SOKOINE UNIVERSITY OF AGRICULTURE

TRANSFORMING AGRICULTURE AND NATURAL RESOURCES FOR SUSTAINABLE DEVELOPMENT TO ATTAIN INDUSTRIAL ECONOMY IN TANZANIA

DIRECTORATE OF POSTGRADUATE STUDIES, RESEARCH, TECHNOLOGY TRANSFER AND CONSULTANCY

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Proceedings of Scientific Conference on Transforming Agriculture and Natural Resources for Sustainable Development to Attain Industrial Economy in Tanzania

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PREFACE

We are privileged to publish the Proceedings of SUA Scientific Conference on 'Transforming Agriculture and Natural Resources for Sustainable Development to Attain Industrial Economy in Tanzania'. The conference was organised by Sokoine University of Agriculture (SUA) to commemorate and honour the life and legacy of the late Hon. Edward Moringe Sokoine, former Prime Minister of the United Republic of Tanzania which was held from 10th to 11th April, 2019 at SUA Main Campus grounds. The proceedings is an output of this scientific conference which serves as a platform to share the knowledge, innovations, solutions, and findings generated by researchers based at SUA as well as those from other national and international partner and collaborating institutions outside SUA.

The Proceedings is organised to cover major sub-themes of the conference namely: Agro-processing and Agro-ecology for Food Security and Economic Growth; Sustaining animal health and livestock productivity; Sustainable environment, natural resources management and tourism; Trade, socio-economic transformation for improved agricultural productivity and Livelihood and Education for skills development and entrepreneurship.

We take this opportunity to thank all contributors, from within and outside SUA, who made efforts to prepare high quality articles published in this proceedings. We appreciate support received from Senate Research and Publication Committee members, Editors of SUA-hosted journals i.e. Tanzania Journal of Agricultural Sciences (Prof. C.N. Nyaruhucha), Tanzania Journal of Forestry and Nature Conservation (Late Prof. S. Iddi-RIP); Tanzania Veterinary Journal (Dr. A.B. Matondo), Prof. J.K. Urassa from the College of Social Sciences and Humanities, and coordination team of Dr. D. Ndossi, Dr. N. Amuri and Ms. L. Madalla during preparations of this proceedings. The Management of Sokoine University of Agriculture is thanked for financial and materials support during organisation of the SUA scientific conference. We recognise generous support from different research projects during conference organisation and production of this proceedings.

I hope that you will find the proceedings to be a useful resource in terms of education and enrichment of your knowledge. Enjoy reading the proceedings!

Prof. E.D. Karimuribo

(Chairman- SUA Scientific Conference)

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Effect of Solar Drying Methods on Total Phenolic Contents, Antioxidant Activity and Vitamin C of Selected Fruits and Vegetable in Tanzania

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Abstract

The effect of different solar drying methods; cabinet direct, cabinet mixed mode and tunnel dryers on total phenolic contents (TPCs), antioxidant activity and vitamin C contents of selected varieties of mango (Dodo, Viringe and Kent), banana (Kisukari, Kimalindi and Mtwike) and tomato (Tanya, Onyx, and Cal J) were investigated in this study using Folin-Ciocalteu reagent, Ferric Reducing Antioxidant Power (FRAP) and High Performance Liquid Chromatography (HPLC) methods respectively. There were significant (p<0.05) variations in TPC (mg GAE/100 g DM), FRAP (µmol/100 g DM) and vitamin C (mg Lasc/100g DM) among the fresh fruits and vegetable samples. The highest TPC (476.6±8.6-538.9±1.4), FRAP (44 .6±1.6-46.8±0.5) and vitamin C (115.1±1.6-26.8±0.5) were in tomato and respective lowest values of 139.3± 2.3-189.2±2.7, 10.8±0.1-15.8±0.2 and 28.3±0.0-29.1±0.0 were in banana. Drying methods had significan t (p<0.05) effect on all parameters assessed. All fresh samples had higher levels but declined significantly in dried samples with exception of tunnel dried tomatoes. Among the dried samples, the tunnel dried samples had higher TPC recovery of 75-125%, FRAP of 78-96% and vitamin C of 6.9-54.4% than cabinet dried samples with respective lower values of 57-95, 44-86 and 3.2-24%. No significant (p>0.05) variations were observed between the cabinet dryers. Moreover, the percentage recoveries differed significantly (p<0.05) in all parameters between the varieties within the fruits/vegetable and drying methods. Therefore, this study has revealed that, solar drying methods have varied low to moderate effects on total phenolic contents and antioxidant activities of selected mango, banana and tomato varieties with tunnel dryer giving significantly higher percentage recovery than cabinet dryers. However, the methods have severe effect on vitamin C contents of dried fruits and vegetables. Application of solar drying technology especially tunnel dryer for processing of fruits and vegetables into shelf life stable dried products rich in antioxidant activities for household consumption and income generation is highly recommended.

Key words: *Solar drying, Total Phenolic contents, Antioxidant, Vitamin C*

Introduction

Fruits and vegetables are of greater nutritional and health importance as they provide essential vitamins, minerals, carbohydrate, fibers and phytochemicals such as phenolic compounds and carotenoids that have been found to possess antioxidant activity within in vitro assays (Galanakis, 2017;Kasote, 2015; Slavin and Lloyd, 2012).Various epidemiological studies have shown that consumption of adequate amount of fruits and vegetables have been associated with reduced risk of some major diseases such as cardiovascular, diabetes, hypertension, certain types of cancer and some of the degenerative diseases (Boeing*et al.*, 2012; Segura-Carretero*et al.*, 2010). Theprotective role of fruits and vegetables has been ascribed to their antioxidant capacities which scavenge and reduce the amount of free radicals in the human body(Alfatemi, 2013). The free radicals and reactive oxygen species (ROS) such as superoxide (O2-), hydrogen peroxide (H2O2), or peroxynitrite (OONO-) are potent genotoxinsgenerated endogenously through aerobic respiration and can adversely

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affect various important biological molecules such as nucleic acids, lipids, and proteins, thereby altering the normal redox status leading to increased oxidative stress, and mutation (Periyasamy, 2015). Vitamin C is essential for life and is considered as potent water-soluble antioxidant which found mainly in fruits and vegetables due to its reducing properties, which allow it to essentially eliminate the threat of free radicals (Reaver, 2015).In addition to its antioxidant properties, vitamin C also plays a role in controlling infections such as to enhance resistance to upper-respiratory-tract infections; production of collagen tissues needed bones, blood vessels, teeth, and gums as well as to reduced inflammation in individuals who have elevated inflammation levels (Peleg *et al*., 2016; Braun, 2013). Therefore, adequate daily consumption of fruits and vegetable is an important health-protecting factor (Pem and Jeewon, 2015; Wijngaard, 2009). A daily intake of at least 400 g of fruits and vegetables has been recommended by experts (FAO/WHO, 2003).

However, despite their nutritional and health benefits, fruits and vegetables are highly seasonal and perishable resulting into huge postharvest losses estimated to range between 50-70% in developing countries, like Tanzania (KarimandHawlader, 2005). Poverty, inadequate postharvest handling techniques, improper processing technology and storage facilities, poor infrastructure and marketing systems are among the most important factors for the high loss (Perumal, 2007). Drying as one of the important food preservation methods, it reduces moisture content to levels that allow safe storage over an extended period, prevent activity of deteriorative enzymes, and prevent the growth of mould and fungi and thus minimizing microbial degradation (Chong and Law, 2010; Doymaz, 2011). Open sun drying is a well-known and most practiced drying method for drying agricultural produces in tropical and sub-tropical. However, the quality of its products is questionable due to its low drying kinetics, coupled with high susceptibility to contamination from dust, soil, sand particles and insects (Dhumne*et al*., 2015; Patel *et al*., 2013). Application of solar energy for drying seems to offer an alternative way to open sun drying for drying agricultural produces in developing countries. Solar energy is one of the most promising renewable energy sources in the world because of its abundance, inexhaustible and non-pollutant in nature compared with higher prices modern drying technologies (Patel *et al*, 2013). However, solar drying has been reported to affect vitamins, total phenol and their antioxidant activity of fruits and vegetables diversely if not well done (Chantaro *et al*., 2008; Kuljarachanan *et al*., 2009). Information on the effect of solar drying methods on total phenolic, antioxidant activities and vitamin C of dried mango, banana and tomato varieties is limited. This study therefore, carried out to study to establish the missing information.

Material and Methods

Study areas

This study was carried out at Sokoine University of Agriculture (SUA), Morogoro, Tanzania and Norwegian University of Life Sciences (NMBU), Aas Norway. Drying activities were conducted at SUA while chemical analyses were carried out at NMBU.

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Plant materials

Mango (Dodo, Viringe and Kent), banana (Kisukari, Malindi and Mtwike) and one tomato (cv. Tanya, Cal J and Onyx) were procured at physiological maturity and ripeness from selected farmers in Morogoro.

Solar dryers

Two solar cabinet dryers: Direct and mixed modes were locally fabricated and one Hoenheim solar tunnel dryer (Innotech, German) was imported and installed in the study area. The dryers consisted of two parts namely collector and a drying unit/tunnel. In addition, the tunnel dryers consist small fans to provide the required air flow over the products to be dried. The CDD had collector dimension of (1.17 x 2.35 m) and drying section of 0.67 x 1.44 x 2.29 m respectively while the d CMD had collector dimension of 1.03 x 1.16 plus 90 x1.16 m for extension and drying section of 1.13 x 1.19 x 1.23 plus 0.99 x 1.23 m for extended part. The tunnel dryer had dimension of 7.1 x 2 m and 10 x 2 m for collector and drying chamber respectively (Plate 1). Both collector and the drying units were covered with UV stabilized visqueen sheets and food grade black paint was used as an absorber in the collectors. The products to be dried were placed in trays in cabinet dryers and a single layer on a wire mesh in the tunnel dryer.

Plate 1. Different solar dryers used in the study: (A) Cabinet direct dryer-CDD, (B) Cabinet mixed mode dryer-CMD and (C) Hoeinheim Tunnel dryer-TD.

Chemicals

Methanol, acetonitrile, acetic acids, FeCl3.6H2O, FeSO4.7H2O, anhydrous sodium carbonate, were obtained from Merck KGaA (Darmstadt, Germany), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 2,4,6-tri(2pyridyl)-s-triazine (TPTZ) were obtained from FlukaChemie GMBH (Buchs, Switzerland). Folin-Ciocalteu phenol reagent (2.0, N), 3, 4, 5,-Trihydroxybenzoic acid (Gallic acid) were bought from Sigma-Aldrich (St Louis, MO, USA). Liquid nitrogen was supplied by Hydro Gas and Chemicals AS (Oslo, Norway). All chemical and gases were of analytical grade.

Research designs

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Completely randomized design (CRD) was used in the study and principal factor was solar drying method (Local cabinet direct dryer (CDD), cabinet mixed mode (CMD) and Tunnel dryer (TD). The samples were analyzed for dry matter, total phenolic contents, antioxidant capacity and vitamin C contents. The effect of the principal factor on these parameters was determined. The mathematical expression is shown in Equation 1

$y_{ij} = \mu i + \tau_i + \varepsilon_{ij}$ ……(Eq1)

i=1,2,..., t, j=1,2,...,ni

Where μis the overall mean, τi is ith treatment effect and εij is the random effect due to jth replication receiving ith treatment.

Drying process

The drying to assess performance of the dryers in retaining phytochemicals was done following methods described by Leon *et al*. (2002). Fresh mature ripe fruit and vegetable samples were washed, peeled and sliced to 5 mm thick and each sample divided into three portions that were subjected in equal loading density of 2.91 kg of fresh produce/m 2 of solar aperture to either cabinet direct dryer (CDD) with temperature ranging from 30-55°C for about 3 days, cabinet mixed dryer(CMD) with temperature ranging from 25-49°C for about three days and tunnel dryer (TD) with temperature ranging from 60-73°C, for about two days. Since solar drying solely depends on weather conditions, these temperatures were not pre-set but obtained during drying process and samples were offloaded from dryers after predetermined duration. The dried products were packed in polyethylene bagsand stored at -4°C prior to laboratory analysis

Determination of dry matter

Dry matter contents of fresh and dried products were determined in triplicate according to the standard methods of AOAC (1995). Five grammes of samples were put in pre-weighed crucibles and oven dried at 105°C for 24 hours until constant weight was achieved.

Sample extraction and preparation for phytochemical analyses

Three grammes of each sample was diluted in 30 ml of methanol and sonicated at 0°C for 15 min in an ultrasonic bath (Model 2510, Branson Ultrasonics Corp, USA). The sample was then flushed with nitrogen in order to prevent oxidation and stored frozen at -20°C prior to analysis. During analysis, the homogenate was centrifuged at 31,000g for 10 min at 4°C using a Beckman J2-21M/E centrifuge (GMI Inc., Ramsey, MIN, USA). The supernatant was decanted and subjected to analysis of total phenols and antioxidant power. All samples were extracted in duplicate and analyzed in triplicate.

Determination of total phenolic contents (TPC)

Total phenolic content was determined using a Konelab 30i (Thermo Electron Corp., Vantaa, Finland) clinical chemical analyser. The procedure was based on using the Folin-Ciocalteureagent (FCR), as described by Singleton*et al*. (1999). A 20 µl sample were added to 100 µl FCR (diluted 1:10 with distilled water), mixed and incubated at 37°C for 60 seconds prior to addition of 80 µl 7.5% (w/v) sodium bicarbonate solution. The samples were automatically mixed incubated at 37°C for 15 minutes prior to absorbance reading at 765 nm.

TPC were assessed against a calibration curve of gallic acid, and the results presented as mg gallic acid equivalents (GAE) per 100 g dry weight (DW)

Determination of Ferric Reducing Antioxidant Power (FRAP)

Antioxidant activity in the samples was measured using the ferric reducing ability of plasma (FRAP) assay described by Benzie and Strain (1996)using the KoneLab 30i (Kone Instruments Corp, Espoo, Finland). Briefly, 200 µl of the FRAP reagents (3.0mM acetate buffer, 10mM TPTZ in 40 mMHCl, 20 mM FeCl3.6H2O, ratio 10:1:1) were automatically pipette separately and mixed in the cuvettes; 8 µl of sample were added and mixed and left to incubate at 37°C for 10 minutes and absorbance read at 595nm. Trolox (Vitamin E analogue) was used as a control. The antioxidant activity in the samples was calculated as mmol Fe2+ per 100 g dry matter.

Vitamin C (L-ascorbic acid) analysis

Vitamin C determination was performed as described by Wold*et al*. (2004) using HPLC. Fifty grams of samples were added to 100 ml 1.0% (w/v) oxalic acids and homogenized for 1 minute using a Braun MR 400 hand processor, then filtered through a Whatman 113 V folded filter (Whatman International Ltd., Brentford, UK) then applied onto a activated (5 ml methanol + 5 ml water) Sep-Pak C18 from Waters Corp. (Milford, MA, USA). The three ml was discarded and the eluent to be analyzed by HPLC was filtered through a 0.45 µm (VWR) prior to injection. All samples were analyzed in duplicate and injected in triplicate. Isocratic HPLC separation and detection were performed according to Williams *et al*. (1973) using an Angilent 1100 Series LC system (Agilent Technologies, Waldbronn, Germany) equipped with a quaternary pump, an inline degasser, an auto sampler, a column oven and a UV detector. The separation was conducted with a Zorbax SB-C18 (250 X 4.6 mm, 5 µm) column with a complementary Zorbax XDB C18 (4 x 4 mm, 5 µm) guard column, Agilent Technologies (Waldbronn, Germany). Injection volume was 5 µl, the flow was 1 ml min-1 of 0.05 M KH2PO4 at 25 ^{o}C and detection was performed at 254 nm. Vitamin C was quantified by external calibration and results were reported as mg L-AA acid per 100 g DM.

Statistical analysis

Data obtained was analyzed in triplicates using analysis of variance R statistical software ((R Development Core Team, Version 3.0.0 Vienna, Austria). One way analysis of variance (ANOVA) was done to determine significant differences between factors. Means were separated by Turkey Honest Significant Difference (THSD) at $p<0.05$. Pearson correlation coefficient was done to determine the relationship between TPC and FRAP. Principal component analysis (PCA) was done to determine systematic variation between variables.

Results and Discussion

Dry matter content

Contents of dry matter in fresh and dried samples are shownin Table 1. There were significant ($p<0.05$) variations in dry matter contents between fresh and dried samples and within the drying methods. Dry matter contents of all fresh samples increased significantly ($p<0.05$) from 19.1±0.29 - 21.0 % to 85.0-86.0 in mango varieties and from 7.7-8.0 to 88.3-88.9

in tomato varieties. The increase was more pronounced in tunnel dried samples. No significant (p>0.05) variation was observed in dry matter contents between the cabinet direct and mixed mode dryers.

Table 1.Dry matter content (%) of fresh and dried fruits and vegetable varieties of three solar drying methods

Fruit/veg.	Cv.	Drying method			
		Fresh	CDD	CMD	TD
Mango	*Dodo*	21.0±0.0 [a]	83.5±0.01[b]	84.0±0.02[b]	86.0±0.49[c]
	Viringe	20.9± 0.3[a]	83.6±0.01[b]	83.8±0.02[b]	85.9±0.06[c]
	Kent	19.1±0.29[a]	82.2±0.0[b]	82.51± 0.01[b]	85.0±0.13[c]
Banana					
	Kisukari	29.2±0.5[a]	83.4±0.17[b]	83.3±0.16[b]	86.1±1.5[c]
	Kimalindi	28.3±0.46[a]	82.2±0.09[b]	82.2±0.24[b]	86.0±2.3[c]
	Mtwike	28.6±0.62[a]	82.3±0.10[b]	82.9±0.03[b]	84.7±2.12[c]
Tomatoes					
	Tanya	7.8±0.13[a]	85.5±0.01[b]	85.8±0.02[b]	88.9±0.00[c]
	Cal J	7.7±0.00[a]	85.6±0.00[b]	85.4±0.00[b]	88.3±0.01[c]
	Onyx	8.0± 0.00[a]	85.7±0.00[b]	85.1±0.14[b]	88.9± 0.01[c]

Data presented as arithmetic means ± SD (n = 3).
Means in row with different small letter are significantly different (p<0.05) between drying methods for the same variety

Drying significantly reduces moisture contents of food materials and causes changes in dry matter contents. observed thatthat the moisture content within biological samples changes during drying and can result in the release of organic compounds, volatile organic compounds (VOCs), destruction of pigments, and changes in chemical composition(Lefsrud*et al.*, 2008; Eze and Akubor(2012). The higher dry matter content in tunnel dryer than in cabinet dryers could be associated with its high drying temperature which caused more moisture release in addition to the release of other of organic compounds.

Total phenolic contents

The mean total phenolic compounds (TPC) of fresh and dried fruit and vegetable varieties are shown in Table 2. Fresh tomato sample varieties had significantly higher TPC value ranged from 448 to 538 than Mango samples varieties with values ranged from 239 to 315mgGAE/100g DM).The level of polyphenolic compounds present in fruits and vegetable depends on cultivar, growth condition (soil, fertilizer, temperature, and cultivation techniques), storage and transport conditions and processing technology (Bennett *et al.*, 2010). The effect of drying methods on TPC was significant (p<0.05) with all fresh samples having higher TPC levels but declined significantly in dried samples with exception of tunnel dried tomatoes. No significant differences were found between the cabinet direct and mixed modes of drying (p>0.05).

Table 2. Total phenolic contents (mgGAE/100g DM) of fresh and dried fruits and vegetable varieties of three solar drying methods

Fruit/Veg	Variety	Drying method Fresh	CDD	CMD	TD
Mango	***Dodo***	315.3±5.4 [a]	261.3 ± 6.7 [b]	263.4 ± 3.1 [b]	91.8 ± 5.4 [c]
	Viringe	311.4±1.5 [a]	261.6 ± 1.3[b]	259.2 ± 3.8[b]	92.9 ± 0.6 [c]
	Kent	239.4±7.9 [a]	184.3 ± 1.8 [b]	181.1 ± 0.8 [b]	01.5 ± 4.4 [c]
Banana	***Kisukari***	139.3±2.3[a]	81.2 ± 0.5 [b]	83.0 ± 0.8 [b]	05.96 ± 2.1 [c]
	Kimalindi	189.2±2.7[a]	116.9 ± 0.8 [b]	118.1 ± 1.5 [b]	45.90 ± 6.4 [c]
	Mtwike	173.6±4.2[a]	98.5 ± 0.4 [b]	100.3 ± 1.8 [b]	33.70 ± 4.4 [c]
Tomato	***Tanya***	476.6±8.6 [a]	448.2 ± 0.8 [b]	454.6 ± 3.1 [b]	87.2 ± 1.3 [c]
	Cal J	448.2±5.8 [a]	418.1 ± 4.8 [b]	415.7 ± 2.8 [b]	88.1 ± 5.8 [c]
	Onyx	538.9±1.4 [a]	512.9 ± 0.9[b]	511.6 ± 1.7 [b]	75.5 ± 1.5 [c]

Results are presented as arithmetic means ± SD (n = 3).
Means within fruit/ vegetable in row with different superscript letters are significantly different (p<0.05).

The percentage recovery varied significantly with drying methods and varieties in each fruit and vegetable. Tunnel dryer recovered significantly higher values of 84-94 and 112-125 % in mango and tomato respectively than respective lower values of 76-84 and 79-95% in cabinet dryers (Figure 1 a-c). Among the tomato varieties, onyx and Tanya had significantly highest recoveries (123-125) than Cal J with value 112 while viringe and Dodo varieties had highest values of 93-94% among mango varieties dried in tunnel dryer. The principal component analysis bi-plot (Figure2) shows PC 1 accounts for 94.5% of variability and it is a contrast between mango and tomato varieties on one side and banana varieties on another side. Cabinet dryers retained more total phenols in dodo and viringevarieties and lowest in bananavarieties whereas tunnel dryer retained more TPC in Tomato varieties. PC 2 accounts for 5.5 % of variability and it is a contrast between varieties and drying methods. The influence of varieties in TPC of dried fruits has also been reported in apricot (Madrau *et al.,* 2008).

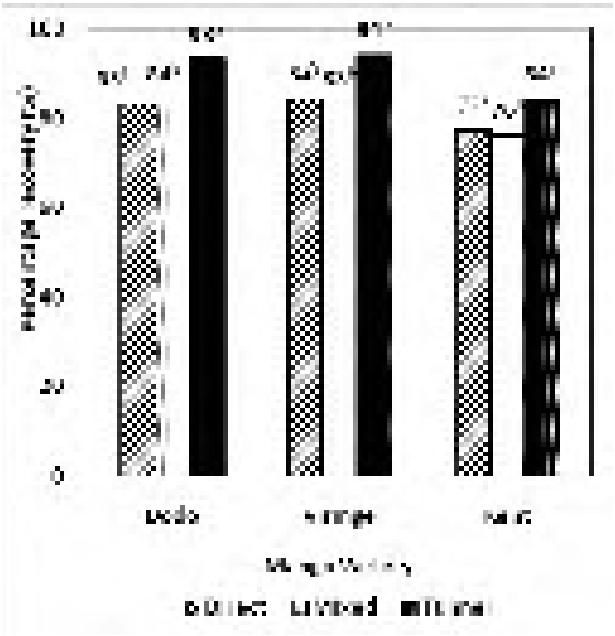


Figure 1 (a): Recoveries of FRAP in mango varieties(Mean ± SD, n=3).

