedy et al. (2014).

### Table 4: Macroinvertebrate size class > 1mm and < 1 mm-size drift densities (ind. m⁻³) between day and night at both the Njoro and Ellegirini Rivers. Bolded values are means ± SE (in parenthesis), n = ranged from 36 - 38 in Njoro and 38-41 in the Ellegirini Rivers respectively. Probability levels (t-test): are denoted by * P < 0.05, **p < 0.01 and ***p < 0.001 and n.s = not significant.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>NJORO RIVER</th>
<th>DAY</th>
<th>NIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 1mm</td>
<td>1mm</td>
<td></td>
</tr>
<tr>
<td>Chironomidae</td>
<td>0.720</td>
<td>9.570</td>
<td>12.088***</td>
</tr>
<tr>
<td></td>
<td>(0.102)</td>
<td>(0.705)</td>
<td></td>
</tr>
<tr>
<td>Simuliidae</td>
<td>0.412</td>
<td>0.844</td>
<td>3.732***</td>
</tr>
<tr>
<td></td>
<td>(0.057)</td>
<td>(0.097)</td>
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</tr>
<tr>
<td>Baetidae</td>
<td>9.344</td>
<td>3.585</td>
<td>8.760***</td>
</tr>
<tr>
<td></td>
<td>(0.572)</td>
<td>(0.287)</td>
<td></td>
</tr>
<tr>
<td>Nematoda</td>
<td>0.000</td>
<td>0.058</td>
<td>4.470***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.013)</td>
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<table>
<thead>
<tr>
<th>Taxa</th>
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<th>NIGHT</th>
</tr>
</thead>
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<tr>
<td></td>
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<td>1mm</td>
<td></td>
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<tr>
<td>Chironomidae</td>
<td>3.305</td>
<td>28.193</td>
<td>8.352***</td>
</tr>
<tr>
<td></td>
<td>(0.392)</td>
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<td>4.981</td>
<td>12.317</td>
<td>4.975***</td>
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<td>(0.806)</td>
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<td>1.541</td>
<td>5.004</td>
<td>4.635***</td>
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<td>(0.725)</td>
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<td>0.167</td>
<td>4.088</td>
<td>2.779**</td>
</tr>
<tr>
<td></td>
<td>(0.126)</td>
<td>(1.405)</td>
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Organisms that drifted tended to behave in a particular manner depending on the stream. In the Njoro River, Chironomidae and Simuliidae drifted in significant high numbers during the day than at night which was not the case with Baetidae and nematodes where drift densities were comparable between day and night samples. In the Ellegirini River, Chironomidae and Baetidae drifted in significant numbers during the night. On the contrary, Simuliidae and nematode drifted in equal numbers irrespective of the time of the day. Presence or absence of organisms in drift is dependent on several biotic and abiotic factors as well as the behavior of individual taxa. The disparity observed in drift densities between the two rivers and among specific taxa, and the fact that inconsistencies were observed when specific families were considered could be attributed to the differences in abiotic factors like discharge (e.g. Kennedy et al., 2014) and conductivity. Njoro River recorded high conductivity values but low discharge in comparison to Ellegirini River. The difference could as well be attributed to other factors that were over looked by the current study such as conditions of the stream channel and the behavior of organisms themselves. Recent study by Hansen & Closs, (2007), Leung et al. (2009) and Naman et al. (2017) indicated that the channel structure, in this case riffles determined the quality and quantity of drifting invertebrates. de Brouwer et al., (2017) was also able to demonstrate that a species of trichoptera was able to actively return to the substrate on dislodgement by high currents an ability that could be lacking in
other taxa that exhibited inconsistencies in drift pattern. Bass, (2004) observed that dipterans were aperiodic and drifted in consistent numbers in Check Hall River in Caribbean Island of Dominica.

Invertebrates in the size class < 1mm drifted more in both rivers in comparison to > 1mm irrespective of the time of the day. Since drift densities depend on the absolute macroinvertebrate numbers in benthos (Bretschko, 1990), most likely this is attributed to size class proportions on stream sediments. Mbaka et al., (2014) working on Honi River in Kenya observed that size class < 0.5mm constituted 85% of benthic densities. It was observed that size class > 1mm drift densities did not differ significantly between day and night samples in the Njoro River while the < 1mm category drifted in significant numbers during the day. Surprisingly, the > 1mm size class drifted in significant numbers during the night in the Ellegirini River. Mean drift densities in the size class < 1mm were statistically the same between day and night samples in the same river. The fact that specific size class in each taxon drifted differently in both rivers and at specific time of the day could have complicated drift patterns in the two rivers. Other factors that were not subject of this study could be the influence of predators in each river. Malmqvist & Sjöström (1987) observed that drift was size-dependent in Baetis rhodani and other taxa in the presence of predacious stone fly in a Swedish stream. McIntosh et al. (1999) established that mayfly nymphs of different sizes reacted differently in the presence of fish odour (chemical cues mimicking predacious trout) in East River in the Colorado Rocky Mountains. Koetsier & Bryan (1992) noted a diel, size-differential drift patterns of three macroinvertebrate species in the lower Mississippi River, Louisiana (USA). The authors observed that drifting organisms exhibited temporal variability. In the same study, large individuals of Hydropsyche orris and Hexagenia limbata were prevalent in the nocturnal but scarce in the diurnal drift in January and April, 1985. In January, large Macrobacticium ohione drifted regardless of time while in April, large M. ohione predominated the nocturnal drift.

CONCLUSIONS AND RECOMMENDATIONS
Invertebrates drift more during the day than night in streams that experience daily physical disturbances on moreso the size class < 1mm dominate drift in rivers. Diel drift densities are taxa-dependent and could be complicated by other underlying factors. It is therefore recommended that future studies on drift should not ignore the size of organisms drifting and should also consider more than two streams. Further, the importance of employing drift as a biomonitoring tool in future should be considered.

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<table>
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<tr>
<th>Treatment</th>
<th>Inter-row spacing (cm)</th>
<th>Fertilizer applied (units ha(^{-1}))</th>
<th>Number of plants ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
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<td>90</td>
<td>0</td>
<td>37,037</td>
</tr>
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<td>S1F4</td>
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<td>20 kg P(_2)O(_5)</td>
<td>37,037</td>
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<tr>
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<td>75</td>
<td>20 kg P(_2)O(_5)</td>
<td>44,444</td>
</tr>
</tbody>
</table>

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![Figure 5: Monthly income from sale of pumpkin fruits by farmers](image)

Plate 1: Pumpkin fruits and leaves

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