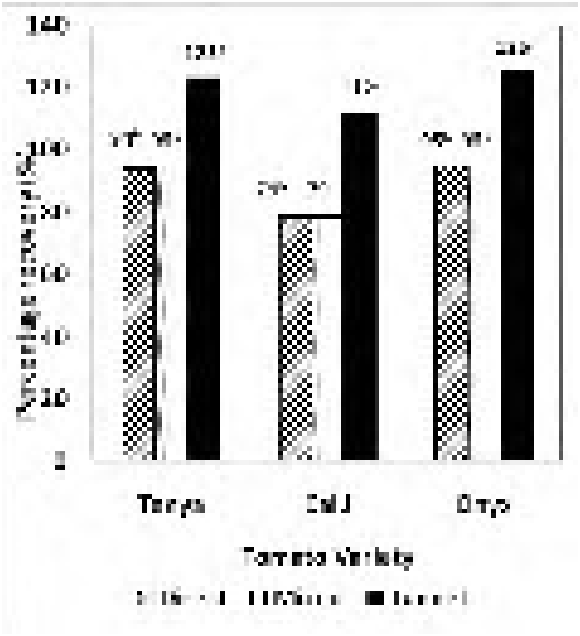


Figure 1 (c): Recoveries of FRAP in tomato varieties. (Mean±SD, n=3). Bar means with different letter are significantly different at p<0.05 for varieties in each drying method

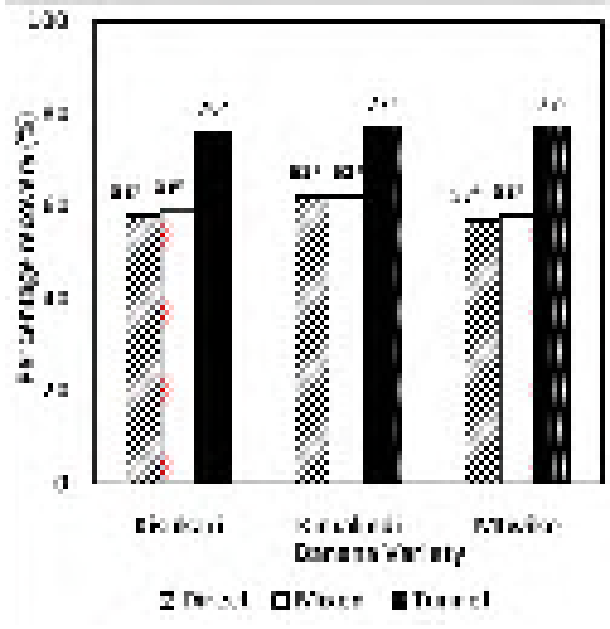
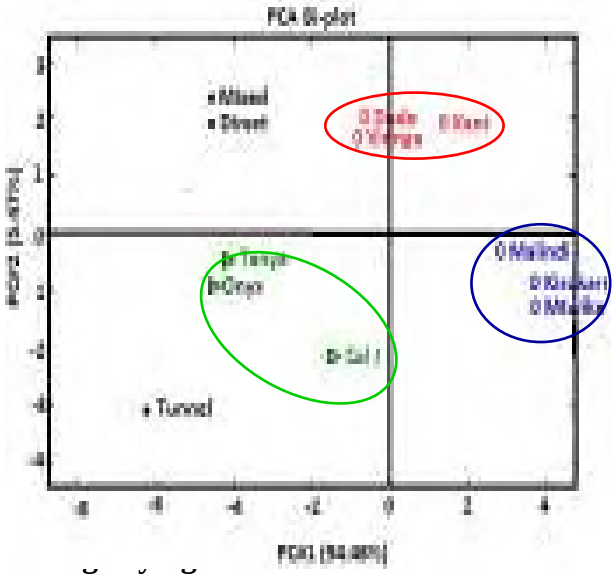


Figure 1 (b): Recoveries of FRAP in Banana varieties(Mean±SD, n=3).



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These findings suggest that drying has variable effects on TPC contents of plant samples. It could result in little or no change, significant declines or enhancement of the TPC (Hamroun-Sellami *et al*., 2012). Chan*et al*. (2009) found that, all methods of thermal drying (microwave, oven and sun drying) resulted in sharp decline in TPC in dried leaf vegetables. The decline is attributed to degradation of phenols during drying (Suvarnakuta *et al*., 2011). The phenolics present in fresh fruit and vegetables are susceptible to oxidative degradation by polyphenol oxidase (PPO) during drying, which leads to intermolecular condensation reactions and their level decreased (Bennett *et al*., (2010). Similar decline in polyphenolic content after drying has been reported in pears (Guiné*et al*., 2015), date (Izli, 2016), African eggplants (Mbodo *et al*., 2018)), spearmint (Orphanides *et al*., 2013), apricots (Madrau *et al*., 2008), and ginger leaves (Chan *et al*., 2009). The higher TPC recovery in tunnel dried samples than cabinet dried samples may be due to higher PPO activity coupled with increased deteriorative reactions in cabinet dryers as results of lower drying temperature and rates compared to tunnel dryer (Haque *et al*, 2013).

The higher TPC contents in tunnel dried tomato than fresh samples and generally lower decline in TPC for other tunnel dried samples could be attributed to increased cell membrane permeability and the release of more bound phenolic compounds from breakdown of cellular constituents of plant cells due to high drying temperature (Norra*et al*., 2017; Rajauria *et al*., 2010; Vega-Galves *et al*., 2009). In addition, higher temperature of 70-90°C coupled with higher drying rate in the tunnel dryer reduce the activity of PPOand its adverse effects (Haque *et al*., 2013; Walker, 1996).SimilarlyNorra *et al*., 2017, Rajauria *et al*., 2010 and Mao *et al*., 2010 found similar increase in polyphenolic contents after drying in Malaysian brownseaweed, Sargassumsp, edible, Irish brown seaweedsand sweet potatoes respectively. In general, the significant effect of different drying methods on total phenolic compound of fruits, vegetables and herbs has widely been reported (Hamrouni-Sellami, 2012; Zhang *et al*., 2012).Findings from this study suggest phenolic contents of fruits and vegetables vary with cultivars in addition to maturity stage and light exposure as reported by Segura-Carretero., 2010; Madrau *et al*., 2008).

Ferric Reducing Antioxidant Power (FRAP)

The mean Ferric Reducing Antioxidant Power (FRAP) of fresh and dried fruit and vegetable varieties are shown in Table 2. Fresh sample differed significantly ($p<0.05$) in FRAP values with tomato varieties having higher value ranged from 44.6 to 46.8 µmol/100 g DM)than mango varieties with values ranged from 23.1 to 27.3µmol/100 g DM. The antioxidant capacities of fruits and vegetable vary with cultivar, growth condition (soil, fertilizer, temperature, and cultivation techniques), storage and transport conditions and processing technology (Bennett *et al*., 2010). As in total phenols, the effect of drying methods on FRAP was significant ($p<0.05$) with all fresh samples having higher FRAP values but declined significantly in dried samples with exception of tunnel dried tomatoes. No significant ($p>0.05$) differences were found between the cabinet direct and mixed modes of drying.

Table 3. Ferric Reducing Antioxidant Power (FRAP) (µmol/100 g DM) of fresh and dried fruits and vegetable varieties of three solar drying methods

		Drying method			
FV	**Var.**	**Fresh**	**Direct**	**Mixed**	**Tunnel**
Mango	***Dodo***	27.3 ± 0.3^{a}	21.3 ± 0.2^{b}	21.6 ± 0.1^{b}	25.1 ± 0.4^{c}
	Viringe	28.5 ± 0.4^{a}	24.2 ± 0.5^{b}	24.1 ± 0.1^{b}	26.9 ± 0.5^{c}
	Kent	23.1 ± 0.4^{a}	15.1 ± 0.2^{b}	14.9 ± 0.2^{b}	20.3 ± 0.2^{c}
Banana	***Kisukari***	10.8 ± 0.1^{a}	5.7 ± 0.1^{b}	6.0 ± 0.2^{b}	8.5 ± 0.2^{c}
	Malindi	15.8 ± 0.2^{a}	8.6 ± 0.0^{b}	8.9 ± 0.0^{b}	12.6 ± 0.5^{c}
	Mtwike	14.5 ± 0.2^{a}	6.4 ± 0.0^{b}	6.7 ± 0.0^{b}	13.1 ± 0.3^{c}
Tomato	***Tanya***	46.8 ± 0.5^{a}	27.9 ± 0.3^{b}	28.3 ± 0.4^{b}	43.0 ± 0.4^{c}
	Cal J	44.6 ± 1.6^{a}	23.8 ± 0.5^{b}	24.4 ± 0.3^{b}	39.2 ± 0.4^{c}
	Onyx	44.6 ± 0.3^{a}	26.5 ± 0.2^{b}	25.7 ± 0.6^{b}	38.6 ± 0.3^{c}

Data presented as arithmetic means ± SD (n = 3).
Means within fruit/vegetable in row with different superscript letter are significantly different ($p<0.05$).

The percentage FRAP recovery varied significantly ($p<0.05$) between drying methods and varieties in each fruit and vegetable. Tunnel dryer recovered higher values of 88-93, 78-90 and87-92 % in mango, banana and tomato respectively than respective lower values of 64-86, 44-57 and53-60% in cabinet dryers (Figure 3 a-c). Among the tomato varieties, Tanya variety had higher recoveryof 92% thanother varieties while viringe had the highest values of 96% than other varieties dried in tunnel dryer (Figure 2b).

The principal component analysis bi-plot (Figure4) shows PC 1 accounts for 94.2% of variability and it is a contrast between mango varieties on one side and tomato and banana varieties on another side. PC 2 accounts for 5.5 % of variability and it is a contrast between varieties and drying methods. The influence of varieties in antioxidant capacity of dried fruits has also been reported in apricot (Madrau *et al.*, 2009).

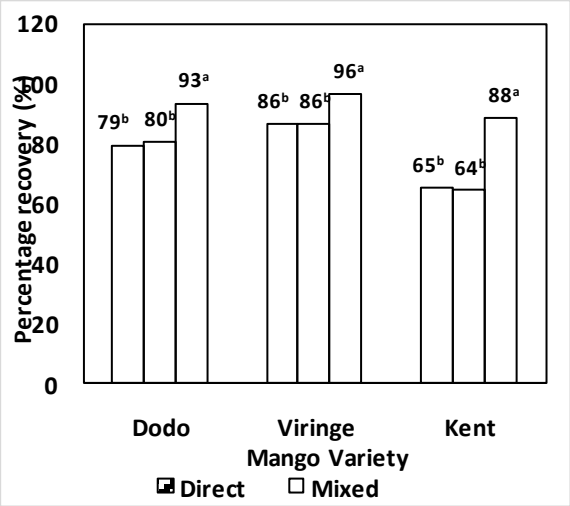

Figure 3 (a): Recoveries of FRAP in mango varieties(Mean ± SD, n=3).

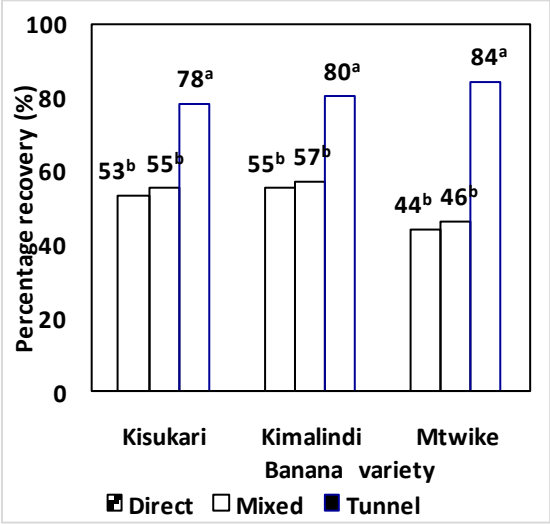

Figure 3 (b): Recoveries of FRAP in Banana varieties(Mean±SD, n=3).

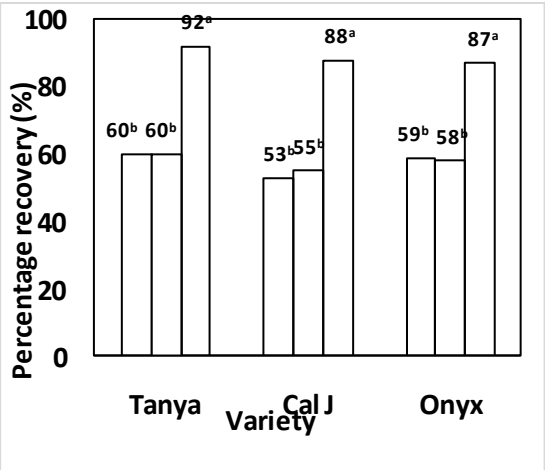

Figure 3 (c): Recoveries of FRAP in tomato varieties. (Mean±SD, n=3). Bar means with different letter are significantly different at p<0.05 for varieties in each drying method

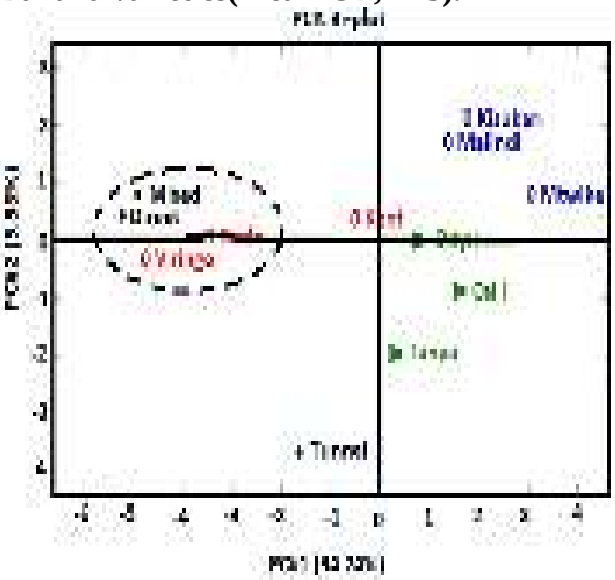

Figure 4: PCA Biplotshowing systematic variations in TPC recovery among drying methods and varieties

The variations in the antioxidant activities among the fruits and vegetables samples could be due to their composition, polyphenol contents and other non-phenolic antioxidants present in samples such as vitamin C, vitamin E, Mallard reaction products, β-carotene and lycopene (Hassanien, 2008; Ali, 2010). The lower FRAP levels in dried samples than their fresh counterpart implies that solar drying has effect on antioxidant activity of dried products. Chemical and enzymatic processes during drying and/or storage can lead to either loss of phenolic-related antioxidant capacity or may generate chemical derivatives with little or no

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change, significant declines or enhancement in antioxidant capacity (Bennet *et al*., 2011). Various studies by Guiné*et al*., (2015); Izli, (2016); Mbondo *et al*., (2018); Orphanides *et al*., (2013), Kuljarachanan *et al*., (2009), Chantaro *et al*. (2008) and Choi *et al*., (2006) have reported similar effect of drying on antioxidant activity of fruits and vegetables. Furthermore, the higher percentage FRAP recovery in Tunnel dried samples than cabinet dryer shows that different drying methods have significant varied effects on dried products. These may be attributed to different dryers design and performances where tunnel dryer generated higher temperature coupled with higher drying rates and short drying times which resulted into lowchanges in phenolic contents and enhances antioxidant activity of the sample. This agrees with findings by Madras *et al*. (2009) whofound that high drying temperature gives product with better polyphenol content with enhanced antioxidant activity. Similar effect of drying on antioxidant capacity of fruits and vegetable has been reported in apple (Anwar *et al*., 2012) and pears (Guiné*et al*., 2015).

Vitamin C contents

The mean vitamin C contents fresh and dried fruit and vegetable varieties are shown in Table 3. Fresh sample differed significantly ($p<0.05$) with tomato varieties having highest value ranged from 115.1 to 126.8 (mg/Lasc/100g) compared to lowest values banana varieties that ranged from 28.3 to 29.1 (mg/Lasc/100g). Furthermore all fresh samples had significant ($p<0.05$) higher values but declined substantially in dried samples from 105.4 ± 0.4 - 119.7 ± 0.3to22.1 ± 0.0 - 65.1 ± 0.0 µmol/100 g DM in mango varieties, from 28.3 ± 0.0 - 29.1 ± 0.0to 8.3 ± 0.0- 9 ± 0.00 µmol/100 g DM in banana varieties and from 115.1±1.6-126.8±0.5to 35.0±0.0-37.0±0.0 µmol/100 g DM in tomatoes varieties.

Table 4.Vitamin C (µmol/100 g DM) of fresh and dried fruits and vegetable varieties of three solar drying methods

		Drying method			
Fruit	**Var**	**Fresh**	**Direct**	**Mixed**	**Tunnel**
Mango	***Dodo***	119.7 ± 0.3^{a}	22.1 ± 0.0^{b}	24.4 ± 0.0^{b}	65.1 ± 0.0^{c}
	Viringe	105.4 ± 0.4^{a}	22.9 ± 0.0 ^{b}	25.1 ± 0.0^{b}	58.8 ±0.0^{c}
	Kent	115.1 ± 0.4^{a}	23.2 ± 0.0 ^{b}	23.3 ± 0.0^{b}	51.9 ± 0.0^{c}
Banana	***Kisukari***	28.3 ± 0.0^{a}	6.4 ± 0.0^{b}	5.1 ± 0.0^{b}	9.1 ± 0.0^{c}
	Malindi	28.7 ± 0.0^{a}	3.9 ± 0.5 ^{b}	5.2 ± 0.1^{b}	8.3 ±0.0^{c}
	Mtwike	29.1 ± 0.0^{a}	4.1 ± 0.2 ^{b}	3.8 ± 0.2^{b}	8.4 ± 0.0^{c}
Tomato	***Tanya***	126.8±0.5^{a}	26.5±0.0^{b}	28.7±0.0^{b}	37.3±0.0^{c}
	Cal J	115.1±1.6^{a}	28.1±0.0^{b}	26.0±0.0^{b}	35.0±0.0^{c}
	Onyx	124.4± 0.3^{a}	28.7±0.0 ^{b}	26.1±0.0^{b}	35.0± 0.0 ^{c}

Data presented as arithmetic means ± SD (n = 3).

Means within fruit/vegetable in row with different superscript letter are significantly different (p<0.05).

The variation between drying method was significant (p<0.05). Among the dried samples, tunnel dried samples had higher percentage recovery of 43.4 - 54.4% in mango varieties, 29.2-31.2% in tomato varieties, 6.9-7.6% in banana varieties than respective lower values of 18.5-21, 21.7-24 and 3.2-5.3% in cabinet dryers (Figure 5). No significant (p>0.05) differences were found between the cabinet direct and mixed modes of drying. The principal component analysis bi-plot (Figure5) shows PC 1 accounts for 90.5% of variability and it is a contrast between mango and tomato varieties on one side and banana varieties on another side. Tunnel dryer retained relatively highest amount of vitamin C in mango varieties whereas cabinet dryers retained higher amount in tomato varieties. Both dryers retained lowest amount in banana varieties. PC 2 accounts for 9.1 % of variability and it is a contrast between the drying methods

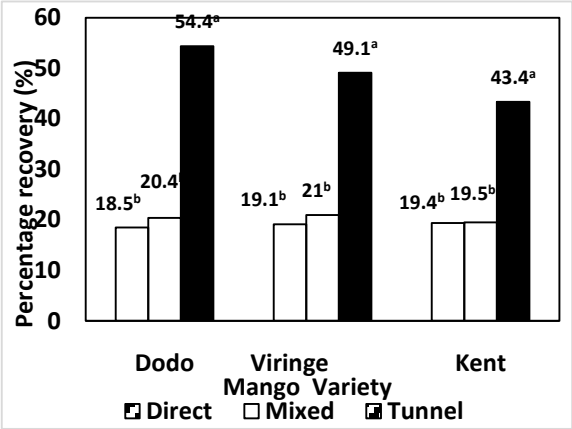

Figure 3 (a): Recoveries of vitamin C in mango varieties (Mean ± SD, n=3).

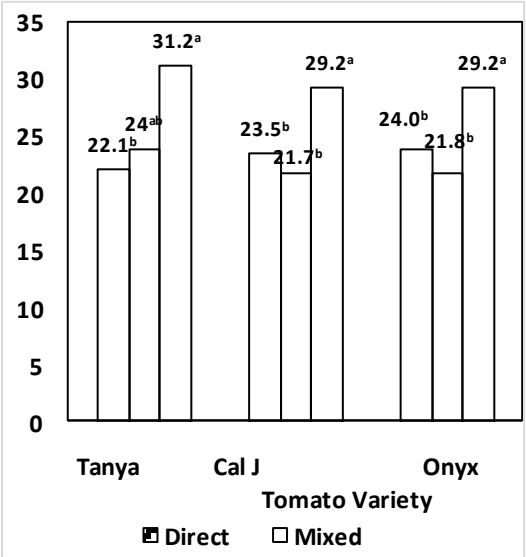

Figure 3 (c): Recoveries of vitamin C in tomato varieties. (Mean ± SEM, n=3). Bar means with different letter are significantly different at p<0.05 for varieties in each drying method

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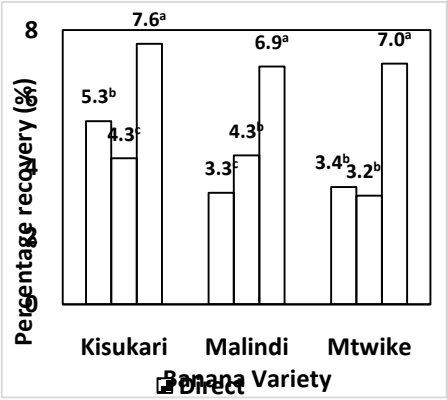

Figure 3 (b): Recoveries of Vitamin C in banana varieties (Mean ± SD, n=3).

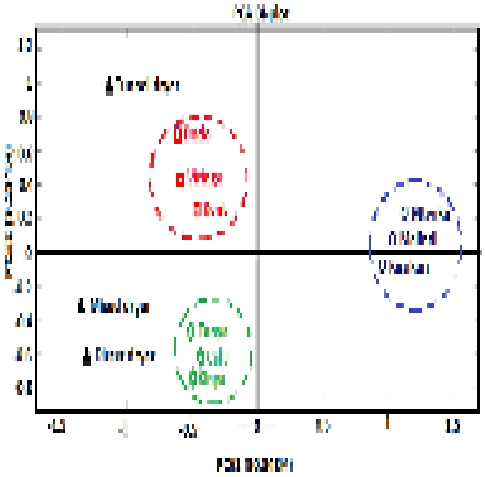

Figure 5: PCA Biplot showing systematic variations in vitamin C Recovery among drying methods and varieties

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The low vitamin C recovery during drying shows that, it is the least stable nutrient during processing and is often used as a quality indicator of food processes (Santos and Silva, 2008). Vitamin C is very sensitive to thermal process, light, oxygen, alkaline pH-values, enzymatic reactions and catalytically active metal ions (Marfil*et al*., 2008). The degradation level increases with increasing drying temperatures andin the presence of oxygen. Vitamin C may be oxidized to dehydroascorbic acid under aerobic conditions, followed by hydrolysis and further oxidation thus subjected to appreciable change during the drying process. The loss of vitamins C due to drying has widely been reported. Goula and Adamopoulos (2006) reported 90 % or higher loss of the vitamin C in dried tomato halves while Ogbadoyi*et al*., (2011) reported a greater loss (83.07%) in sun dried amaranthus species. The reported losses are similar to the findings of this study with exception of tunnel dried samples. The degradation of vitamin C is associated with quality loss in a product (Giovanelli*et al*., 2002).The observed variation in vitamin C contents between and within the fruits and vegetable varieties could be influenced by presence of dissolved oxygen, pH 4.0 and water activity level in the products (Bulent-Koc, 2007; Rahman*et al*., 2007). The high pH and rate of enzymatic oxidation as manifested by severe browning in banana may be accounted for its highest vitamin C loss. This was further supported by Methakhup*et al*., (2003) who found the rate of ascorbic acid oxidation to be pH dependent, showing a maximum at pH 5.0 and minimum at a pH range of 2.5 to 3.0.Leaching is another important factor that could have led to loss of vitamin C along with the water during the preparation and drying process as was previously observed by Kirimire *et al*., (2010).

The differences in vitamin C degradation between the drying methods could be influenced by temperature, drying kinetics and water activity. The high temperature in the tunnel dryer inactivated the ascorbic acid oxidase and offered vitamin protection towards enzymatic oxidation (Leong and Oey, 2012). Furthermore, the shorter drying time in tunnel dryer than in cabinet dryers reduced the exposure time to oxidizing agents resulted into relatively lower vitamin C degradation in its samples as previously observed by Santos and Silva, (2008). The findings are in agreement with other studies in tomato (Leong and Oey, 2012), broccoli (Munyaka*et al*., 2010) and cow pea leaves (Wawire*et al*., 2011) that have similarly reported relatively reduced in vitamin C loss with increasing drying air temperature. However, McLaughlin and Magee (1998), Caixeta*et al*. (2002) and Wennermark*et al*. (1994) have contrastingly observed a decrease in vitamin C content with increasing drying temperature.

The relatively higher moisture content in cabinet dried samples than in tunnel dried samples could have contributed to their relatively higher vitamin C degradation. Vitamin C stability is reduced in aqueous state than in the dry state (Kirimire, 2010). Based on the observed substantial loss, it is apparently suggest consumption of large quantities of dried fruits and vegetables to meet RDA of 75 and 90 mg/day for women and men respectively and 45 mg/day for children 9-12 years old (USDA, 2010).

Correlation analysis between total phenolic contents, vitamin C and FRAP

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The correlation analysis between total phenolic, and antioxidant activities of fresh and dried fruits and vegetable are shown in Figure 6 (a and b). About 94.4 and 87% of FRAP in fresh and dried samples were respectively explained by TPC implying strong correlation between the two

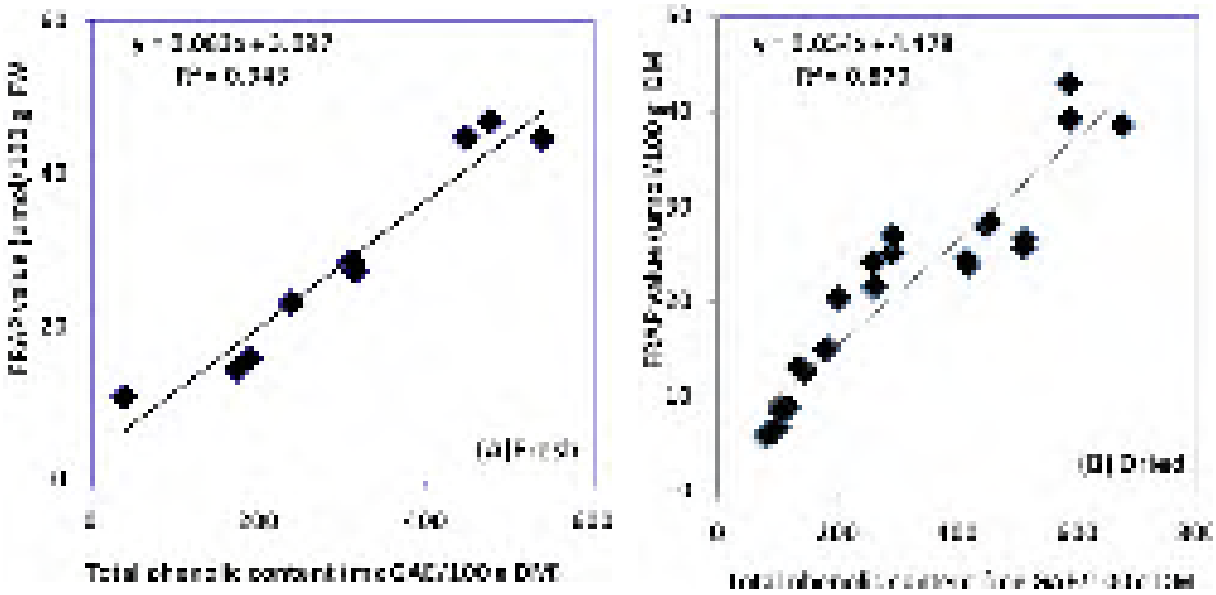

Figure 6 : Correlation between total phenolic contents and FRAP in Fresh (A) and Dried (B) Fruits and vegetable.

However, moderate correlation (R2=0.6965) was observed between vitamin C and antioxidant activities in fresh samples (Figure 7 (a) where weak correlation (R2=0.4973) of the same was observed in their dried sample counterparts. This implies that only 50 % of the antioxidant activity in dried samples was explained by vitamin C.

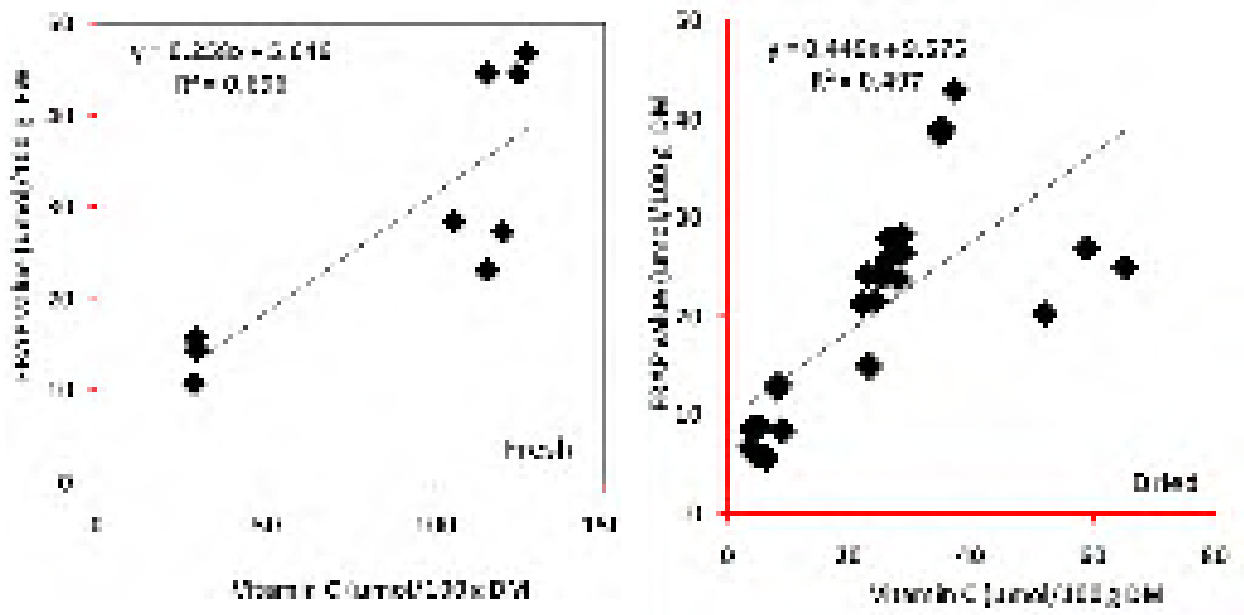

Figure 7: Correlation between total phenolic contents and FRAP in Fresh (A) and Dried (B) Fruits and vegetable.

These finding implies that, the antioxidant activity of fresh fruits and vegetables is strongly correlated to the TPC contents and moderately on Vitamin C. Contrastingly, Alves *et al*.,(2017)observed more strong correlation (R2=0.994) between vitamin C and antioxidant activity in Brazilian Savannah native fruits(Cagaita, cerrado cashew and gabiroba). The variation may be due to fruits types, composition and location. Many other studies (Anwar *et al*., 2012; Zhang *et al*., 2012; Sreeramulu*et al*, 2010; Mao *et al*., 2010) have reported similar moderate to strong correlations. Regrettably, the findings showed antioxidant activities of dried fruits and vegetables under the study samples were weakly correlated to Vitamin C. This may be ascribed to significant vitamin C loss during drying

Conclusion and recommendations

Solar drying has significant effect on total phenolic contents and antioxidants activities of dried mango, and tomato which varies depending on the method used. Tunnel dried samples have lower decline in TPC and antioxidant activities than cabinet dried samples due to higher drying temperature and shorter drying rate. Moreover, the percentage recoveries of total phenols and antioxidant capacities of dried fruits and vegetables differ according to varieties. Finally, the antioxidant capacities of plants materials including fruits and vegetables are strongly depend on the total phenolic compounds and vitamin C present. However due to its significant loss during drying, vitamin C correlated weakly with antioxidant activity. Application of solar drying technology especially tunnel dryer for processing of fruits and vegetables into shelf life stable dried products rich in antioxidant activities for household consumption and income generation is highly recommended.

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Dietary Intake and Diversity among Children of Age 6-59 Months in Lowland and Highland Areas in Kilosa District, Tanzania

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Abstract

Adequate nutrition during infancy and early childhood is essential to ensure growth, health, and development of children to their full potential. Geographical location may influence dietary intake, and hence, nutritional status of the population. This study aimed to assess dietary intake among children of age six to fifty-nine months in the lowland and highland areas in Kilosa district. A cross-sectional study involved 200 randomly selected households from the lowland and 141 in highland areas of Kilosa district. Socio-demographic, feeding practices and 24-hours dietary recall information was collected using a pretested questionnaire. Statistical Package for Social Sciences (SPSS) version 20 was used to analyse socio-demographic and feeding practices data. Significant difference between highlands and lowlands areas were determined at $p<0.005$. The 24-hour dietary records were converted to nutrient intake using Nutri-Survey software and compared to recommended dietary intake. A study involved 341 children aged 6-59 months where 51% were boys. Less than half of the children in lowland (43%) and in highland (45%) met Recommended Dietary Allowance (RDA) for protein. Inadequate intakes of vitamin A, calcium and iron were observed more in younger children of age 6-12 months where none of them met the RDA. Grains, roots and tubers were the most popular food groups consumed almost all children while eggs were the least consumed by only 1.2% of the studied children. Majority of children (80.6%) consumed less than four food groups in the last 24 hours preceding the survey. Children in lowland area had significantly more diversified diet. Low dietary diversity, limited intake of animal source foods and hence limited micronutrients intake was observed in the study population. Feasible strategies are needed to address the dietary inadequacies.

Key words: Dietary intake, children, highlands, lowlands, Tanzania

Introduction

Growth and development of young children forms conditions for development during the school age period and in adolescence. This will be carried through into adulthood and old age and will result in life time of economic, social and personal benefit (WHO, 2003). Adequate nutrition during infancy and early childhood is essential to ensure growth, health, and development of children to their full potential (WHO, 2009). Appropriate feeding practices during early childhood stimulate psycho-social development, lead to good nutritional status and physical growth, reduce susceptibility to common childhood infections and improve resistance to cope with them (Golan, 2006).

Inadequate dietary intake is one of the immediate causes of malnutrition especially undernutrition in under-five children. Undernutrition increases the risk of dying from common infections, increases the frequency and severity of such infections and delays recovery. Nearly half of all deaths in children below five years are attributable to undernutrition, translating into the loss of about 3 million young lives a year (UNICEF, 2018). High prevalence rate of macronutrient and micronutrient deficiencies observed in developing countries is mainly due to

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inadequate intake of dietary energy and protein, the low content of micronutrients in the diet and poor bioavailability (Rivera *et al*., 2003). Also, it was reported that inadequate dietary intakes and poor feeding practices directly affect the nutritional status of children in the Tanzania (Kulwa*et al*., 2015).

Feeding practices has high effect on nutritional status of the children and may differ from one area to another. For better growth, appropriate feeding practices are recommended. WHO recommended child to be exclusively breast fed for six months, continued breastfed up to two years or more, introduced semi-solid and solid food at 6 months, appropriate dietary diversity, appropriate frequency of meals, safe preparation of food and feeding infant or young child in response to their cues (WHO, 2010).

The studies on feeding practices conducted in different rural African countries came up with different findings. Almost all mothers breastfed their children but prevalence of exclusive breastfeeding for six months is very low (Savadogo*et al* 2018,Senbanjo*et al*., 2016). This could probably be due to lack of awareness about value of breastfeeding (Senbanjo*et al*., 2016). Most studies conducted in rural areas reported less diversified diets which is defined as diet containing at least four or more food groups from seven recommended food groups as a problem among children (Badake*et al*., 2014, Kulwa*et al*., 2015).

A study conducted by Abdul-Aziz and Devi (2012) in Selangor Malaysia reported that calories, fat, iron and protein intake among rural children was higher than Recommended Nutrient Intake (RNI) while Akerele*et al*., (2017) reported that substantial proportiona of households suffer deficiency of calories and proteins. Reason for iron and fat intake exceeding the RNI was high consumption of meat, fish and poultry as their main dish while higher calories were due to consumption of fast food such as chocolate and ice cream. Most studies reported inadequate intake of micronutrients especially calcium (Abdul-Aziz and Devi, 2012; Grobbelaar, 2013; Akerele*et al*., 2017). Govender*et al*. (2016) reported in his review that children in rural Kwa Zulu Natal consume more energy, protein, fat and carbohydrate while fibre and micronutrient intake is poor.

Malnutrition is still a significant health problem in infants and young children in Tanzania. Prevalence of stunting (33.4%) and underweight (11.5%) was reported in Morogoro Region and much higher prevalence were recently reported in Kilosa district (50.7% stunting and 15.8% underweight)(TDHS-MIS, 2016, Mrema*et al*., 2018). It was further observed that children living in highland area of Kilosa District are more stunted and underweight (64.6 and 22%) compared to those living in lowland area (41 and 11.5%) respectively (Mrema*et al*., 2018).

Although it is well documented that inadequate dietary intake is the immediate cause of undernutrition (UNICEF, 1998), the causes may differ from one area to another. Due to different rates of undernutrition observed between lowland and highland of Kilosa District therefore, the aim of this study was to assess dietary intake and diversification among children aged 6-59 months in lowland and highland areas of Kilosa District.

Methodology

Study area and design: Kilosa district is one of the eight districts of Morogoro region. It is located in East Central Tanzania, about 148 km from Morogoro town. Kilosa extends between latitude 5°55′ and 7°53′ South and longitudes 36°30′ and 37°30′ East (Ishengoma*et al*., 2016). Data were collected in five villages Chanzuru, Peapea, Batini, Mfuluni and Unone. A cross-sectional study design was conducted in five randomly selected villages, three in lowland and two in highland areas. A total of 200 households from the lowland and 141 from the highland areas with a child of age 6-59 were involved in the study. In case there was more than one child from the target age group in one household, the youngest child was selected. The main respondent was the mother/care taker of the index child.

Data collection: Mothers with children 6-59 months of age who were willing to participate in this study were interviewed using a pre-tested questionnaire. Information collected included socio-demographic characteristics and child feeding practices (breastfeeding and complementary feeding). In assessing dietary intake, 24 dietary recall was used where a mother/care giver was asked to recall foods and beverages fed to the index child in the twenty-four hours prior to the interview. A mother/caregiver was requested to show the local utensils such as bowl, cup or plate used and amount of food fed to the child in order to estimate the food portion/weight in grams. Kitchen weighing scale (TANITA digital kitchen scale) was used to estimate actual weight of the foods and measuring cylinders were used for liquid foods. The foods mentioned were then combined into the seven main food groups which are grains, roots and tubers; legumes and nuts; vegetables; fruits; dairy products; and flesh foods and eggs. For each food group consumed, a score of one was assigned and a zero score for the non-consumed group. Dietary diversity score (DDS) was then calculated by summing up all the food groups eaten by the index child in the last 24 hours preceding the survey (WHO, 2010).

Data processing and analysis: Statistical Package for the Social Sciences(SPSS) version 20 was used to analyse data where descriptive statistics such as frequencies and percentages were generated. Dietary intake data were analysed using Nutrisurvey (2007) to get the actual amount of nutrients from macronutrients (carbohydrate, protein and fats) and micronutrients (vitamin A, calcium, zinc and iron) consumed and compared with Recommended Dietary Allowance (RDA). Comparison on dietary diversity between lowland and highland were compared by chi-square.

Ethical consideration and study permit: Research proposal was approved and research permit granted from Muhimbili University of Health and Allied Science (MUHAS) with Ref. No. 2016-10-19/AEC/Vol.XI/307. In addition, permission letter was obtained from Sokoine University of Agriculture and District Executive Director of Kilosa. Details of the study were well explained to the mothers, before commencement of data collection and they provided written consent.

Results

Socio-demographic Characteristics

Socio-demographic characteristics of the mothers and their children are presented in Table 1.

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About 47% of the mothers were ranging within the age range of 25-34 years and 82.1% were married. Fifty one percent of children were boys and majority were at the age range of 36-59 months. More than half of the households (53.5%) in lowland were based on agriculture while in highland were based on both agriculture (48.9%) and casual labour (49.6%).

Table 1: Demographic characteristics of the studied population

Socio-demographic information	Lowland (N = 200)		Highland (N = 141)		Total (N=341)	
	n	%	n	%	n	%
Marital status						
Single	33	16.5	28	19.9	61	17.9
Married	167	83.5	113	80.1	280	82.1
Maternal education level						
Informal education	36	18	25	17.7	61	17.9
Primary	147	73.5	107	75.9	254	74.5
Secondary/university	17	8.5	9	6.4	26	7.6
Occupation of mother						
Farmer	185	92.5	139	98.6	324	95
Employed	5	2.5	0	0	5	1.5
Business	10	5.0	2	1.4	12	3.5
Household main source of income						
Salary / wage	9	4.5	0	0	9	2.6
Agriculture	107	53.5	69	48.9	176	51.6
Business	17	8.5	2	1.4	19	5.6
Casual labour	67	33.5	70	49.7	137	40.2
Head of household						
Male	169	84.5	115	81.6	284	83.3
Female	31	15.5	26	18.4	57	16.7
Age of mothers/caregiver						
14-24	56	28	57	40.4	113	33.2
25-34	98	49	62	44	160	46.9
≥35	46	23	22	15.6	68	19.9
Sex of children						
Boys	106	53	68	48.2	174	51
Girls	94	47	73	51.8	167	49
Children age						
6-23 months	63	31.5	51	36.2	114	33.4
24-35 months	58	29	44	31.2	102	29.9
36-59 months	79	39.5	46	32.6	125	36.7

Infant and Young Child Feeding Practices

Almost all children were breastfed. However, 57.2% were breastfed within one hour after birth and 97.7% were breastfed on demand. About seven in ten children (70.4%) were exclusively breastfed for six months and majority stopped to be breastfed at 24 months of age. Majority of children (74%) in lowland were exclusively breastfed for six months and compared to 65.2% in highland area ($P<0.05$). Early complementation was noted among about 30% of the children, majority being from the highland areas (Table 2).

Table 2: Young children feeding practices in the lowland and highland areas

Variable	Lowland (N=200)		Highland (N=141)		Total (N=341)	
	n	%	n	%	n	%
Breast feeding						
Yes	198	99	141	100	339	99.4
Initiation of breast feeding						
I don't know	2	1	7	5	9	2.6
Within 1 hour	132	66.7	63	47.7	199	57.2
1-6 hours	64	32.3	69	48.9	134	39
More than 6 hours	2	1	2	1.4	4	1.2
Frequency of breastfeeding/ day						
On demand	195	97.5	138	97.9	333	97.7
Twice	0	0	1	0.7	1	0.3
Three times	1	0.5	0	0	1	0.3
Four times	4	2	2	1.4	6	1.7
Exclusive breastfeeding (6months)*						
No	52	26	49	34.8	101	29.6
Yes	148	74	92	65.2	240	70.4
Breastfeeding duration						
7-12 months	4	2	3	2.1	7	2.1
13-18 months	16	8	15	10.6	31	9.1
24+ months	128	64	76	54	204	59.8
Were continue breastfeeding	52	26	47	33.3	99	29
Time started complementary food*						
< 6 months	52	26	49	34.8	101	29.6
On 6 months	138	69	87	61.7	225	66
>6 months	10	5	5	3.5	15	4.4
No. of meals per day						
One	6	3	2	1.4	8	2.4
Two meals	25	12.5	23	16.3	48	14.1
Three meals	134	67	109	77.3	243	71.2
Four meals	22	11	5	3.6	27	7.9
More than four meals	13	6.5	2	1.4	15	4.4

**Significant difference between highlands and lowlands ($p<0.05$)*

Dietary intake in the lowland area

The mean and standard deviation of each nutrient intake in each age group (6-12, 13-36 and 37-59 months) in comparison with their daily recommendation are shown in Table 3. The mean intake of majority of children was below RDA. All age groups did not meet the RDA for calcium. Generally, less than half of the children (43%) met their RDA for protein. All of infants (6-12 months of age) did not meet the RDA for fat, vitamin A, calcium and iron.

Table 3: Protein, fat, carbohydrate, vitamin A, calcium, iron and zinc intake of children 6-59 months in lowland area

	Nutrients						
	Protein (g)	**Fat(g)**	**CHO (g)**	**Vit. A (µg)**	**Calcium (mg)**	**Iron (mg)**	**Zinc (mg)**
6-12 months							
Mean (SD)	8.7(7.5)	5.5(5.7)	61.0(33.8)	121.0(177.2)	52.5(51.8)	2.8(2.1)	1.4(0.9)
n(%) who met RDA	7(28)	0(0)	4(16)	0(0)	0(0)	0(0)	2(8)
13-36 months							
Mean	18.4(14.1)	14.7(10.8)	116.5(64.3)	234.9(282.5)	80.5(46.3)	6.5(4.4)	3.1(2)
n(%) who met RDA	54(54)	6(6)	27(27)	34(34)	0(0)	19(19)	38(38)
37-59 months							
Mean	19.8(9.4)	13.7(5.2)	129.2(43.9)	343.7(322.3)	94.8(39.6)	6.7(2.3)	3.5(1.4)
n(%) who met RDA	25(33.3)	1(1.3)	29(38.7)	29(38.7)	0(0)	3(4)	9(12)
Total							
Mean	17.8(13.1)	13.3(9.7)	114.0(61.9)	263.8(300.4)	82.4(47.9)	6.1(4)	3.0(1.9)
n(%) who met RDA	86(43)	7(3.5)	60(30)	63(31.5)	0(0)	22(11)	49(24.5)

Dietary intake in the highland area

Mean intakes of almost all nutrients in nearly all age categories were below RDA. Generally, 44.7% of the children met their RDA for protein and none met the RDA for calcium. In group of infants (6-12 months of age) very few (5.6%) met RDA for vitamin A but none met RDA for fat, calcium, iron and zinc. About half of the children (51.9) aged 13-36 month met their RDA of protein compared to other age groups (Table 4).

Table 4: Protein, fat, carbohydrate, vitamin A, calcium, iron and zinc intake of 6-59 months children in highland area

	Nutrients						
	Protein (g)	**Fat (g)**	**CHO (g)**	**Vit. A (µg)**	**Calcium (mg)**	**Iron (mg)**	**Zinc (mg)**
6-12 months							
Mean	6.4(5.1)	3.0(2.3)	69.7(57.9)	37.1(105.6)	30.4(23.1)	2.6(1.6)	1.3(0.8)
n(%) who met RDA	3(16.7)	0(0)	5(27.8)	1(5.6)	0(0)	0(0)	0(0)
13-36 months							
Mean	15.4(7.60	11.4(5.6)	110.5(38.8)	290.8(215)	81.8(37)	5.6(1.9)	2.9(1.1)
n(%) who met RDA	40(51.9)	1(1.3)	24(31.2)	37(48.1)	0(0)	13(16.9)	35(45.5)
37-59 months							
Mean	19.2(5.7)	14.8(5.1)	121.1(36.2)	333.4(280.3)	98(38.2)	7.1(1.9)	3.6(0.9)
n(%) who met RDA	20(43.5)	1(2.2)	17(37)	17(37)	0(0)	6(13)	3(6.5)
Total							

Mean	15.5(7.7)	11.4(6.2)	108.7(43.5)	272.3(245.4)	80.5(41.2)	5.7(2.3)	2.9(1.2)
n(%) who met RDA	63(44.7)	2(1.4)	46(32.6)	55(39)	0(0)	19(20.6)	38(27)

Dietary energy intake

Generally, only 20.5% of children meet their RDA for energy. More than half of the children below 24 months of age met their RDA for energy compared to older children (24 months and above). Based on location, majority of children (85.7%) aged 9-11 months in highland met their RDA for energy compared to their peers in lowland area (62.5%) (Figure 1).

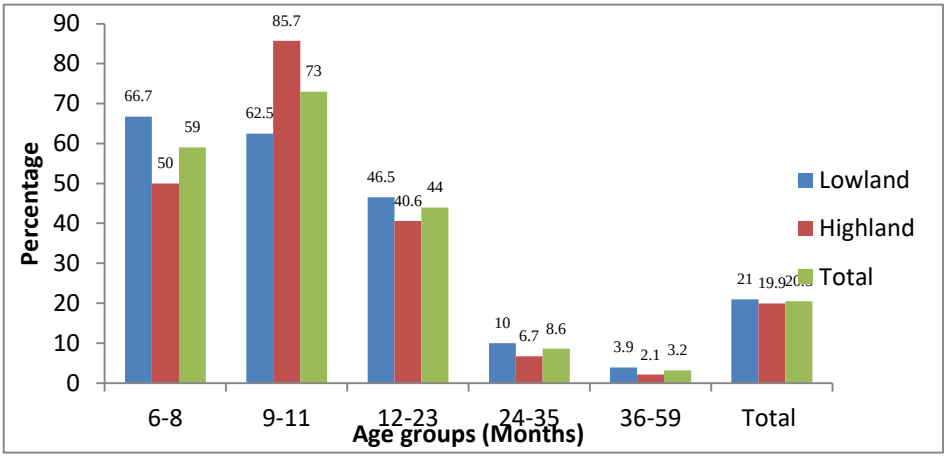

Figure 1: Percentage of children who met RDA for energy intake

Dietary diversity

Table 5 summarizes the food groups consumed in the lowland and highland areas as obtained by 24 dietary recall questionnaires. Grain, roots and tubers (starchy foods) were the most popular food groups consumed by children (99.1%) followed by legumes and nuts (64.2%) and vegetables (60.7%). Eggs and dairy products were the least consumed, at 1.2 and 2.3% respectively. It is important to note that fruits were also rarely consumed by the studied children

Table 5: Distribution of the children by food group they consumed in lowland and highland

Food groups	**Lowland (n = 200)**		**Highlands (n=141)**		**Total (N= 341)**	
	n	%	n	%	n	%
Grains, roots and tubers	197	98.5	141	100	338	99.1
Legumes and nuts	136	68	83	58.9	219	64.2
Vegetable	114	57	93	66	207	60.7
Flesh food	52	26	51	36.2	103	30.2
Fruits	34	17	8	5.7	42	12.3
Dairy product	6	3	2	1.4	8	2.3

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Egg	3	1.5	1	0.7	4	1.2

Dietary diversity score

Dietary diversity scores of children in the lowland and highland areas are summarized in Table 6. Majority of children (80.6%) consumed less than four food groups. only 19.4% met a minimum of four or more food groups. Children in the lowland area had more diversified diet compared to the highland area children (p=0.04).

Table 6: Dietary diversity scores in lowland and highland

	Lowland (N=200)		Highland (N=141)				
	n	%	n	%	χ^2	Degree of Freedom	*P* value
Dietary diversity scores							
<4 food groups	154	77	121	85.8	4.12	1	0.04*
≥4 groups and above	46	23	20	14.2			

*significant at $p<0.05$

Discussion

The present study aimed to assess dietary intake and diversity in children aged 6-59 months in Kilosa District and has highlighted inadequate nutrient intake and poor dietary diversity. Almost all children were breastfed in both lowland and highland areas of Kilosa where 74.4 and 66.2% were exclusively breastfed for six months respectively. The observed exclusive breastfeeding rate is higher compared to country average reported in TDHS-MIS (2016) and it was also higher compared to world-wide exclusive breastfeeding rate (40%) (UNICEF/WHO, 2017). Currently, exclusive breastfeeding rate increased in Tanzania from 41% in 2004/05, 50% in 2010 to 59% in 2015 (TDHS-MIS, 2016). The observed high rates in this study could be a result of recent emphasis of exclusive breast feeding during antenatal clinic visits. As human milk contains hundreds to thousands of distinct bioactive molecules protect against infection and inflammation and contribute to immune maturation, organ development, and health microbial colonization (Ballard and Morrow, 2013). In Tanzania it reported declined of stunting from 42% in 2010 to 34% in 2015 and mortality rate from 81 deaths per 1000 live births in 2010 to 67 deaths per 1000 live births in under-five children of which increased exclusive breastfeeding could be one of the contributing factors for this decrease. However, it may also not reflect the true picture because in the rural communities, water and other drinks are not considered as foods hence the actual exclusive breastfeeding rate may be lower than reported in this study. A study conducted by Kulwa*et al*. (2015) in rural central Tanzania reported majority of the children were breastfed as recommended but many were introduced to liquids earlier than recommended six months.

Initiation of breastfeeding within one hour after birth was higher in lowland than in highland areas but in both areas children were breastfed on demand. Most mothers in highland area had few antenatal clinic visits (≤3) due to long walking distance to the health facility so are not well informed on important of early initiation of breastfeeding. There was relatively high home delivery in the highland areas hence limited emphasis for initiation of breastfeeding within one

hour. To improve the current situation on early initiation of breast feeding, facility delivery should be emphasized especially for women residing in highland areas.

Majority of the mothers/caregivers introduced complementary food at the right time though diversification was a big problem where 80.6% failed to meet a minimum dietary diversity of four or more food groups. The foods introduced were mostly starchy foods with limited animal source foods. Animal source foods are very important to children as it fills multiple gaps at lower volume of intake than can plant source foods. Animal source foods not only having many micronutrients but also the nutrients are often more bioavailable (WHO and FAO, 2004). It is hard to acquire the recommended amount of zinc, iron and riboflavin by eating only plant source foods. Due to poor intake of animal source foods children may become anaemic in future, have poor cognitive development and reduced immunity. Observed poor diversification can be due to poor knowledge on nutrition. For example, the period of data collection was mango season and almost all households had mango trees but only 12.3% of the children consumed fruits. It is a usual practice that fruits are not given to children especially for those who are below two years of age and are unable to pick on their own. Another reason could be due availability where grains (maize and rice) are produced by almost all households and due to poverty, many households cannot afford to buy other foods that they do not produce. Similar results were reported in Tanzania that, although infants and young children are commonly given fruit and vegetables rich in vitamin A, their complementary foods are insufficiently diversified; in particular, consumption of animal foods, which are rich in essential micronutrients, especially vitamin A, iron and calcium, is not widespread even in the older age group (FAO, 2008). Most studies in rural population from different countries reported low dietary diversification (Nyaruhucha *et al*., 2006; Badake*et al*, 2014; Kulwa*et al*, 2015).

Nearly, all the infants did not meet RDA for almost all nutrients except dietary energy. Twenty-four hour dietary recall revealed that most of the infants were only fed maize or rice porridge with sugar or salt which are poor sources of other nutrients such as protein, vitamins and minerals. Intakes of vitamin A rich food like eggs, fruits vegetable were also limited in this age group of the children. Observed inadequate intake could be due to the fact that foods fed were of poor nutritional quality or in too small amount or were not frequently fed (WHO, 2009). Prolonged inadequate dietary intake during infancy exposes infants to macronutrient and micronutrient deficiency and chronic malnutrition (Kulwa*et al*., 2015). This was proved by nutritional status assessed in the Kilosa where young children (6-23 months) had higher prevalence of stunting compared to older children (Mrema*et al*., 2019). This result relates with that of Kulwa*et al*. (2015) which reported inadequate dietary intake among children in rural central of Tanzania.

Some of the children aged above one year met RDA for protein, carbohydrate and vitamin A. This group eats family foods in which stiff porridge and rice are the good sources of carbohydrate. Kidney bean is a good source of protein and also vitamin came from green leafy vegetables like sweet potato leaves, pumpkin leaves and amaranth. Like the infants, none in this group met RDA for calcium probably because foods rich in calcium like eggs and milk were

rarely consumed. Egg and dairy products were least consumed reported by only about 2% of the studied children. This can be due to availability or poor maternal nutritional education. This study concurs with a study conducted in Kenya, where it was confirmed that the diets of children were predominantly based on starchy staples (Badake*et al*., 2014). Also, the similar results were reported in Tanzania that, there was limited inclusion of other nutrient-dense foods (e.g. legumes, beef, fish, sardines, vegetables) in the meals and only few infants consumed these foods (Kulwa*et al*., 2015). WHO recommended that complementary foods need to be nutritionally adequate, safe, and properly fed in order to meet the young child's energy and nutrient needs. WHO also reported that the problems on complementary feeding are foods being too dilute, not fed often enough or in too small amounts, or replacing breast milk while being of an inferior quality (WHO, 2009). Feeding frequency is generally low among the rural Tanzanian children. Though WHO recommends 3-4 meals per day plus 1-2 snacks, in this study 14.1% were fed only twice a day, majority were fed three times per day and very few (7.9%) were fed four times per day. This could be the reason for the observed inadequate intake of most of the nutrients.

Conclusion and recommendation

The present study aimed to assess the dietary intake among children aged 6-59 months in the lowland and highland areas in Kilosa District. Generally, most complementary foods were cereal based with limited consumption of animal source foods and fruits. Majority of the studied children consumed less than four food groups hence had less diversified diets where a significant difference was noted; children in lowlands had relatively more diversified diet compared to those from the highlands. Most children did not meet iron, calcium, zinc and vitamin A intake and the results were similar in both locations. Nutritional education based on the use of locally available foods and proper complementary feeding (quality, frequency and time) should be emphasized to mothers in order to improve dietary intake hence reduce the undernutrition among children below five years.

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Competing interests

No conflict of interest to declare

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Sustainable Maize and Rice Production Using Recycled Urban Green Biowastes from Open Markets in Dar es Salaam, Tanzania

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Abstract

A pot experiment study was carried out from October 2018 to January 2019 to assess the potential of pelletized and non-pelletized urban green biowastes from open markets in Dar es Salaam as organic fertiliser. A split plot design was adopted whereby pelletized and non-pelletized biowastes were used as the main plots and their rates were treated as subplots. Four rates of pelletized and non-pelletized biowastes were used (0, 150, 300 and 600 mg N kg^{-1} soil). Complementary application of 300 mg N of biowaste mixed with 300 mg N of urea per kg soil as well as treatment with recommended rate of 600 mg N of urea kg^{-1} soil were used as reference treatment. Plant growth and yields were used to evaluate response of rice and maize. Use of pelletized biowaste at a rate of 0 to 600 mg N kg^{-1} soil increased maize height from 59.19 to 82.52 cm and rice from 80.43 to 84.87 cm. Maize dry matter yield increased from 3.8 to 8.77 g pot^{-1} and rice grain weight per pot increased from14.84 to 26.19 g. However, the highest maize and rice plant heights of 92.61 and 100.43 cm, respectively, and maize dry matter yield of 14.46 g pot^{-1} and rice grain weight per pot of 68.16 g were recorded in the treatment combination of 300 mg N of biowaste and 300 mg N of urea kg^{-1} soil. Results of non-pelletized biowaste followed the same trend as those of pelletized biowaste for both maize and rice crops. The increase in all cases was statistically significant (P = 0.05).The overall results indicated that use of both biowaste and inorganic fertilizer was the best in improving crop yield. It also reduces the use of inorganic fertilizer and assists in recycling of biowastes. However, these results should be verified in the field.

Key words: Maize, Rice, Organic fertilizer, Urban green biowaste

1 Introduction

Sustainable crop cultivation needs appropriate treatment of nutrient resources and conservation of soil fertility. But depletion of soil fertility is a main problem to sustain agricultural production and productivity in many countries including Tanzania. Productivity of maize and rice crops in Tanzania has been reported to be very low. Maize yield averages 1.4 t ha^{-1} while the potential yield is 5 t ha^{-1} and rice yields 0.5-2 t ha^{-1} for upland ecologies and 4.5-6.0 t ha^{-1} for irrigated ecologies compared to the potential yield of 5 t ha^{-1} and 10-11 t ha^{-1} respectively (Luzi-Kihupi *et al.*, 2015). The two crops are the primary staple cereal food crops ranking first and second, respectively in Tanzania (Kahimba *et al.*, 2014; Lyimo *et al.*, 2014). Maize and rice crops are also used as cash crops in regions like Morogoro and Mbeya. The main reason among others for such low productivity is low soil fertility mainly N nutrient (Yin *et al.*, 2014).

Soil fertility is defined as the capacity of a soil to supply nutrients in adequate amounts and in proper balance for sustainable biological productivity, maintain environmental quality and promote plant and animal health (Hartemink, 2006; Roba, 2018). One of the most important

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nutrient input sources into the soil is fertilizer. Fertilizer is organic or inorganic that supplies plants with the necessary nutrients for plant growth and maximum yield (Alimi, 2007).

Cultivated soils do not usually have sufficient amounts of plant nutrients for high and sustained productivity (Quansah, 2010) due to soil degradation, soil acidification, soil organic matter reduction and decrease in the soil aggregate stability (De Meyer, 2011). In one hand, continuous cultivation without soil nutrients replenishment coupled with total crop residual harvest leads to nutrient depletion, reduced soil organic matter and soil aggregate stability decrease (De Meyer, 2011; Roba, 2018). On the other hand, continuous cultivation with inorganic fertilizer application, especially N fertilizers leads to soil degradation and acidification (Han, 2016; Roba, 2018).

Emerging facts illustrated that combined application of organic and inorganic fertilizers increases the productivity of maize, wheat and rice, (Amujoyegbe *et al.*, 2007; Mahmood et al., 2017; Moe *et al.*, 2017) without negative effect on crop and grain quality (Abedi *et al*., 2010) and improves soil fertility through increasing plant residues than the values obtained by organic or inorganic fertilizers separately.

Integrated nutrient management system is an alternative and is characterized by reduced input of inorganic fertilizers and combined use of inorganic fertilizers with organic materials such as green urban biowaste, animal manures, crop residues, green manure and composts (Negassa *et al.*, 2007; Chen, 2008). Combined use of organic and inorganic fertilizers plays a significant role in sustaining soil fertility (Ali *et al.*, 2009; Elkholy *et al.*, 2010; Vanlauwe *et al.*, 2010). The use of organic fertilizers together with inorganic fertilizers has also a higher positive effect on microbial biomass and enhances soil health (Elkholy *et al.*, 2010), improves the use efficiency of recommended inorganic fertilizer and reduces its cost (Ali *et al.*, 2009; Abedi *et al.*, 2010). However, because of the diversity of organic materials in terms of nutrient content and suitability for crop production as a function of type of material, source and handling (Kokkora, 2008) each organic material intended for agricultural use should be characterized and assessed for its suitability for crop production. Several researchers have reported on animal manures, crop residues, green manure and composts as source of nutrients for crop production (Widowati *et al.*, 2012; Negassa *et al.*, 2007; Chen, 2008). Use of these materials in agriculture is limited with its availability (Kayeke *et al.*, 2007). None or very few studies have been conducted to assess the suitability of urban green biowaste for crop production in Tanzania. Urban green biowaste production has been increasing daily in big cities of Tanzania particular Dar es Salaam city. For example, Dar Es Salaam produces between 1040 and 1400 t day^{-1} and about 83 % of these wastes are left near the house premises in open pits, streets, markets or storm water drainage channels (Simon, 2008). This study therefore aimed at evaluating the agronomic potential of urban green biowaste from Dar es Salaam as organic fertilizer for maize and rice production.

3.0 Materials and Methods

3.1 Study Site

This study was conducted in a screen house located at SUA, Morogoro (6.8405°S, 37.6533° E), Soil samples used in this experiment were collected from Tanzania Agricultural Research Institute (TARI)-Dakawa, located between (7.42605°S, 37.70272°E) and (7.426733°S, 37.7045°E). The site is situated in Morogoro region at altitude 154 m above sea level. The soils at Dakawa are sandy clay loam classified by Mbaga *et al.* (2017) as Inceptisol (Soil Taxonomy) and Cambisol (World Reference Base). Morogoro region is one of the major rice and maize producing regions in Tanzania. Dakawa ward in Mvomero district is one of the major rice and maize growing areas in Morogoro. Therefore, Dakawa site is considered to have high potential for rice and maize production (Makoi and Mmbaga, 2018).

3.2 Experimental materials, Treatments and Experimental Design

Urban Green Biowaste (UGB) processed in two forms viz., pelletizedUGB (PUGB) and non-pelletized UGB (NPUGB), Inorganic fertilizers (IF) (Urea, Muriate of Potash (MOP), and Triple supper phosphate (TSP)), Maize and rice crops were used in this experiment. A split plot design was adopted whereby the forms of UGB (pelletized and non-pelletized) were the main plots. Each main plot was subdivided into six subplotscomprising of four subplots with pelletized/non-pelletized UGB applied at a rate of 0,150, 300 and 600 mg N kg^{-1} soil. The fifth subplot was applied only urea (inorganic fertilizer)at a rate of 600 mg N kg^{-1} soil and sixth subplot was applied either pelletized/non-pelletized UGB at rate of 300 mg N kg^{-1} mixed with urea at a rate of 300 mg N kg^{-1} soil. .

Maize and rice were used as test crops. The experimental units (maize and rice crops in pots) were randomly arranged in blocks and replicated three times. The blocking variable was sunlight gradient in the screen house, which occurred during the mornings and evenings. The pots were randomly arranged in blocks (replicates) to counteract light gradient. The used screen house can protect plants from external pests but is less effective in ensuring uniform sunlight.

Urea was applied as top dressing in two splits. First split (50%) was applied at 15 and 25 days after emergence (DAE) for maize and rice crops, respectively. The second split (50%) was applied at 35 and 50 DAE for maize and rice crops, respectively.In totality the splits amounted to a total rate of 300 and 600 mg N kg^{-1} soil (i.e. 2.61 g and 5.22 g for 4 kg soil, respectively) to respective treatments. Phosphorus (P) and potassium (K) were applied at optimal level to enhance correct investigation of the response of maize and rice to N. Potassium was applied as muriate of potash (MOP), and phosphorus as triple super phosphate (TSP). Both potassium and phosphorus were applied at a rate of 240 kg ha^{-1}(i.e. 0.95 g MOP and 2.39 g TSP per 4 kg soil respectively). All UGB, MOP and TSP were applied at planting as basal.

Eight maize (SEEDCO-SC 403 variety) and rice (TXD 306 variety) seeds were sown in eight-litre plastic pots containing 4 kg of 8-mm sieved soil. Potted soil was moistened to field capacity and equilibrated for one day before sowing. Water content was maintained close to field capacity

throughout the experiment (45 DAE) for maize crop and for the first 21 days for rice crop before continuously flooding (flooding depth was made not to exceed a maximum of 10 cm above soil surface to allow tillering) which went to maturity of the plant. Thinning was done at 15 DAE to remain with two and three seedlings per pot for maize and rice crops, respectively.

3.4 Data collection

Plant growth and yield parameters were recorded.Plant height (cm), number of green leaves, number of dry leaves, stem girth (cm) and chlorophyll content were measured at 45 DAE. The two maize plants were harvested by cutting at 1 cm above the soil surface at 45 DAE for dry biomass yield measurement. Shoots were washed with distilled water, air dried for 48 hours and then oven dried at 65°C to constant weight, and weighed to obtain dry matter yields (DMY). Data collected for rice crop were plant height, number of effective tillers, number of non-effective tillers, number of panicles per plant, panicle length, panicle weight, 100-grain weight and grain weight per pot. Plant height was measured using tape measure and chlorophyll content was measured using atLEAF Digital chlorophyll meter device. All grain weights were measured by electronic weighing balance and were adjusted to weight at 14% moisture content.

3.5 Data Analysis

Maize and rice growth and yield parameters were subjected to two way analysis of variance (ANOVA) using GenStat 15th Edition. Mean separation was done by Tukey's Honestly Significant Difference (HSD) Test (P = 0.05). The coefficient of variation (CV) in percentage was also recorded.

4.0 Results

4.1 Effect green urban biowastes on soil properties

The soil properties at the experimental site before planting and after harvesting the crop were as presented in Table 1 and 2. The soil of the experimental site had a pH of 7.27, organic carbon (1.18%) and total N (0.01%) before application of UGB.These levels are considered as neutral, low and very low, respectively according to Landon ratings (Landon, 1991). Increases in pH from 7.27 to 7.72 in PUGB and 7.95 in NPUGB; OC from 1.18 to 2.48% in PUGB and 2.44 % in NPUGB; and total N from 0.01 to 0.24 % in PUGB and 0.25% in NPUGBwere noted in highest rate of UGB (600 mg N kg^{-1} soil). Use of inorganic fertilizer at 600 mg N (UREA) kg^{-1} soildecreased the soil pH from 7.27 to 6.33 in PUGB and 6.48 in NPUGB. A complementary useof UGB and inorganic fertilizer (300 mg N kg^{-1} (UGB) + 300 mg N (UREA)kg^{-1} soil)decreased a pH from 7.27 to 6.84 in PUGB and 7.11 in NPUGB; increased OC from 1.18 to 1.63 in PUGB and 1.65 in NPUGB; and increased total N from0.01 to 0.11 in PUGB and 0.13 in NPUGB.

Table1: Soil analytical data of some selected parameters before and after maize pot experiment treated by PUGB

		pH	EC	OC	N	Olsen Ext P	K^+
			dS/m	(%)	(%)	mg kg^{-1}	Cmolc kg^{-1}
Before pot experiment		7.27	0.11	1.18	0.01	33.59	0.38
After pot experiment	Treatment					Olsen/Bray-I Ext P (mg kg^{-1})	
	0 mg N kg^{-1} soil	7.01	0.69	1.18	0.01	93.09	0.44
	150 mg N (PUGB) kg^{-1} soil	6.77	0.29	1.20	0.05	101.25	0.50
	300 mg N (PUGB) kg^{-1} soil	7.43	0.24	1.57	0.09	93.18	1.24
	600 mg N (PUGB) kg^{-1} soil	7.72	0.34	2.48	0.24	90.68	2.07
	600 mg N (UREA) kg^{-1} soil	6.33	0.52	1.18	0.13	98.73	0.43
	300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	6.84	0.29	1.63	0.11	89.84	1.05

Note: PUGB = pelletized urban green biowaste

Table 2: Soil analytical data of some selected parameters before and after maize pot experiment treated by NPUGB

		pH	EC	OC	N	Olsen Ext P	K^+
			dS/m	(%)	(%)	mg kg^{-1}	Cmolc kg^{-1}
Before pot experiment		7.27	0.11	1.18	0.01	33.59	0.38
After pot experiment	Treatment					Olsen/Bray-I Ext P (mg kg^{-1})	
	0 mg N kg^{-1} soil	6.96	0.23	1.16	0.01	107.49	0.46
	150 mg N (NPUGB) kg^{-1} soil	7.47	0.22	1.19	0.06	99.60	0.82
	300 mg N (NPUGB) kg^{-1} soil	7.51	0.24	1.52	0.08	97.06	1.12
	600 mg N (NPUGB) kg^{-1} soil	7.95	0.30	2.44	0.25	77.87	2.01
	600 mg N (UREA) kg^{-1} soil	6.48	0.43	1.18	0.14	83.43	0.43
	300 mg N (NPUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	7.11	0.36	1.65	0.13	88.40	1.14

Note:NPUGB = non-pelletized urban green biowaste

4.2 Overall effect of PUGB and NPUGB on growth and yield of maize.

Table 3 presents the overall effects of urban green biowaste on growth and yield of maize.

Table 3: Overall effects of PUGB and NPUGB on maize plant growth and dry biomass yield.

Type of biowaste	Plant height(cm)	No. Green leaves per plant	Chlorophyll content	Stem girth (cm)	Dry matter yield (g pot^{-1})
PUGB	77.69	7	40.51	3.89	8.36
NPUGB	74.91	7	40.69	3.81	7.75
L.S.D (0.05)	3.032	0.4	1.30	0.79	1.19
Significance	ns	Ns	ns	ns	ns

L.S.D = least significance difference, ns = non-significant

Maximum plant height (77.69 cm), stem girth (3.89 cm) and dry matter yield (8.36 g pot^{-1}) were produced in PUGB while the maximum leaf chlorophyll content (40.69) was produced in NPUGB. Both PUGB and NPUGB produced the same number of green leaves per plant was. The difference between application of PUGB and NPUGB was insignificant (P = 0.05) across all parameters.

4.2.1 The effects of PUGB on maize growth and dry biomass yield

The effects of PUGB on maize plant height, stem girth and dry biomass are presented in Table 4

Table 4: The effects of pelletized biowaste on maize plant height, stem girth and dry biomass yield.

Treatment	Plant height (cm)	Stem girth (cm)	Dry matter yield (g pot^{-1})	Chlorophyll content	No. of green leaves	No.of dry leaves,
0 mg N kg^{-1} soil	59.19 a	3.27 a	3.80 a	25.46 a	4.826 a	4.01 c
150 mg N (PUGB) kg^{-1} soil	67.36 ab	3.44 abc	5.48 ab	30.41 ab	5.51 ab	2.67 abc
300 mg N (PUGB) kg^{-1} soil	73.11 abc	3.62 abc	6.64 ab	31.42 ab	6.16 abcd	2.34 abc
600 mg N (PUGB) kg^{-1} soil	82.52 cd	3.64 abc	8.77 ab	49.44 c	7.16 bcde	2.01 a
600 mg N (UREA) kg^{-1} soil	83.02 cd	4.24 cd	9.18 bc	51.36 cd	7.92 cdef	1.34 a
300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	92.61 d	4.87 d	14.46 d	55.48 d	9.49 f	1.34 a
F-Prob.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	6.4	7.4	18.6	4.9	10.3	24.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P = 0.05).

Note: PUGB = pelletized urban green biowaste, CV = coefficient of variations, F-Prob. = F-Probability value

Greatest plant height (92.61 cm) and stem girth (4.87 cm) were recorded in the combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1}. It was followed by sole inorganic fertilizer (600 mg N (Urea) kg^{-1} soil) which produced plants with 83.02 cm height and 4.24 cm stem girth. The shortest plant (59.19 cm) and smallest stem girth (3.27 cm) were obtained in the control which was significantly different (P = 0.05) over combined fertilization of

300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} and sole application of 600 mg N (UREA) kg^{-1} soil and sole application of 600 mg N (PUGB) kg^{-1} soil for plant height case (Table 4). Use of sole inorganic fertilizer (600 mg N (Urea) kg^{-1} soil) and sole application of PUGB (600 mg N (PUGB) kg^{-1} soil) which produced comparable (P = 0.05) plant heights (83.02 cm and 82.52 cm, respectively). The effects of NPUGB on plant height and stem girth followed the same trend as those of pelletized PUGB (Table 5).

Measurement of leaf chlorophyll concentration and number of leaves is a basic tool of growth analysis. The two parameters are directly related with both biological and economical yield. In case of any plant, leaves are important organs which have an active role in photosynthesis (Krishnaprabu and Grace, 2017). On the other hand, leaf chlorophyll concentration is often well correlated with plant metabolic activity (e.g., photosynthetic capacity and RuBP carboxylase activity; Fanizza *et al.*, 1991), as well as leaf N concentration. To achieve high yield, maximization of leaf area and leaf chlorophyll concentration are important factors (Krishnaprabu and Grace, 2017). In the present study the greatest leaf chlorophyll content (55.48) and number of green leaves (9.49) were recorded in the treatment combination of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil which was significantly different (P = 0.05) over control which produced plants with (4.826) number of green leaves and (25.46) leaf chlorophyll content (Table 2). Sole application of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) and use of PUGB alone (600 mg N (PUGB) kg^{-1} soil) produced statistical similar (P = 0.05) number of green leaves (7.92 and 7.16 respectively) and leaf chlorophyll content (51.36 and 49.44 respectively) as those of combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil.

The lowest number of dry leaves (1.34) was recorded in the treatment combination of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil and in an exclusive application of 600 mg N (UREA) kg^{-1} soil. It was followed by sole application of PUGB (600 mg N (PUGB) kg^{-1} soil) which produced (2.01) number of dry leaves. The highest number of dry leaves (4.01) was recorded in the control treatment which was significant different (P =0.05) over treatment combination of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil, an exclusive application of 600 mg N (UREA) kg^{-1} soil and the sole application of PUGB (600 mg N (PUGB) kg^{-1} soil). The effects of NPUGB on leaf chlorophyll concentration and number of green leaves and number of dry leaves followed the same trend as those of pelletized PUGB (Table 5).

Greatest dry matter yield (14.46 g pot^{-1}) was observed in the combined fertilization of inorganic fertilizer and PUGB (300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) which was significantly different (P = 0.05) over all other treatments including sole application of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil), sole application of PUGB (600 mg N (PUGB) kg^{-1} soil) and control with numerical values of 9.18, 8.77 and 3.80 g pot^{-1} respectively. The effects of NPUGB on dry biomass yield followed the same trend as those of pelletized PUGB (Table 5).

Table 5: The effects of NPUGB on maize plant height stem girth and dry biomass yield

Treatment	Plant height (cm)	Stem girth (cm)	Dry matter yield (g pot^{-1})	Chlorophyll content	No. of green leaves	No.of dry leaves,
0 mg N kg^{-1} soil	61.64 a	3.19 a	4.09 a	26.88 a	4.841 a	3.92 bc
150 mg N (NPUGB) kg^{-1} soil	67.48 ab	3.34 ab	5.37 ab	29.82 ab	5.83 abc	2.33 ab
300 mg N (NPUGB) kg^{-1} soil	72.81 abc	3.74 abc	7.96 ab	34.55 b	6.84 abcde	2.33 ab
600 mg N (NPUGB) kg^{-1} soil	77.39 bc	3.79 abc	7.97 ab	47.92 c	7.17 bcde	1.66 a
600 mg N (UREA) kg^{-1} soil	83.34 cd	4.17 bcd	9.49 bc	50.75 cd	8.17 def	1.49 a
300 mg N (NPUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	95.14 d	4.86 d	13.44 cd	53.67 cd	8.84 ef	1.99 a
F-Prob.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CV (%)	6.4	7.4	18.6	4.9	10.3	24.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P = 0.05).

Note: NPUGB=Non-pelletized urban green biowaste, CV = coefficient of variations, F-Prob. = F-Probability value

4.3 Overall effect of PUGB AND NPUGB on rice plant growth and grain yield

Table 6 presents the overall effects of UGB on growth and yield of maize.

Table 6: Overall effect of PUGB AND NPUGB on rice plant growth and grain yield

Type of biowastes	Plant height (cm)	Number of effective tillers per plant	Number of non-effective tillers per plant	Number of panicles per plant	Panicle length (cm)	100-Grain Weight (g)	Grain weight per pot (g)	Panicle weight (g)
PUGB	88.83	5.13	1.25	5.15	20.08	2.85	39.41	2.31
NPUGB	88.80	5.04	1.08	5.06	19.99	2.86	38.24	2.37
L.S.D (0.05)	6.428	0.969	0.668	1.190	0.719	0.059	7.732	0.146
Significance	Ns	ns	Ns	Ns	ns	ns	ns	ns

L.S.D = least significance difference, ns = non-significant

Maximum plant height (88.83 cm), number of effective tillers (5.13), number of non-effective tillers (1.25), number of panicles per plant (5.15), panicle length (20.08 cm), panicle weight (2.31 g) and grain weight per pot (39.41 g) were produced in PUGB while the maximum 100-grain weight (2.86 g) was produced in NPUGB. The difference between use of PUGB and NPUGB was insignificant (P = 0.05) across all parameters.

4.3.1 Rice plant growth and yield response to application of PUGB.

Table 7 presents the effect of PUGB on rice plant height, number of effective tillers per plant, number of non-effective tillers per plant, number of panicles per plant, panicle length, 100-grain weight, grain weight per pot and panicle weight.

The greatest plant height (100.43 cm) was observed in a treatment combination of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil. It was followed by the use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) which produced plants with (98.65 cm) heights. The third treatment in terms of plant height performance was the sole application of 600 mg N (PUGB) kg^{-1} soil which produced plants (84.87 cm) heights. The shortest plant height (80.43 cm) was recorded in the control which was significantly different (P = 0.05) over treatment combination of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil, inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) and the sole application of 600 mg N (PUGB) kg^{-1} soil. The effect of NPUGB on rice plant height followed the same trend as those of PUGB (Table 8).

Tillering is an important trait for grain production and is thereby an important aspect in rice yield. However, the productivity of rice plant is greatly dependent on the number of effective tillers (tillers with panicles bearing at least one filled grain) rather than the total number of tillers. In the present study the greatest number of effective and non-effective tillers per plant (9.62 and 2.21 respectively) was recorded in exclusive application of 600 mg N (UREA) kg^{-1} soil which was significantly different (P = 0.05) over the control treatment (2.731 and 0.855). Comparable number of effective tillers per plant (9.62 and 8.065) and non-effective tillers per plant (2.21 and 2.124) was obtained in the treatment with sole applications of 600 mg N (UREA) kg^{-1} soil and in the treatment combination of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil, respectively. Application of exclusive 600 mg N (PUGB) kg^{-1} soil gave results which were statistically similar (P = 0.05) to that of control treatment on number of effective and non-effective tillers per plant. The effect of NPUGB on number of effective tillers per plant and number of non-effective tillers per plant followed the same trend as those of PUGB (Table 8).

Table 7: The effects of PUGB on rice plant growth and yield parameters

Treatment	Plant height (cm)	Number of effective tillers per plant	Number of non-effective tillers per plant	Number of panicles per plant	Panicle length (cm)	100-Grain Weight (g)	Grain Weight per pot (g)	Panicle weight (g)
0 mg N kg^{-1} soil	80.43 a	2.731 a	0.855 a	2.731 a	18.84 ab	2.811 a	14.84 a	1.861 a
150 mg N (PUGB) kg^{-1} soil	84.20 ab	2.843 a	0.381 a	2.843 a	19.23 abc	2.817 a	17.39 a	2.039 a
300 mg N (PUGB) kg^{-1} soil	84.31 ab	3.287 a	0.794 a	3.287 a	19.71 abcd	2.876 a	21.21 a	2.102 a
600 mg N (PUGB) kg^{-1} soil	84.87 abc	3.954 a	0.635 a	3.954 a	19.90 abcde	2.872 a	26.19 a	2.261ab
600 mg N (UREA) kg^{-1} soil	98.65 bcd	9.620 bc	2.210 b	9.620 b	21.80 e	2.882 a	85.17 b	2.982 c
300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	100.43 cd	8.065 bc	2.124 b	8.176 b	20.71 bcde	2.898 a	68.16 b	2.814 bc
F-Prob.	<.001	<.001	<.001	<.001	<.001	0.318	<.001	<.001
CV (%)	6.0	12.9	25.2	13.1	3.5	2.1	16.8	9.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P = 0.05).

Note: PUGB = pelletized urban green biowaste, CV = coefficient of variations, F-Prob. = F-Probability value

The greatest number of panicles per plant (9.62), longest panicle length (21.8 cm) and panicle weight (2.982 g) were obtained in treatment with sole applications of 600 mg N (UREA) kg^{-1} soil which was significantly different (P = 0.05) over the control treatment (Table 5). Comparable number of panicles per plant (9.62 and 8.176) was recorded in treatment with sole applications of 600 mg N (UREA) kg^{-1} soil and in a treatment combination of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil. The effect of NPUGB on number of panicles per plant, panicle length and panicle weight followed the same trend as those of PUGB (Table 8).

The heaviest 100-grain weight (2.898 g) was recorded in a treatment combination of 300 mg N (PUGB) kg^{-1} soil and 300 mg N (UREA) kg^{-1} soil. However there was no significance difference (P = 0.05) between the control and other treatments on 100-grain weight parameter. The effect of NPUGB on 100-grain weight followed the same trend as those of PUGB (Table 8).

The greatest grain weight per pot (85.17 g) was recorded in sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil). It was followed by the combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil which produced grain weight of 68.16 g and it was statistically similar (P = 0.05) to sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil). The minimum grain weight per pot (14.84 g) was noted in the control which was significantly different (P = 0.05) over the sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) and the combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil. The effect of NPUGB on grain weight per pot followed the same trend as those of PUGB (Table 8).

Table 8: The effects of NPGUB on rice plant growth and yield parameters

Treatment	Plant height (cm)	Number of effective tillers per plant	Number of non-effective tillers per plant	Number of panicles per plant	Panicle length (cm)	100-Grain Weight (g)	Grain Weight per pot (g)	Panicle weight (g)
0 mg N kg^{-1} soil	78.91 a	2.824 a	0.853 a	2.824 a	18.42 a	2.8 a	15.64 a	1.837 a
150 mg N (NPUGB) kg^{-1} soil	82.91 ab	2.935 a	0.468 a	2.935 a	19.28 abc	2.827 a	18.62 a	2.151 a
300 mg N (NPUGB) kg^{-1} soil	84.35 ab	3.491 a	0.881 a	3.491 a	19.38 abcd	2.847 a	19.39 a	2.159 a
600 mg N (NPUGB) kg^{-1} soil	88.13 abcd	3.602 a	0.468 a	3.491 a	20.48 abcde	2.871 a	23.28 a	2.177 ab
600 mg N (UREA) kg^{-1} soil	97.02 bcd	9.824 c	2.315 b	9.824 b	21.46 de	2.877 a	87.25 b	2.911 c
300 mg N (NPUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil	101.57 d	7.824 b	2.015 b	8.046 b	21.18 cde	2.934 a	68.78 b	2.824 bc
F-Prob.	<.001	<.001	<.001	<.001	<.001	0.318	<.001	<.001
CV (%)	6.0	12.9	25.2	13.1	3.5	2.1	16.8	9.2

Means in the same column followed by the same letter are not significantly different according to Tukey's Honestly Significant Difference (HSD) Test (P = 0.05).

Note: NPUGB = Non-pelletized urban green biowaste, CV = coefficient of variations, F-Prob. = F-Probability value

5.0 Discussion

5.1 Effect urban green biowastes (UGB) application on soil properties

The low soil nitrogenand organic carbon at the experimental site could be due to negative nutrient imbalance that is often associated with intensive cropping and inappropriate application of inorganic fertilizer in the traditional cropping, as reported by Adejobi and Kormawa (2002). This implies that addition of N and organic matter to the soils is necessary for increased and sustainable yield of maize and rice in the study area. The increase in pH of the soils in response to application of either PUGB or NPUGB alone at 600 mg N kg^{-1} soil compared to other treatments could be due to break down of organic materials to ammonium (mineralization)and carbon dioxide release during organic matter decomposition whereas the increase in OC and total N could have been attributed to decompositionand mineralization of UGB respectively.On the other hand decrease in pH due to application of 600 mg N (UREA) kg^{-1} soil could have been attributed to nitrification of ammonium-N produced by urea.The pH obtained in pots treated with a combination of UGB and inorganic fertilizer (300 mg N kg^{-1} (UGB) + 300 mg N (UREA) kg^{-1} soil) were favorable for maize and rice production as has been stipulated byMcCauley *et al*.(2009) that the pH range of 6.5 to 7.5 is ideal for production of cereal crops.

Based on these findings, it is clearly that application of 600 mg N of either PUGB or NPUGB per kilogram of soil improved the soil by increasing the soil OC and total N.

5.2 Overall effect of PUGB and NPUGB on growth and yield of maize

Insignificant different between the two forms of biowaste could be due to the fact that the same materials were used but in different forms, some were made pellets for easy application and handling while others were left in non-pellets form. However, the difference observed could be due additional nutrients present in the clay soil used for binding up the biowastes when making pellets. Generally use of PUGB and NPUGB improved growth and yield of maize significantly ($P = 0.05$) as it is revealed in their different rates applied (Tables 4 and 5), though PUGB would be relatively better option.

5.3 The effects of PUGB on maize growth and dry biomass yield

The significant influences on plant height and stem girth due to combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil might be due to sufficient macro and micronutrients in these fertilizers and enhanced absorption of nutrients by plants. It might also be due to the enhanced metabolic activities which lead to an increase in various plant metabolites responsible for cell division and elongation (Siavoshi *et al.*, 2013). Adamu and Leye (2012)reported that plant height of corn had a high positive correlation with the addition of manure alone or with inorganic fertilizers.

The positive effect of the combined fertilization treatment (the 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) on increasing leaf chlorophyll content and number of green leaves compared to inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) and other treatments may be due to the role of PUGB with inorganic fertilizers in providing the

essential nutrient elements necessary for plant growth especially nitrogen which result in the improvement of plant growth and yield parameters (Amanolahi- Baharvand *et al.*, 2014). According to Fageria *et al.* (2010) and Wang *et al.* (2014) nitrogen is one of the most important nutrients essential for the growth of crops, and is a major component of chlorophyll and protein which are closely associated with leaf color, crop growth status and yield.

The greatest dry matter yield recorded in the combined fertilization of inorganic fertilizer and PUGB (300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil) could have been attributed to highest plant height, greatest number of green leaves, stem girth and chlorophyll content which were recorded in the same treatment. Such growth parameters are positively associated with dry matter accumulation (Latt *et al.*, 2009). Several other researchers have reported similar trend of findings on maize crop in response to combined fertilization of inorganic and organic fertilizers (Afe *et al.* 2015; Fabunmi and Balogun, 2015).

As discussed above, it is clear that the combined fertilization of 300 mg N of PUGB per kg soil and 300 mg N of urea per kg soil significantly increased plant height, number of green leaves per plant, stem girth, leaf chlorophyll content and dry matter yield. This suggests that combined fertilization of half dose of PUGB or NPUGB and urea at rate of 300 kg N kg^{-1} soil would improve growth and yield parameters of maize plant as compared to sole application of full dose of either PUGB, NPUGB or urea at a rate of 300 kg N kg^{-1} soil.

5.4 Overall effect of pelletized and non-pelletized biowaste on rice plant growth and yield

Insignificant different between the two forms of biowaste could be due to the fact that the same materials were used but in different forms, some were made pellets for easy application and handling while others were left in non-pellets form. However, the difference observed could be due additional nutrients present in the clay soil used for binding up the biowastes when making pellets. Generally use of PUGB and NPUGB improved growth and yield of rice crop significantly (P = 0.05) as it is revealed in their different rates applied (Tables 7 and 8), though PUGB would be relatively better option.

5.5 Rice plant growth and yield response to application of PUGB.

The relative increase in plant height in response to integrated use of 300 mg N (PUGB) kg^{-1} soil and 300 mg N (UREA) kg^{-1} soil over other treatments could be due to enhanced N availability and uptake to the crop plant following the application of inorganic fertilizer in combination with PUGB.

The recorded increase in number of tillers per plant in sole application of inorganic fertilizer compared to other treatments could be due to the enhanced N availability and uptake to the crop plant following an increased N rate which was 600 mg N (UREA) kg^{-1} soil. Nitrogen loses through leaching and volatilization was prevented by using non-perforated pots and continuous flooding throughout the experiment. This might have induced the nitrogen nutrient uptake by a crop plant and led to enhanced metabolic

activities increasing production of various plant metabolites responsible for cell division and elongation (Siavoshi *et al.*, 2013).

The significant increase in number of panicles per plant and panicle length could be due to the enhanced nutrient availability particularly N to the crop plant uptake following an increased rate of inorganic fertilizer which was 600 mg N (UREA) kg^{-1} soil. Nitrogen loses through leaching and volatilization was also prevented by using non-perforated pots and continuous flooding hence higher number of green leaves that led into higher photo-assimilates and thereby resulted in greater number of panicles per plant and longest panicle length (Siavoshi *et al.*, 2013).

Observed increase in 100-grain weight in the integrated use of 300 mg N (PUGB) kg^{-1} soil and 300 mg N (UREA) kg^{-1} soil compared to sole fertilization of 600 mg N (UREA) kg^{-1} soil and other treatments could be due to the ability of the combined fertilization to check N losses. A combined use of organic and inorganic fertilizers checks nitrogen losses through conserving it by forming organic-mineral complexes and thus ensures continuous N availability to rice plants and greater yields (Joshi *et al.*, 2017).

The relative increase in yield of rice in response to inorganic fertilization of 600 mg N (UREA) kg^{-1} soilcompared to other treatments could be due to the increased yield parameters viz., number of effective tillers per pot, panicle length, number of panicles per plant and panicle weight which were observed in the pots treated with inorganic fertilizer (600 mg N (UREA) kg^{-1} soil).

As discussed above, it is clear that the sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil significantly increased plant height, number of effective tillers per plant, number of panicles per plant, panicle length, panicle weight and grain weight per pot. This implies that sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil would improve growth parameters and yield of rice plant as compared to other treatments applied.

6.0 Conclusions and Recommendations

6.1 Conclusions

Results from the present study have indicated that:

- The use 600 mg N of either PUGB or NPUGB per kilogram soil increased soil OC and total N.
- The use of PUGB or NPUGB improved growth and yield parameters of both maize and rice crops.
- The use of PUGB and NPUGB did not differ significantly across all growth and yield parameters of both maize and rice crops. However, use of PUGB slightly improved growth and yield parameters of both maize and rice crops.
- Use of combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil improved growth and yield parameters of maize plant.
- Sole use of inorganic fertilizer (600 mg N (UREA) kg^{-1} soil) improved growth parameters and yield of rice plant.

6.2 Recommendations

The present study recommended the following:

- PUGB or NPUGB can be used as soil amendment in maize and rice production. However, PUGB would be a better option due its added advantages of easy application and handling apart from slight improvement of growth and yield parameters.
- For better improved maize yield use of combined fertilization of 300 mg N (PUGB) kg^{-1} soil + 300 mg N (UREA) kg^{-1} soil is recommended.
- For better improved rice yield use 600 mg N (UREA) kg^{-1} soil rate of inorganic fertilizer alone is recommended.
- Further study should be conducted under field conditions to verify the findings of the present study.

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Are the Levels of Organochlorine Pesticides in Fish Species from Lake Victoria in Tanzania a Health Risk?

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Abstract

Global food security is being threatened by many emerging issues of food safety concern such as consumption of unsafe foods contaminated by organochlorine pesticides (OCPs). Scientific evidence has indicated that consumption of unsafe foods results into more deaths than even malnutrition. There has been an increase in cancer such as liver, prostate and breast cancers and other food borne illnesses which are attributed to unsafe foods.Organochlorine pesticides were studied in L. niloticus and O. niloticus from Lake Victoria in Tanzania. In this study, of the 19 OCPs which were considered,only 7 OCPs (α- HCH, β-HCH, HCB, Aldrin, Dieldin, p,p'-DDE and p,p'- DDT) were detected at variable concentrations in one or more of the composite samples. Samples extractions were effected by QuEChERS method and identification and quantification by GC- ECD. Detection of high levels of HCH isomers (α- HCH and β-HCH) and decomposition product DDE than the parent compounds γ- HCH (Lindane) and DDT respectively indicates historical use of the pesticides in the study area. Comparison of Dieldrin to Aldrin ratio in the current study gave values greater than 1 indicating that the detected residues were not likely from the recent applications of Aldrin. The levels of these contaminants were below the limits set by FAO/WHO suggesting that the fish were fit for human consumption in regard to OCPs concentrations. Human health risk assessment indicated a cancer risk between 1E-06 to 1E-04 implying a very low to low risk while the hazard indices were less than one indicating that the non-cancer risks due to consumption of fish from Lake Victoria are insignificant.

Key words: Agriculture, OCPs, POPs, fish, Lake Victoria

1 Introduction

Sustainable agriculture is one of the supreme challenges in Tanzania as well as other developing countries. Sustainability implies that agriculture and agriculture related activities not only increase country's economy and secure a sustained food supply, but also their environmental, socio-economic and human health impacts are recognized and accounted for within national development plans (Tilman, 1999 & Kihampa and Wenaty, 2013). FAO's 1990, defined sustainable development as the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations (FAO, 1990;&Kihampa and Wenaty, 2013). Such development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable (Pretty, 2008). In the past few decades there has been a remarkable growth of agriculture sector in many parts of Tanzania with an increased use of agrochemicals such as pesticides for enhancement of productivity.

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These practices have raised public concern about the condition of fresh water and aquatic organisms in the country due to expansion of agricultural activities in the vicinity of water resource catchments. One of the serious problems is the contamination of water resources and aquatic organisms by toxic chemicals such as pesticides, fertilizers, livestock chemicals and the by-products that originate from agriculture fields (Kihampa and Wenaty, 2013). These have resulted into conservative water pollution and reduction of river in such a way that pollution can no longer be remedied by dilution in many countries (Park *et al*., 2006). The principal environmental and public health dimensions of the global freshwater quality problems include ecosystem dysfunction and loss of biodiversity, contamination of marine ecosystems from land based activities, contamination of groundwater resources, global contamination by persistent organic pollutants and death of millions of people annually from water-borne diseases (Ongley, 1996). Among the important persistent organic pollutants of public health concerns are organochlorine pesticides (OCPs). The organochlorine pesticides (OCPs) are characterized by high persistent, low polarity, low aqueous solubility and high lipid solubility (lipophilicity) (Olayinka *et al*., 2015&Wenaty *et al*., 2019). They are ecotoxic, non- biodegradable and able to bioaccumulate and biomagnify in living organisms (Polder *et al*., 2014; Lars, 2000 & Afful *et al*., 2010). They are listed in the Stockholm Convention as persistent organic pollutants (POPs) due to their effects on the environment. Their toxicity has caused them to be banned for use in developed and some developing countries. However, some developing nations are still using them for various purposes (Ssebugere *et al*., 2014; Ennacer *et al*., 2008; Adeyemi *et al*., 2011 & Henry and Kishimba, 2006). They are among the agrochemicals that have been extensively used for long periods in agriculture as well as mosquito and termite control programs (Farshid *et al*., 2012). Besides their persistence in the environment, OCPs move considerable long distances from their points of applications and get accumulated in vegetation, soil and water bodies (Olayinka *et al*., 2015). In East Africa, particularly in Kenya, Uganda and partly Tanzania, there have been reports of some levels of OCPs in water, sediments and fish (Henry and Kishimba, 2006; Polder *et al*., 2014 & Ssebugere *et al*., 2014). However, the data on OCPs levels in fish from Tanzanian side of Lake Victoria are inadequate. The main contributors to the levels of OCPs in environmental matrices are reported to be several human activities such as waste from industrial chemical production, pesticide runoff from agricultural areas, sewage and refuse dumps. Because of their efficiency, potency and low cost compared to other alternative pesticides currently in use, OCPs are still being used in some parts of Lake Victoria (Henry and Kishimba, 2006 & Ssebugere *et al*., 2014). It is therefore necessary to establish levels of OCPs in fish from the lake due to a reason that residues of these pesticides used in agricultural and vector control activities are washed into the rivers when rain falls and then to the lake. These substances being highly hydrophobic can potentially bioaccumulate in human beingsthrough eating the fish (Afful *et al*., 2010 & Olayinka *et al*., 2015). This study therefore aims to determine levels of OCPs residues in L. niloticus and O. niloticus from Lake Victoria, Tanzania.

2 Materials and Methods

2.1 Description of the Study Area

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Lake Victoria is a trans-boundary lake shared between Tanzania (51%), Uganda (43%) and Kenya (6%). It is the World's second largest lake with an approximated total surface area of 68,800 km2 after Lake Superior located in North America. The lake supports one of the World's most productive inland fisheries of commercial species such as Nile perch, Nile tilapia and other species. The highly caught and consumed fish species at international and local/regional markets are Nile perch (L. niloticus) and Nile tilapia (O. niloticus) respectively.

In Tanzania the lake is shared by five Regions, namely; Mwanza, Mara, Kagera, Simiyu and Geita (Fig. 1).

Figure 1: A map showing Tanzanian side of Lake Victoria and sampling points

2.2 Sampling

Samples of L. niloticus and O. niloticus were collected from randomly selected fish folks at nine nationally designated landing sites from seven districts of Tanzanian side of Lake Victoria between July – August 2016. The two fish species are major commercial fish species highly consumed in the Lake Victoria basin and they have different feeding habits and trophic levels. Fish samples were measured for total length and weight by using a ruler and a beam balance respectively and stored in cool box at 4°C and transported to the laboratory for deep freezing at -18°C until extraction.

2.3 Fish Samples Extraction and Cleanup

Fish samples extraction and cleanup for determination of PCBs was effected using QuEChERS procedure at the National Fish Quality Control Laboratory in Mwanza, Tanzania. Three samples of almost the same size and weight (Kasozi *et al*., 2006) from the same sampling location, and same species were pooled and homogenized to form a single composite sample (Polder *et al*., 2014). Thirty grams of each sample was measured in triplicates (3 x 30g) and ground using a motor and pestle to homogenize. Fifteen grams of composite samples were transferred into 50mls centrifuge tubes. Fish samples to be treated as control samples were spiked with a known concentration of OCPs. Thereafter, 2.5g of sodium bicarbonate (NaHCO3), 60 mL of ethyl acetate and 15g of anhydrous Na2SO4were added and placed in a vortex mixer to homogenize for 2 minutes. The supernatants were transferred into 15mL centrifuge tubes containing 0.125g of Primary Secondary Amine (PSA) and 0.75g of anhydrous MgSO4 (Anastassides *et al*., 2003&Wenaty *et al*., 2019). The mixture was centrifuged at 2500rpm for 5 minute and left to separate for further 2 minutes. The supernatants were transferred into vials. Prior to GC analysis, the supernatants were evaporated with a stream of nitrogen to dryness to assess the lipid content and concentrate the analytes. Supernatants with large amounts of lipids were further cleaned as follows; the extract was transferred to an Agilent EMR Lipid dSPE 15 mL tube, vortexed and centrifuged for 5 min. Polishing salts from an Agilent EMR MgSO4 polish pouche were added, vortexed and shaken immediately. The sample was centrifuged and an aliquot transferred to a micro centrifuge tube containing Agilent EMR MgSO4 polish and centrifuged at 14500 rpm for 5 min. The supernatant was finally transferred to a GC vial, eluted with isooctane and internal standards added for GC analysis.

2.4 Recoveries And Analytical Quality Control

Recovery tests were done for OCPs of interest. Blank samples were spiked with standards and were subsequently extracted and analysed in the same way as other samples. To maintain the quality of analytical results blanks and standards were analysed every after analysis of five samples. The limits of detection (LODs) of the analytes were calculated as concentrations whose peaks were three times the peaks of signal to noise (S/N) ratios while their corresponding limits of quantification (LOQs) were determined as concentrations whose peaks were ten times the peaks of signal to noise (S/N) ratios

2.5 Chemical Analysis

Chemical analysis was performed at the laboratory of Food Analytical Chemistry, Technical University of Denmark (DTU), Denmark. The samples of fish species collected were analyzed for 19 OCPs namely; p, p'- DDT, o, p- DDT and metabolites p, p'- DDE and p, p'- DDD, α – HCH, β – HCH, γ – HCH (lindane), HCB, Heptachlor, Heptachlor epoxide, Aldrin, Dieldrin, Endrin, Isodrin, α– Endosulfan, Oxychlordane, γ– Chlordane, α– Chlordane and Transnonachlor. The studied OCPs are listed in the Stockholm Convention on POPs for initial elimination and reduction in use because of their effects on environment as well as living organisms.

2.6 Detection of OCPs in Fish Samples

Separation and detection of OCPs were performed on a Hewlett Packard Gas Chromatography (Agilent 6890 Series gas chromatography system; Agilent Technologies) equipped with an autosampler (Agilent 7683 Series; Agilent Technologies). For optimum separation, a dual capillary column system with two separate columns of different polarity and selectivity were used (Chrompac CP – sil 5CB and J & W DB- 17), Nominal length 50m & 60m respectively, 0.25mm ID, 0.25µm film thickness) and coupled to two 63Ni electron capture detectors (Agilent 6890 ECD). The following GC conditions were used: Injector temperature: 280°C; injection volume: 2µL; injector mode: split less; purge flow: 42mL/min; purge time: 0.60min; carrier gas: Helium; constant flow: 2.0mL/min and 1.3mL/min respectively and make up gas: Nitrogen. The temperature programme was 90°C held for 2.0minutes; 30°C/min increased to 170°C held for 7.5minutes; 2.0°C/min increased to 185°C; 3.0°C/min increased to 220°C held for 15minutes; 3.0°C/min increased to 255°C held for 2minutes and 5.0°C/min increased to 280°C held for 10minutes. The detector temperature was 300°C(Wenaty *et al*., 2019).

2.7statistical Analysis

All statistical analyses were performed with SAS Version 9.4. Data on OCP concentration were presented as mean ± SD per site and per species. One – way ANOVA was used to compare concentrations between sites and between species. In data processing, the concentrations of OCPs in samples below the limit of detection (<LOD) were treated as zero. Relationship between OCPs concentration in L. niloticus and O. niloticus were analysed using Pearson's correlation. Significance was declared at $p<0.05$ for all analyses.

2.8 Risk Assessment Model

The estimated dose (CDI) received through consumption of fish products was calculated using equation (i) and the cancer risk (CR) using equation (ii), adopted from the Environmental Protection Agency (USEPA, 1997; UESPA, 2009) of the United States.

$$CDI = \frac{C \times IR \times EF \times ED}{BW \times AT} \text{ ---------- (i)}$$

$$C_R = SF * CDI \text{ ---------- (ii)}$$

For non-carcinogenic risks, the hazard quotients (HQ) of each organochlorine pesticide measured and the overall hazard indices (HI) were calculated by using equations (iii) and (iv)

$$HQ = \frac{CDI}{RfD} \text{ ---------- (iii)}$$

$$HI = \sum HQ_x \text{ ---------- (iv)}$$

Where;

CDI (mg/kg-day) is the estimated chronic daily intake

C_R is the cancer risk via consumption of contaminated fish products

C (mg/kg) is the measured concentration of OCPs in fish products

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IR (kg/day) is the consumption rate
HI (mg/kg-day) is the hazard index (overall non- cancer risk via consumption of contaminated fish products
HQ (mg/kg-day) is the hazard quotient (individual compound non- cancer risk via consumption of contaminated fish products)
EF is the exposure frequency, 365days/year (USEPA, 1989)
ED is the exposure duration, 60 years for adults and 12 years for children (USEPA, 1989)
SF is the cancer slope factor, in this study, 2 $(mg/kg\text{-}day)^{-1}$ (Ge *et al*., 2013) for all OCPs detected.
RfD is the Reference Dose (mg/kg-day), varied from one organochlorine pesticide to another

BW is the hypothetical average body weight, in this study, 70kg for adults and 29kg for children (USEPA, 2001).

AT is the averaging time, 60 years* 365 days/year= 21900 days for adults and 12 years* 365 days/year= 4380 days for children (USEPA, 2001; Ge *et al*., 2013).

Qualitative descriptions of lifetime cancer risks were based on ATSDR standards as follows; very low when the estimated value is ≤10E-06, low: 10E-06<value≤10E-04, moderate: 10E-04<value≤10E-03, high: 10E-03<value≤10E-01 and very high when the estimated value is ≥10E-01 (ATSDR, 1995, Ge *et al*., 2013). For non- carcinogenic risks, hazard index (HI), calculated as sum of hazard quotients (HQs) greater than one was considered risky while HI less than one was considered no risk associated with consumption of fish products.

3 Results And Discussion

3.1 Results

3.1.1 Concentrations of organochlorine pesticides in fish species

The mean concentrations of the detected OCPs in both L. niloticus and O. niloticus from Lake Victoria are presented in Table 1. Of the 19 OCPs which were considered in this study, 7 OCPs (α- HCH, β- HCH, HCB, Aldrin, Dieldin, p,p'-DDE and p,p'- DDT) were detected in one or more composite samples from Lake Victoria.

The average amount of α- HCH in L. niloticuswas 2.75µg/kg while the mean concentration for O. niloticus was 1.36µg/kg. Beta (β- HCH) was also detected in both fish species; L. niloticus andO. niloticus, at an average concentration of 1.31µg/kg and 0.49µg/kg respectively.The concentration of HCB was 2.15 and 1.20 µg/kg for L. niloticus and O. niloticus respectively. Aldrin was not detected in composite samples of O. niloticus whereas the mean concentration of Aldrin in L. niloticus was 0.72 µg/kg. Dieldrin concentration was 1.30 µg/kg in L. niloticus and 1.08 µg/kg in O. niloticus. The quantities of the two DDT isomers which were detected in fish species in this study ranged from 0.61 to 1.20 µg/kg and 0.15 to 0.16 µg/kg for p, p'- DDE and p, p'- DDT in L. niloticus and O. niloticus respectively.

Table 1: Overall mean concentrations and standard deviations (Mean ± SD) of the 7 detected OCPs for the two fish species from Lake Victoria

Species	α-HCH	β-HCH	HCB	Aldrin	Dieldrin	p,p'- DDE	p,p'- DDT
L. niloticus	2.75±1.88	1.31±1.78	2.15±1.72	0.72±1.35	1.30±1.47	1.20±0.97	0.16±0.47
O. niloticus	1.36±1.72	0.49±0.97	1.20±1.77	0.00±0.00	1.08±2.01	0.61±1.11	0.15±0.45

Number of composite samples per species; n = 27

3.1.2 Comparison of Organochlorine Residue Levels to International Standards

Table 2 compares the mean concentrations of the detected organochlorine pesticides in the present study to maximum residue limits (MRLs) recommended by some International statutory bodies for aquatic biota (Afful *et al*., 2013). Generally, the mean residue levels of the organochlorine pesticides in the investigated fish species from Lake Victoria were far below the MRLs recommended by the European Food Safety Authority and Food and Agricultural Organization (FAO) of the United Nations (Table 2) for fish and other fishery products. The results herein suggest that persistent organochlorine pesticides investigated in the present study may not pose health hazards to humans.

Table 2: Comparison of mean OCPs concentrations (µg/kg) in fish from Lake Victoria to maximum residual limits (MRL) stipulated by some statutory agencies

Compound	This work	EFSA, 2007	FAO/WHO, 1997
Aldrin	0.72	50	ND
∑DDT	2.12	ND	300
Dieldrin	2.38	ND	300
α- HCH	4.11	ND	ND
β- HCH	1.80	ND	300
γ- HCH	ND	ND	300
HCB	3.35	ND	200

ND means Not Determined

3.1.3 Statistical relationships

Pearson's correlation coefficients are presented in Table 3. The whole fish data set for the 7 OCPs detected in fish samples from Lake Victoria was subjected to Pearson's correlation analysis to determine their influence on each other in terms of their sources. Pairwise correlations between these environmental variables indicates that β-HCH and p, p'- DDT were positively correlated ($r = 0.6978$; $p<0.05$) suggesting that they originate from the same source. Moreover, Aldrin was positively correlated with Dieldrin ($r = 0.7464$; $p<0.05$), Dieldrin with p, p- DDT ($r = 0.6594$, $p<0.05$) and p, p'- DDE with p, p'- DDT ($r = 0.8559$, $p<0.05$). This is an indication that these environmental toxicants are emanating from the same source. Other variables did not correlate in any statistically significant way suggesting possible differences in their origins.

Table 3: Pearson's Correlation Coefficients

Variables	α-HCH	β-HCH	HCB	Aldrin	Dieldrin	p,p'-DDE	p,p'-DDT
α-HCH	1.0000						
β-HCH	0.0011	1.0000					
HCB	<0.0001	<0.0001	1.0000				
Aldrin	0.0001	0.0014	0.0037	1.0000			
Dieldrin	0.0005	0.3587	0.0105	0.7464**	1.0000		
p,p'-DDE	0.0007	0.0018	<0.0001	0.0009	0.1385	1.0000	
p,p'-DDT	0.2077	0.6978**	0.0630	0.0363	0.6594**	0.8559**	1.0000

** Correlation is significant at 0.05 levels

3.1.4 Human Health Risk Assessment

Human health risk assessment for organochlorine pesticides in fish species which were considered in this study are presented in Table 4. α-HCHhad the highest cancer risks compared to other established organochlorine pesticides having a cancer risk of 1.0E-04 for children and 4.35E-05 for adults while p, p'-DDT had the lowest non cancer risks with3.28E-06and 7.91E-06 for adults and children respectively. The carcinogenic risks ranged from 3.3E-06 to 4.4E-05 for adults and 8E-06 to 1E-04 for children. In both cases the cancer risks were between 1E-06 and 1E-04.

Table 4 shows as well the non- carcinogenic risks of OCPs associated with consumption of fish products from Lake Victoria. The individual compounds hazard quotients (HQs) ranged from 2.00E-04 to 2.17E-03 for adults and from 1.98E-04 to 2.60E-03 for children with α-HCH and p, p'-DDT having the highest and lowest HQs respectively. The Hazard Index (HI)(sum of Hazard Quotients (HQ)) were4.6E-03 and 9.2E-03 for adults and children respectively.

	Cancer Risk		Non cancer Risk	
OCPs	Adults	Children	Adults	Children
α-HCH	4.35E-05	1.00E-04	2.17E-03	2.60E-03
β-HCH	1.90E-05	4.59E-05	1.00E-03	1.15E-03
HCB	3.54E-05	8.55E-05	2.00E-03	2.14E-03
Aldrin	7.61E-06	1.84E-05	4.00E-04	4.59E-04
Dieldrin	2.52E-05	6.07E-05	1.3E-03	1.52E-03
p, p'-DDE	1.91E-05	4.62E-05	1.00E-03	1.15E-03
p, p'-DDT	3.28E-06	7.91E-06	2.00E-04	1.98E-04
HI =∑HQs			4.60E-03	9.24E-03

4 Discussion

3.2.1 Concentrations of organochlorine pesticides in fish species

The quantities of HCHs (α- HCH, β- HCH and γ- HCH) in both L. niloticus and O. niloticus established in this study are far lower than those which were established by Ssebugere *et al*. (2014) in the Ugandan side of Lake Victoria. According to Ssebugere*et al*. (2014), the concentrations in L. niloticus ranged from 5.7 µg/kg to 26 µg/kg, 7 µg/kg to 34 µg/kg and 5 µg/kg to 13µg/kg for α- HCH, β- HCH and γ- HCH isomers respectively. The maximum concentrations of HCHs in O. niloticus were 9 µg/kg for α- HCH, 8 µg/kg for β- HCH and 7 µg/kg for γ- HCH. The levels of γ- HCH (<LOD) at all sites where HCH isomers were detected were lower compared to other isomers (α- HCH and β- HCH), this could be explained by a better transportability of α- HCH than γ- HCH and/ or photochemical transformation and biodegradation of γ- HCH to α- HCH in environmental matrices (Strandberg *et al*., 1998 & Ssebugere *et al*., 2014). This could also be attributed to the fact that β- HCH is more persistent in the environment compared to other isomers because of its lower solubility in water and vapour pressure and it has 10 – 30 times higher ability to accumulate in fatty tissues (Kim *et al*., 2002). Moreover, α- HCH has a higher Henry's law constant and vapour pressure than β- HCH or γ- HCH isomers, rendering atmospheric transport more important for this isomer (Suntio *et al*., 1988). Detection of high levels of α- HCH and β- HCH isomers in the present study than their parent γ- HCH (Lindane) suggests historical or earlier usage of the pesticide and not current applications.

The ∑HCH values in the present study varied widely with mean concentration values ranging from 1.85 µg/kg to 4.06 µg/kg in O. niloticus and L. niloticus respectively. The HCH values were far lower than those reported in fish from Napoleon Gulf in Uganda; 14.95 µg/kg to 45.9 µg/kg (Ssebugere *et al*., 2014) and Tana and Sabaki River in Kenya (Lalah *et al*., 2003). Furthermore; studies in Ghana reported HCH residues ranging from 0.7 µg/kg to 13.6 µg/kg in fish (Tilapia zilli) from Lake Bosomtwi (Darko *et al*., 2008). The results herein were 4 times higher than those established by Darko and others. The HCH levels in all the investigated fish from nine sampling sites were below the extraneous residue limit of 5,000 µg/kg recommended for fish and other fisheries products by FAO/WHO Codex Alimentarius Commission (FAO/WHO, 1997). In regard to HCHs, the results from the present study give no indication of human health risks associated with consumption of fish from Lake Victoria.

Hexachlorobenzene (HCB) residues were also observed in fish samples of L. niloticus collected from different sampling sites in Lake Victoria Region of Tanzania. The overall mean concentration of HCB in the present study ranged from 1.20 µg/kg for O. niloticus to 2.15 µg/kg for L. niloticus. HCB levels were low and in the same range as other lakes in Tanzania studied by Polder *et al*. (2014) in which the concentrations of HCB in O. niloticus ranged from 1.4 – 4.0 µg/kg (L. Victoria), 1.1 – 1.3 µg/kg (L. Tanganyika), 1.2 – 2.9 µg/kg (L. Nyasa) and 0.6 – 2.8 µg/kg (L. Babati). This may possibly indicate that, HCB in Tanzanian fish reflects a general background level related to long range atmospheric transport (LRAT) rather than to local sources. The HCB

levels in the current study were also in the same range (2.1 µg/kg) as those in red- belly tilapia (Tilapia zilli) found in Ghana (Darko *et al*., 2008). A similar concentration of 1.3 µg/kg ww of HCB was also reported in mussel samples in the Coastal region of China (Monirith *et al*., 2003). HCB is mainly used as a fungicide and also generated as a byproduct during the production and usage of different agrochemicals and industrial chemicals and released into the environment by waste incineration (Van- Birgelen, 1998). HCB is similarly known be volatile in nature (Kannan *et al*., 1995). Since there is no evidence that HCB was used as a fungicide in the study area (URT, 2005), the occurrence of relatively small concentrations of HCB in fish muscles in the current study is probably a reflection of limited sources and its volatile nature (Jiang *et al*., 2004). The HCB levels in both L. niloticus and O. niloticus in this study were far lower than the tolerable limit of 200 µg/kg set for fish and other fishery products by the European Union.

Two drins residues (Aldrin and Dieldrin) were detected in measurable quantities in L. niloticus whereas the drins residues in O. niloticus were below their lowest limits of detection (<LOD). The mean concentration of aldrin in L. niloticus in this study was 0.72 µg/kg and <LOD in O. niloticus. Dieldrin was detected at a mean concentration of 1.30 µg/kg in L. niloticus and 1.08 µg/kg in O. niloticus. The levels of Aldrin and Dieldrin established in the current study are lower than those which were detected by Kasozi *et al*. (2006) in fish from the Ugandan side of Lake Victoria. According to a study by Kasozi *et al*. (2006); Aldrin and Dieldrin were detected at a concentration of 1.79 µg/kg and 1.17 µg/kg in L. niloticus and 1.88 µg/kg and 2.22 µg/kg in O. niloticus respectively. The levels of both Aldrin and Dieldrin in L. niloticus were higher than those found in O. niloticus. This difference suggests higher accumulation potential of Dieldrin and Aldrin in L. niloticus compared to O. niloticus. Comparison of Dieldrin and Aldrin ratio (Dieldrin/Aldrin) in both L. niloticus and O. niloticus gave values greater than 1 indicating that the detected residues were not likely to be from the recent applications of Aldrin. A similar trend was observed in water on the Kenyan side of Lake Victoria (Madadi *et al*., 2002). Aldrin readily changes to Dieldrin once enters either the environment or the body of an organism by the action of sunlight and bacteria in the environment. Therefore, with recent applications of Aldrin higher levels of Aldrin than Dieldrin and smaller Dieldrin to Aldrin ratio (Ratio<1) could be expected. However, the concentrations of both Aldrin and Dieldrin in fish for this current study were below the residual limit of 200 µg/kg set for fish and fishery products by competent authorities.

DDT residues were detected in both L. niloticus and O. niloticus at only one site (S5) with mean concentrations 1.43µg/kg and 1.39µg/kg respectively. The levels of DDT revealed from this study are comparable to some earlier findings (1.4 µg/kg) (Polder *et al*., 2014) and lower than another earlier finding in Southern Lake Victoria (30 µg/kg) (Henry and Kishimba, 2006). Detection of DDT at this site indicates current use of the chemical. Most fish in this site come from areas around Mara bay which carries contaminants all the way from Kenya to the lake through River Mara. Some studies have revealed that DDT is still in use in some parts of Kenya despite its ban earlier 1990s (IPEP, 2005 & Wandiga *et al*., 2002).

The degradation product; p, p'- DDE was also detected at measurable quantities in both fish species which were considered in this study. The mean concentrations of p, p'- DDE were 1.20 and 0.61 µg/kg for L. niloticus and O. niloticus respectively. However, low DDT/DDE ratio which means presence of high levels of the decomposition product DDE than the parent compound DDT in fish species from the Tanzanian side of Lake Victoria is mainly due to accumulation in the food chain and not due to current use (Henry and Kishimba, 2006, Ssebugere *et al*., 2014 & Oluoch- Otiego *et al*., 2016). Similarly, high concentrations of DDE than DDT in this study can be explained by the fact that metabolism of DDT in fish is generally accomplished through dechlorination process to DDE (Bhuvaneshwari and Babu Rajendran, 2012).

The levels of all organochlorine pesticides which were present in fish species were found to be higher in L. niloticus compared to those in O. niloticus. This observation is attributed to their differences in feeding habits and trophic levels. While L. niloticus is a carnivorous feeding into various fish species including its own siblings, O. niloticus is a rather herbivorous feeding mainly on phytoplankton and zooplanktons (Ssebugere *et al*., 2014). In this case L. niloticus accumulate more of the persistent organochlorine compounds compared to O. niloticus.

However, the levels of the detected organochlorine pesticides in fish species as per this study are far below the recommended limits set for fish and fishery products indicating that the fish species from Lake Victoria are safe for human consumption.

Human health risk assessment

The cancer risks associated with consumption of fish species from Lake Victoria as reported in this study were very low. This observation indicates that there are few cancer risks of OCPs associated with consumption of fish products from Lake Victoria. In this study, children were found to have higher values of cancer risks than adults because of their low body weights. Based on ATSDR standard, the cancer risks for OCPs in this study are between very low to low. Wenaty *et al*. (2019) reported comparable findings regarding carcinogenic risks associated with consumption of processed fish products from Lake Victoria. Similarly, the non- cancer risks determined as hazard indices were all less than one. Similar findings have also been reported in processed fish products from Lake Victoria (Wenaty *et al*., 2019). According to recommendations by United States Environmental Protection Agency (USEPA, 2009), the values were very low (<1), suggesting that the risks associated with consumption of the analyzed fish species from Lake Victoria are insignificant for both adults and children.

4.0 Conclusion

The present study analysed OCPs in both L. niloticus and O. niloticus from Lake Victoria in Tanzania. The levels of the detected chemicals were far below the MRLsset for fish and fishery products indicating that pollution in Lake Victoria has not reached alarming levels and that the fish are safe for human consumption. The cancer and non-cancer risks associated with consumption of fish species from Lake Victoria were very low and insignificant respectively. Therefore the levels of organochlorine pesticides

from Lake Victoria in Tanzania is not a health risk.

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Nutrient Content of Complementary Foods for Children of Age 6-23 Months Old in Rombo District, Tanzania

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Abstract

Complementary feeding is an effective strategy in reducing the levels of malnutrition among children aged 6-23 months. Less is known about preparation and nutrient content of locally made complementary foods in Tanzania. This study was carried out with the aim of analysing nutrient content of the frequently used complementary foods for children of age 6 to 23 months. A cross-sectional study was conducted in three randomly selected villages in Rombo district, Kilimanjaro region, Tanzania. Information on the types of complementary foods was collected using semi-structured and 24-hour dietary-recall questionnaires. Seven samples of frequently consumed complementary foods (banana and maize-based porridges) were collected and analysed for proximate composition, vitamin A and C as well as iron, zinc, calcium and iodine. The results showed that, the amount of energy, vitamin A, vitamin C, iron, zinc, calcium and iodine of the food samples ranged from 317.98 to 379.23 kcal, 195.83to 971.05 µg RE, 3.48 to 9.02 mg, 2.48 to 22.86 mg, 0.92 to9.57 mg, 73.13 to 400.58 mg and 10.18 to 200.93 µg/100 g dry-weight, respectively. Conclusively, the amount of vitamin C, iron, zinc, calcium and iodine of the frequently used complementary foods in the study area was low as compared what is recommended by World Health Organization. It is important to develop recipes that may either fill or narrow this gap by using low-cost, locally available and culturally acceptable ingredients.

Key words: Complementary foods, Energy, Micronutrients, Porridge

1 Introduction

The first 1000 days of life, from conception until the child's second birthday, are considered the critical window of opportunity for preventing undernutrition and its long-term consequences (Hlaing *et al*., 2015). Poor breastfeeding patterns, low nutrient density and poor quality of complementary foods account for nutrient deficiency, illness and infections in children, leading to malnutrition at an early age (Srivatsava&Sandhu, 2007). This in turn prevents children from reaching their full physical and mental potential later in life due to delayed physical growth and motor development, low intellectual quotient (IQ), greater behavioural problems, deficient social skills as well as their increased susceptibility to contracting diseases (Kandala *et al*., 2011). The common nutritional problems among children aged 6-23 months in many countries include protein-energy malnutrition (PEM), vitamin A deficiency (VAD), iodine deficiency disorders (IDD) and iron deficiency anaemia (IDA) (IFPRI, 2016).

Globally, an estimated 156 (23.8%), 95 (14%), 50 (7.5%) and 16 (2.4%) million children under-five years of age are stunted, underweight, wasted and severely wasted, respectively (IFPR1, 2016; UNICEF/ WB/ WHO, 2016). In addition, over 160 million children worldwide are vitamin A deficient with a prevalence of about 30% in all developing countries and over 293 million (47.4%) of pre-school age children are

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anaemic (WHO, 2015; UNSCN, 2016).

In Africa, 58.5 (37%), 13.9 (28%) and 10.3 (25%) million children under the age of five years are stunted, wasted and overweight respectively (IFPRI, 2016; UNICEF/ WB/ WHO, 2015). TDHS-MIS (2015-2016) and IFPRI (2016) Tanzania ranks 105 out of 132 countries surveyed with stunting, wasting, underweight, severely underweight and anaemia prevalence of 34.7, 3.8, 14, 3 and 39.6%, respectively.

Complementary feeding is an effective strategy in reducing the levels of malnutrition among children aged 6-23 months (Haile *et al*., 2015). Breast milk alone can be used to properly feed infants for the first six months of life, but as infants grow and become more active following the first 6 months of life, breast milk alone falls short of providing the full nutritional requirements and the gap keeps expanding with increasing age of the infants and young children; hence complementary feeding plays critical role in bridging these gaps (Monte & Giugliani, 2004;Abeshu, 2016). Major problems at this stage include poor timing of introducing complementary foods (too early or too late), poor food preparation and feeding practices, the use of complementary foods with low energy and nutrient density, low nutrients' bioavailability as well as poor processing methods and all of these are exacerbated by poverty and food insecurity (Hussein, 2005; Nyaruhucha *et al*, 2006; Kulwa *et al*., 2015; Williams *et al*., 2015).

Kilimanjaro region, just like other regions of Tanzania has malnourished children of which 18.3, 7.5 and 4.0% of children less than five years of age are stunted, underweight, and wasted respectively (TFNC, 2014). Also, 48.9% of children under this age group are anaemic while 34.2% are vitamin A deficient (TDHS-MIS, 2015-2016). About 4% of children aged 0-5 years in Rombo district died from malnutrition in the year 2013 (Rombo DC Profile, 2013). One of the possible explanations for malnutrition could be inadequate nutrient intake from the commonly consumed foods.

In Rombo district, studies on the nutrient content of the frequently used complementary foods for children aged 6-23 months are very limited. The few available studies were on mycotoxins level in complementary foods as well as prevalence and predictors of exclusive breastfeeding among breastfeeding women (Shirima*et al*., 2000; Kimanya*et al*., 2014; Mgongo *et al*., 2013; Acton, 2013). The present study was undertaken to assess the nutrient content of frequently used complementary recipes in Rombo district, Kilimanjaro region. The results will help in planning diet modification studies to improve nutrient content of commonly used complimentary foods.

Materials and Methods

Study Area

This study was conducted in Kilimanjaro Region in Tanzania Mainland. Rombo district was selected by simple random sampling. The district receives annual rainfall ranging from 500 to 1000 mm per annum and the mean monthly temperature is 22–260C with maximum temperatures of 35oC. The main economic activity practiced in Rombo District is agriculture. This carries about 90% of the total activities while 7% of the residents are doing small businesses and 3% are the employed workers (Rombo DC

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Profile, 2013). Food crops include banana, maize, sorghum, sweet potatoes, cassava and legumes, fruits and vegetables; whereas the main cash crop is coffee.

Study Design and Sample Size

A cross sectional study was conducted in three randomly selected villages of Urauri, Kibaoni and Kikelelwa.The study subjects were mothers/caregivers and their children who were 6 to 23 months old during data collection period. Children who were under special nutritional therapies and those with medical disorders or chronic health conditions were excluded from the study. The sample size was obtained from the general stunting percentage (18.3%) for children less than 5 years in Kilimanjaro region (TFNC, 2014). The formula used was adopted from SMART (2012) and a total of 230 respondents were involved in this study.

Data Collection

Instrument for data collection

Identification of the frequently used complementary foods was done by using semi-structured questionnaires. The information collected included social and demographic characteristics of the mother/caregiver and the child, types of complementary foods and preparation methods.

Before administration of the questionnaires, five enumerators were enlightened on the main and specific objectives of the research and familiarized with data collection instruments. Pre-testing of the questionnaire was done at Mazimbu Morogoro region before the beginning of data collection in a randomly selected sample of 10 individuals who were not included in the study but had similar characteristics to the study sample. After pre-testing the questionnaires, corrections were made to avoid misleading information, ambiguous sentences and repeated questions.

Before the beginning of the interview, the enumerators introduced themselves, explained the purpose of the study as well as the potential benefits and risks and then the respondents were asked to voluntarily sign the consent form. For those respondents who were unable to read and write, they were helped by a closer relative, neighbour or the enumerator and give their oral consent. The questionnaire was administered through face to face interview.

Collection of food samples and laboratory analysis

Seven samples of frequently used complementary foods given to children 6-23 months of age were taken for laboratory analysis for proximate composition and vitamin A, vitamin C, iron, zinc, calcium and iodine contents (Table 1).

Before collection of cooked samples, there was a focus group discussion (n=10) with women who came to clinic (RCH unit) at Tarakea health centre on preparation methods of the seven selected complementary foods. When the common procedures, ingredients, amounts, preparation and cooking methods were agreed, the ingredients such as meat, fish, milk, onions, tomatoes, rice, pumpkins and bananas were purchased at Tarakea market. Complementary food samples were prepared by seven randomly

selected mothers/caregivers (one for each recipe) at different households in the three villages. Mothers/caregivers from Urauri prepared banana porridge with meat and with fish while those from Kibaoni village prepared banana porridge with pumpkin and with milk. Mothers/caregivers from Kikelelwa village prepared maize, rice and composite flour porridges. This was done without the interference from the researcher. The task of the researcher was only to provide ingredients and record the procedures.

During preparation of complementary foods, the ingredients (name and amount used) were recorded first before cooking and then the mother/caregiver prepared and cooked the food while the researcher was observing and recording the procedures. When the food was ready, it was left to cool and then served in clean tight plastic food containers, weighed again and then stored in a cool box with iced water tightened in plastic bag then transported for analysis in the laboratory on the next day. The remaining foods and ingredients were given to the mothers/caregivers who prepared the foods. CAMRY kitchen weighing scale (Model: EK3651, Max. 5000g/11lb, Japan) was used to weigh the ingredients and cooked samples.

Table 1: Frequently used complementary foods in the study area selected for laboratory analysis

Name of the food sample	Swahili name (Local name)
Banana porridge with beef	*Mtori wa nyama*
Banana porridge with fish	*Mtori wa samaki*
Maize porridge (sugar and cooking oil added)	*Uji wa mahindi (Uji)*
Banana porridge with milk	*Mtori wa maziwa (kitawa/ kena)*
Composite flour (maize, finger millet, rice, maize, groundnuts and soya beans) porridge	*Uji wa unga mchanganyiko / lishe*
Banana porridge with pumpkins (salt and oil added)	*Mtori wa maboga (mtori wa masidi)*
Rice porridge (with milk)	*Uji wa mchele/wali madida (Mshele)*

(a) Sample preparation

The cooked food samples were stored in the freezer for ten days waiting for analysis at Sokoine University of Agriculture, Morogoro. During analysis, the food samples were thawed in running water and then mixed thoroughly (homogenization) while maintaining its representativeness. Nutrient composition analysis was done in duplicate for all seven samples and the results were presented in grams (g), milligrams (mg) or micrograms (µg) per hundred grams.

(b) Laboratory analysis

The proximate composition of each of the frequently used complementary food samples were determined by using the standard methods of AOAC (2000) and the results were presented as an average of the duplicate determinations. Crude protein was determined by Kjehdahl method (AOAC, 2000, official method 925.09), total fat by using Soxhlet system (HT model 1043-extraction unit AB, Sweden) following the procedures shown in AOAC (2000; official method 4.5.01.) while Ancom fibre analyser (Model ANCOM 220, USA) was used to determine crude fibre content as outlined by AOAC (2000) in official

method 962. 09. Moisture and ash contents were determined using oven drying (AOAC, 2005; method 925.09) and (AOAC, 2000; method 923.03), respectively for five hours. The ash content of the samples was calculated as the difference between weight of the sample before and after incineration.Energy values of all the complementary food samples were determined by calculation using Atwater's conversion factors (FAO, 2003).

Vitamin A (Beta carotene) content was determined using UV-Visible Spectrophotometer following the procedures described by Rodriguez-Amaya and Kimura (2004). A conversion factor of 6 µg of β-carotene equivalent to 1 µg of Retinol Equivalent (RE) was used.. Retinol was determined following the procedures described by Lietz *et al*. (2000), Rutkowski and Grzegorczyk (2007) and Kandar *et al*.(2012). Vitamin C determination was done following AOAC (2000) procedures using method No. 985.33 by titration. Iron, zinc, calcium and iodine contents were determined using the AOAC (2000) procedures, method no. 985.35 by using atomic absorption spectrophotometer

Data Analysis

Data was cleaned to adjust for inconsistent, conflicting and implausible responses and carefully subjected to the descriptive analyses using the computer Microsoft Office Excel 2007, Statistical Products and Service Solution software (SPSS) version 20.0 and R Software (Ri386) version 3.3.1. Means were calculated for continuous variables and for categorical variables frequencies and percentages were used. For laboratory results of the nutrient content of the frequently used complementary foods, each determination was carried out in duplicate and results were reported as an average value (mean ± standard deviation (SD)). Turkeys Honest Significant Difference test was used for multiple mean comparison tests. Statistical significance was set at $p<0.05$.

Ethical Clearance

The study protocol was approved by the National Institute for Medical Research (NIMR/HQ/R.8a/Vol. IX/2362), Sokoine University of Agriculture and Rombo District Executive Director. Written informed consent was obtained from all mothers/caregivers who took part in this study as well as the village leaders who issued a letter of acceptance for the research. All the participants were ensured of confidentiality and autonomy and that the information obtained will not be misused.

Results

Social and demographic characteristics of the study participants

Table 2 shows the socio-demographic characteristics of the 236 mothers/caregivers who provided complete information. They were from three villages namely Kikelelwa (30.4%), Kibaoni (38.7%) and Urauri (30.9%). Majority of the children (51.4%) were of age between 12-23 months at the time of data collection. Most of the mothers/caregivers (95.65%) were able to at least read and write their names. The mean age was 27 years, 63.9% had completed primary school education and 50.9% were involved in agriculture. The average number of people per household was 5 (53.5%). Predominantly produced food crops were cereals, legumes and banana. Thirty nine percent of the respondents

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reported to keep poultry in their households.

Table 2: Socio-demographic characteristics of the study participants

Variable	Number	Percent
Age of children (months)		
6-8	52	26.1
9-11	45	22.5
12-23	103	51.4
Age of mothers (years)		
<20	31	13.5
20-35	143	62.2
> 36	56	24.3
Marital status		
Single	63	27.4
Married	167	72.6
Education level		
Informal	10	4.3
Primary school	147	63.9
Secondary school	67	29.1
Post-secondary school	6	2.6
Occupation		
Housewife	33	14.3
Agriculture	117	50.9
Employed formal	11	4.8
Employed informal	6	2.6
Self employed	63	27.4
Number of under five children per household		
1-2	93.9	216.0
3 or more	60	14.0
Food crops produced		
Cereals	146	63.5
Legumes	136	50.5
Bananas	90	39.1
Root crops (potatoes and cassava)	129	56.1
Fruits	23	10.0
Vegetables	30	13.0
Domesticated animals		
Chicken	90	39.1
Cattle	64	27.8
Goats	72	31.3
Pigs	47	20.4
Sheep	23	10.0
Ducks	9	3.9.0

Nutrient content of the frequently used complementary foods

Proximate composition and energy content

Proximate composition of the seven frequently used complementary foods (banana porridge with beef, fish, milk or pumpkins, composite flour porridge, maize porridge and rice porridge with milk) for children 6-23 months of age in Rombo district on wet basis are shown in Table 4.

Moisture content of the samples ranged from 65.51 to 81.66%. Banana porridge with milk had significantly lower moisture content than the rest of the formulations. The lower moisture content could be attributed to the addition of milk instead of plain water during stirring. Maize porridge had higher moisture content but it was not

significantly (p>0.05) different from composite flour porridge. Banana porridge with beef, banana porridge with fish, banana porridge with pumpkins and rice porridge were not significantly different (p>0.05) in terms of moisture content.

The value of ash content for all the formulations ranged from 1.05 to 3.54%. Composite flour had significantly higher ash content (3.54) ($p < 0.05$). Milk based samples (banana porridge with milk and rice porridge with milk) had similar levels of ash content. Maize porridge had the lowest ash content followed closely by banana porridge with pumpkins and they were not significantly different from one another.

Maize porridge, rice porridge with milk and banana porridge with pumpkins had lower total fibre content (14.25, 14.61 and 16.52%, respectively). The values of fibre content ranged from 14.25 to 27.55%. The highest fibre content was found in composite flour porridge followed by banana porridge with beef.

Protein content ranged from 8.33 to 25.12%. There was no significant difference in protein content among the samples. Porridge made from composite flour as well as banana porridge with milk had significantly higher fat content than other formulations ($p<0.05$). Fat content for all the samples ranged from 1.05 to 20.72 g/100 g (dry weight). Banana porridge with pumpkins had the lowest fat score followed by rice porridge with milk and banana porridge with fish.

Available carbohydrate ranged from 34.34 to 72.61%. Banana porridge with fish had relatively higher carbohydrate content compared to the rest of the samples. The lowest carbohydrate content was reported in composite flour porridge.

Energy content of the frequently used complementary foods ranged from 317.98 to 379.23 kcal per 100 g (dry weight). Composite flour and banana with milk porridges were characterised by the highest levels of energy as compared to the rest of the analysed complementary food samples. Banana porridge with beef had the lowest energy value (317.98 kcal). Energy content of banana porridge with fish, banana porridge with pumpkins and maize porridge were not significantly different ($p > 0.05$) from one another.

Table 4: Proximate composition of frequently used complementary foods (g/100 g dry weight)

	Banana porridge with beef	Banana porridge with fish	Maize porridge	Banana porridge with milk	Composite flour porridge	Banana porridge with pumpkin	Rice porridge with milk
Energy	317.98±16.49^{b}	348.14±10.55^{ab}	334.51±12.88^{ab}	373.44±22.34^{a}	379.23±7.51^{a}	333.29±5.31^{ab}	345.79±10.10^{ab}
Protein	9.74±2.48^{c}	8.34±2.57^{c}	13.47±1.07^{c}	8.33±1.48^{c}	13.84±1.58^{bc}	23.65±5.02^{ab}	25.12±1.27^{a}
Fat	3.59±1.08^{c}	2.71±0.25^{c}	6.55±1.93^{bc}	10.66±2.77^{b}	20.72±0.97^{a}	1.05±0.37^{c}	2.36±0.02^{c}
CHO (Available)	61.67±0.76^{ab}	72.61±5.76^{a}	55.41±2.20^{b}	61.05±0.82^{ab}	34.34±2.48^{c}	57.31±4.51^{b}	56.01±3.79^{b}
Moisture	72.36±1.34^{b}	67.72±0.84^{bc}	81.66±1.43^{a}	65.51±1.32^{c}	79.72±0.58^{a}	71.44±2.78^{b}	68.67±1.14^{bc}
Ash	2.71±0.25^{b}	2.10±0.01^{c}	1.05±0.02^{e}	1.68±0.07^{cd}	3.54±0.19^{a}	1.47±0.05^{de}	1.89±0.003^{cd}
Fibre	22.28±3.04^{ab}	14.25±2.93^{c}	23.52±0.83^{ab}	18.28±2.18^{ab}	27.55±2.90^{a}	16.52±0.92^{c}	14.61±2.53^{c}
Dry matter	27.64±1.34^{b}	32.28±0.84^{ab}	18.34±1.43^{c}	34.49±1.32^{a}	20.28±0.58^{c}	28.56±2.78^{b}	31.33±1.14^{ab}

Values are means ± SD of duplicate determinations. Values with different superscripts in a row differ significantly ($p<0.05$).

Vitamins A and C composition of the complementary foods

Shown in Table 5 are values of vitamins A and C of the seven frequently used complementary food samples in Rombo district. Vitamin A content ranged from 195.83 to 971.05 µg/100 g (dry weight). The lowest vitamin A content was observed in maize porridge. Food samples with animal products such as meat, fish and milk had relatively higher vitamin A contents.

Vitamin C content ranged from 3.48 to 9.56 mg/100 g dry weight, with the highest contents found in composite flour porridge and banana porridge with fish; and the lowest in banana porridge with beef. Milk based complementary food samples (banana porridge with milk and rice porridge with milk) as well as maize porridge and banana porridge with pumpkins had similar levels of vitamin C.

Table 5: Vitamins A and C composition of the frequently used complementary foods in Rombo district (g/100 g dry weight basis)

Complementary foods	B-carotene (µg/100gRE)	Retinol (µg/100g)	Total vitamin A (µg/100g)	Vitamin C(mg/100g)
Banana porridge with beef	170.13±11.45de	582.62±49.22^{a}	752.75±60.67^{bc}	3.48±0.12^{c}
Banana porridge with fish	143.73±0.22de	401.02±9.21^{b}	544.76±8.98^{d}	9.02±0.31^{a}
Maize porridge	195.83±16.77cd	0.00^{c}	195.83±16.77^{f}	5.23±0.52^{b}
Banana porridge with milk	105.30±3.93e	676.01±37.84^{a}	781.32±33.91^{b}	5.62±0.18^{b}
Composite flour porridge	971.05±10.75a	0.00^{c}	971.05±10.75^{a}	9.56±0.23^{b}
Banana porridge with pumpkin	401.49±39.05b	0.00^{c}	401.489±39.05^{e}	6.46±0.58^{b}
Rice porridge with milk	262.66±9.54c	387.51±10.34^{b}	650.17±0.80^{cd}	6.05±0.36^{a}

Values are means ± SD of duplicate determinations. Values with different superscripts in a column differ significantly ($p<0.05$). The sample with 0.00 were from plant sources and therefore retinol was not analysed

Iron, Zinc, Calcium and Iodine content of the frequently used complementary foods in Rombo district

Iron content ranged from 2.48 to 22.86 grams per 100 grams of the dry sample as shown in Table 6. There was no significant difference in iron content between banana porridge with fish and banana porridge with milk. Banana porridge with beef had significantly ($p<0.05$) higher iron content as compared to the rest of the sample. Banana porridge with pumpkins had lowest iron content.

With regard to zinc content, samples had zinc content below the minimum recommended levels for complementary foods with the exception of banana porridge with beef. It ranged from 0.92 to 9.57 mg/100 g (dry weight). Banana porridge with beef had the highest zinc content (9.57) as compared to banana porridge with pumpkin which had less than 1mg/100 g (Table 6). Banana porridge with pumpkin had the lowest zinc content but it was not significantly different from composite flour porridge,

banana porridge with fish and banana porridge with milk.

Calcium levels ranged from 82.73 to 400.58 milligrams as shown in Table 6. Banana porridge with beef had significantly ($p<0.05$) higher calcium content than the rest of the samples. The lowest calcium content (73.13 mg/100 g dry weight) was reported in maize porridge and in rice porridge with milk (73.12 mg/100g dry weight)

Composite flour porridge had significantly ($p<0.05$) higher iodine content (200.93µg/100g dry weight) while banana porridge with beef had the lowest score (10.18 µg/100g dry weight). The rest of the sample had almost similar iodine levels.

Table 6: Mineral composition of frequently used complementary foods for children aged 6-23 months at Rombo district (g/100 g dry weight)

Complementary foods	Iron (mg/100g)	Zinc (mg/100g)	Calcium (mg/100g)	Iodine (µg/100g)
Banana porridge with beef soup	22.86±1.09^{a}	9.57± 0.85^{a}	400.58±40.22^{a}	10.18±4.23^{d}
Banana porridge with fish soup	5.99±0.17^{d}	1.17±0.02^{bc}	82.73±1.47^{d}	40.24±4.54^{cd}
Maize porridge with sugar and oil	9.12±1.24^{b}	2.53±0.15^{b}	149.75±5.11^{bc}	42.04±8.66^{cd}
Banana porridge with milk	4.88±0.39^{cd}	1.38±0.12^{bc}	194.56±6.19^{b}	56.86±9.46^{bc}
Composite flour porridge	9.21±0.53^{b}	1.05±0.12^{c}	111.55±6.84^{cd}	200.93±15.34^{a}
Banana porridge with pumpkin	2.58±0.40^{d}	0.92±0.05^{c}	135.15±11.37^{bcd}	31.73±10.52^{cd}
Rice porridge with milk	2.48±0.24^{d}	1.36±0.35^{bc}	73.13±3.77^{d}	85.12±6.52^{b}

Values are means ± SD of duplicate determinations. Values with different superscripts in a column differ significantly ($p<0.05$).

Discussion

This study aimed at assessing the nutrient content of frequently used complementary foods in Rombo district. The moisture content of the porridges was similar to the findings of Anigo*et al*. (2010) and Kulwa *et al*. (2015). A complementary food that is more energy and micronutrient-dilute needs a larger volume to cover the gap (WHO, 2009). High moisture content in food products have also been associated with increased growth of microorganisms, which in turns causes spoilage and low nutritional qualities of the food products (Steve & Babatunde, 2013).

The ash content reported in the present study was lower than what was reported by Tiencheu *et al*. (2016) but similar to that of Steve and Babatunde (2013) and Parvin*et al*. (2014). The lower values of ash content in the samples used in this study may probably indicate lower mineral contents. Composite flour porridge had higher ash content relative to other foods due to the presence of variety of ingredients such as maize, rice, soya beans, groundnuts and finger millet that may have more minerals (particularly iron, zinc and calcium) relative to other samples.

The findings from this study revealed that most of the complementary foods in Rombo

district meet the recommended amount of protein needed from complementary foods. Even the foods that could not meet WHO recommendations (banana porridge with fish and banana porridge with milk), they were still able to provide at least 50% of the amount of protein needed from complementary foods (WHO, 2003). The higher protein content in rice porridge may be contributed by the addition of milk which is a good source of protein. Pumpkin seeds (usually discarded during peeling) have been reported to have more protein than the flesh (Usha *et al*., 2010;Karanja *et al*., 2013).

In order to meet amount of energy, essential fatty acids and uptake of fat soluble vitamins by lipids, fat from complementary foods should provide approximately 30 to 45% of the total energy required by infants and young children based on their age and development stage (Monte & Giugliani, 2004). Fat content of the complementary food samples ranged from 1.05 to 20.72 g/100 g (dry weight). Composite flour porridge had significantly higher ($p<0.05$) fat content relative to the rest of the complementary food samples. The high fat content in composite flour may be due to the inclusion of oily seeds such as groundnuts, soya beans and whole grains as well as addition of vegetable oil during cooking. Also addition of whole milk in banana porridge may have contributed to the high fat content of the sample.

The carbohydrate (excluding fibre) contents of complementary food sample in this study were in the range of 34.34 to 72.61%. These values are higher than what was reported by Kulwa *et al*. (2015)on maize-based complementary foods but lower than that of Martin *et al*. (2010) on banana based complementary foods.

The recommended energy intake from complementary foods varies according to the age of child, amount of breast milk consumed, fat content in breast milk and the frequency of feeding (WHO, 2003). A review conducted by Muhimbula and Issa-Zacharia (2010) revealed that, most of the complementary foods in Tanzania are bulky but with lower energy and micronutrient concentrations. The findings from this study support this review because the energy content of all the samples of the frequently used complementary food were below the recommended amount of energy need from complementary foods for children aged 12-23 months but for the younger ones (6-11 months), the energy content was satisfactory. The energy content of the samples ranged from 317.6 to 379.23 kcal/100 g (dry weight) and banana porridge with beef had the lowest score. These values are similar to that of Bassey *et al*. (2013).

In this study, total vitamin A content of all the samples were higher than the range reported by Isingoma *et al*. (2015), with the exception of maize porridge. Samples that contained animal products such as meat, milk and fish had higher vitamin A which is supported by Englberger *et al*. (2003). Maize porridge had the lowest vitamin A content which in agreement with what was reported by Jemberu *et al*. (2016). The observed lower than recommended vitamin A content in the in maize porridge which is one of the frequently used complementary food in Tanzania, encourages the formulation complementary foods using more nutritious ingredients such as orange-fleshed sweet potatoes (Jemberu *et al*., 2016), carrots, legumes (Abebe *et. al*., 2006) and seeds (Stodolak *et al*., 2009) as well as using improved traditional processing methods such as fermentation, soaking, germination/malting and de-hulling (Hotz and Gibson, 2007).

Studies have shown that most homemade complementary in Ethiopia have low vitamin C content (Abeshu *et al.*, 2016). This is not different from what has been reported by this study whereby vitamin C content of the frequently used complementary foods in Rombo district ranged from 3.48 to 9.56 mg/100g of dry sample. Composite flour porridge and banana porridge with fish had the highest vitamin C content relative to the rest of the complementary food samples. This may be due to the addition of fish at the end of cooking which reduced the cooking time of fish since ascorbic acid is heat labile. World Health Organization (2003), recommended addition of vitamin C rich ingredients such as citrus fruits, tomatoes, green, yellow and red peppers as well as green leafy vegetables to home-made complementary foods.

Iron, zinc, and calcium have always been reported as limiting nutrients in unfortified plant-based complementary foods commonly used in developing countries (Gibson *et al.*, 2010; Abeshu *et al.*, 2016). Similarly, most of locally used complementary foods in Tanzania were poor in iron, zinc and calcium because they are mainly plant-based with little or no addition of animal products. The findings from this study have also shown lower than recommended amount of iron, zinc and calcium in the frequently used complementary foods in the study area.

Banana porridge with beef was the only sample that was able to provide more than the amount of iron needed from complementary foods assuming moderate bioavailability. With the exception of banana porridge with milk, banana porridge with pumpkin and rice porridge with milk; all the other samples were able to provide at least half of the recommended iron intake from complementary foods according to WHO recommendations. Several studies have suggested addition of animal products, the use of commercial infant formulas (Steve and Babatunde, 2013) as well as micronutrient powders (WHO, 2011) to improve iron status of infants and young children in developing countries. In order to increase iron content and reduce anti-nutrients such as phytates, some studies suggested soaking and germination of cereals and legumes prior to processing (Mihafu *et al.*, 2017).

According to FAO/WHO (2001) complementary foods should provide 86-100% of zinc based on the age and breastfeeding status of the child. With the exception of banana porridge with beef, all the other samples of frequently used complementary foods in Rombo district had less than 3 mg/100g of zinc. These values are higher than the findings of Jani *et al.* (2009) in Pakistan and Kulwa *et al.* (2015) in Tanzania. The higher zinc content in banana porridge with meat could be due to the presence of meat, which was a good source of zinc.

The recommended amount of calcium (196-353 mg/d) needed from complementary foods for children aged 6-23 months cannot be met by plant-based complementary foods in Rombo district. Only banana porridge with beef had the calcium value above the recommended range. Even the milk containing foods such as rice porridge and banana porridge with milk had lower calcium values relative to beef-containing foods. Another study conducted by Pereira *et al.*, (2009) have also reported lower than recommended amount of calcium in complementary foods.

The lowest iodine concentration was found in banana porridge with beef (10.18 µg/100 g dry weight) and the highest was found in composite flour porridge (200.93 µg/100g dry weight). With the exception of banana porridge with beef, iodine content of all other samples were above the recommended intake of 19, 30 and 51 µg/d from complementary foods for infants and young children aged 6-8, 9-11 and 12-23 months respectively (WHO, 1998). The reason for low iodine concentration in banana porridge with beef might be the use of poorly stored and expired salt.

Conclusion

Most of the frequently used complementary foods were found to contain lower than recommended amount of energy, protein, vitamin C, iron, zinc, calcium and iodine. Therefore this study provides a benchmark for educating mothers on the importance of including nutrient-dense ingredients and proper preparation methods for complementary foods.

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Assessment of Effective Control Methods for Parthenium Weed in Maize Fields

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Abstract

In the near future, labour to assist in weed management in the villages will become scarce and expensive, because of population drift from villages to cities. It is necessary to develop cheaper methods of weed management that will reduce weed impact on maize yield. A field experiment was conducted at the Tropical Pesticides Research Institute (TPRI), Arusha-Tanzania during the long rain season of 2017, to identify control methods for parthenium weed (Parthenium hysterophorus L.). The experiment was laid out in a randomized complete block design (RCBD) with four replications. Treatments were hand hoeing (twice), mulches (dry grass and cowpeas), application of 2, 4-D (twice), weed free plots and un-weeded plots. Data collected include plant height at flowering (m), leaf length and width (m), number of leaves at flowering, number of days to (tasseling, silking and milking), tassel length (m), number of days to maize maturity, plant height at maturity (m), number of plants harvested, ear length and diameter (m), number of kernel rows/ear, number of kernels/row and grain yield (t/ha)at 12% moisture content, parthenium weed plant height (m), canopy width (m), and number of parthenium plants before weeding, height (m) and number of parthenium plants at maize maturity. Statistical analysis was performed using Genstat software (16th edition) and means were separated by Tukey's mean separation test at $p \leq 0.05$. The results show that, mulches significantly reduced parthenium height and population in the maize crop at maturity ($p<0.05$). Plant height at flowering, leaf length and width, number of days to tasseling, tassel length, number of days to silking, milking, maturity, plant height at maturity and number of plants harvested were not significantly affected by any of the weed management methods. Thus mulching and 2, 4-D were found to be the best methods for controlling parthenium weed growth and population.

Key words:*Parthenium weed, Control methods, Maize, Weeds*

Introduction

Maize (Zea mays) is the world's widely cultivated highland cereal and primary staple food crop in many developing countries. Pradeep *et al*. (2017) ranked maize as the third in cereals world production after rice and wheat, but in productivity, it surpasses all cereals. In Tanzania maize is one of the dependable food and cash cereal crops but its production has been hindered by both biotic and abiotic factors. Among the biotic constraints, weeds are considered as an important category. Invasive weeds are considered to be among the biotic factors that hinder maize production. Parthenium weed is one of the threatening invasive weeds due to its allelopathic properties, as it produces parthenin compound that hinders germination of crop seeds and hence reducing crop establishment and yields (Tomado *et al*., 2002a; Singh *et al*., 2004).

Various methods have been tested to reduce the impact of parthenium on crop production in countries like Australia, Sri-Lanka, India, Pakistan and Ethiopia. For example, herbicides have proved effective for the control of parthenium weed. Singh *et*

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al. (2004) found that atrazine and 2, 4-D caused 45% mortality to parthenium weed in India when applied to young plants. Shabbir, (2014) discovered that, Glyphosate and Isoproturon are effective selective herbicides in controlling parthenium weed although Glyphosate was comparatively more effective as compared to Isoproturon. Methods such as manual weeding and use of atrazine, hexazinone and biological control, using a moth (Epiblema strenuana) have been suggested by Masum *et al*. (2009) and Abebe and Chemeda, (2016) to manage parthenium weed in Bangladesh.

Manual uprooting of parthenium weed before flowering and seed setting is the most effective method. This is due the fact that, uprooting the weed after seed setting will lead to weed seed dropping and hence increase the area of infestation (Manpreet *et al*., 2014). The author reported that, although there are some landholders that have achieved success in ploughing parthenium weed in the rosette stage before it seeds, but this must be followed up by sowing a crop or direct seeding the perennial pasture. Talemos *et al*. (2013) argued that, parthenium weed management practices like manual uprooting should be handled with care, which is, a person should make sure that protective gear such as gloves and masks are in place to prevent health hazards of the weed.

Serious inspection of parthenium weed seeds at border entry points and Airports could be a proper method of preventing and managing the weed. In South Africa, the weed is regulated as well under the existing legislation (Conservation of Agriculture Resources Act 2002-Category 1 according to which invader plants must be removed and destroyed immediately. No trade in these plants and is also reported as a noxious weed by the government of Kenta and Puerto Rico (European Plant Protection Organisation, 2014).

Despite the presence of some effective control measures, these technologies have not been used widely in Tanzania. Furthermore, from a wide range of available technologies, selecting appropriate combination suitable for the area based on existing cropping systems is yet to be established. Therefore, the present research work was carried out to evaluate different weed management practices with intension of obtaining the most effective and easily adoptable weeding technique in controlling parthenium weed in maize fields.

Materials and Methods

Description of the study area

A field experiment was conducted at the Tropical Pesticides Research Institute (TPRI) in Arusha, Tanzania, during the long rain season from February to July 2017. TPRI is located at 3º1953.265''S latitude and 36º37.38.667'E longitude and at an elevation of 1451m above sea level. Selection of the experimental site was done following the presence of parthenium weed based on the survey report carried in March 2011 (Clark and Lotter, 2011).

Methods

Parthenium weed seeds were broadcasted in equal amounts in each plot of maize. The experimental site was ploughed and leveled before the field layout was made. The experiment consisted of six treatments namely weed free, hand hoeing, dry grass mulching, 2, 4-D application; cover crop mulching (cowpeas) and no weeding. Hand weeding and 2, 4-D applications were twice (4th and 8th week after planting). The herbicide, 2, 4-D was applied at the rate of 960g a.i/ha in a plot area of $9m^2$. The treatments were arranged in randomized complete block design (RCBD) with four replications. The distance between adjacent replications and plots were 1m each.

A maize variety SC 403 was used as a testing variety, which was sown by the dibbling method. Thus, space between one plant and another was 0.03m while rows were spaced at 0.75m. There were 4 rows per plot and 10 plants per row. Urea fertilizer was applied 16 days after sowing by banding method at the rate of 102kgN/ha. Other weeds were removed from the experimental plots by hand hoeing or hand pulling as soon as they emerged.

Data collection and analysis

Data were collected based on maize descriptor prepared by Badu-Apraku *et al*. (2012). The collection of maize data was done from ten (10) plants in the two middle rows with 3.6 m2 as sampling area. Statistical analysis was performed using Genstat software (16th edition) and means were separated using the Tukey mean separation test ($p<0.05$). Analysis of variance was done based on the statistical model for randomized complete block design: $Y_{ij} = \mu + \alpha_i + b_j + \varepsilon_{ij}$ whereby Y_{ij} indicates random variable representing the response for treatment (i) observed in block j, μ is the constant (which may be thought of as the overall mean, α_i stand for the (additive) effect of the ith treatment, b_j is the (additive) effect of the jth block, ε_{ij} is the random error for the ith treatment in the jth block.

Results and Discussions

Results

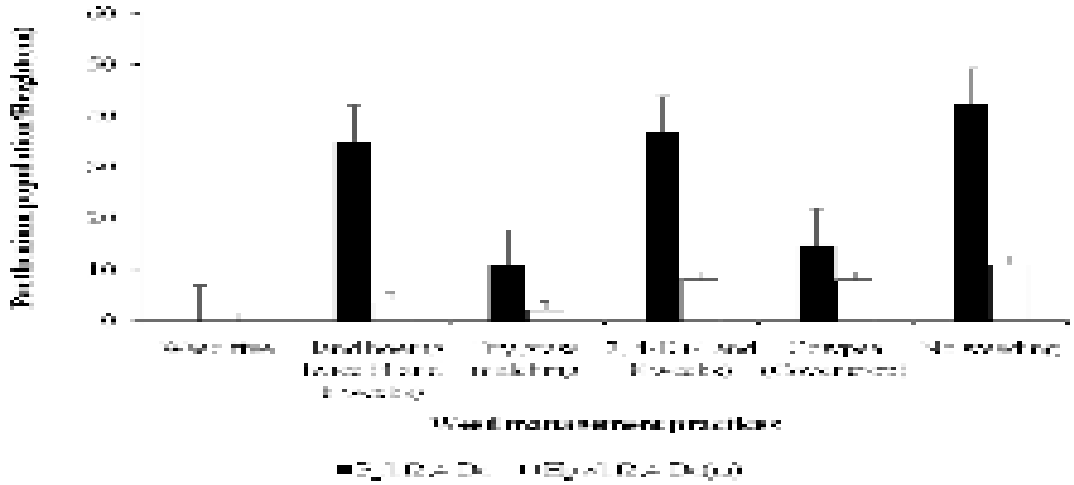
Effect of control method on parthenium weed population and height before first weeding and 2, 4-D application

Population and height of parthenium weed was observed to be significantly different ($p<0.05$) among the applied treatments. Plots treated with dry grass mulches had lower parthenium weed population and height than cover crop treated plots while high parthenium weed population and height were observed from un-weeded plots (Fig. 1). Hand weeding was observed to reduce height of the weed compared to when a plot was left un-weeded.

Effect of control method on population and height of parthenium weed after maize maturity

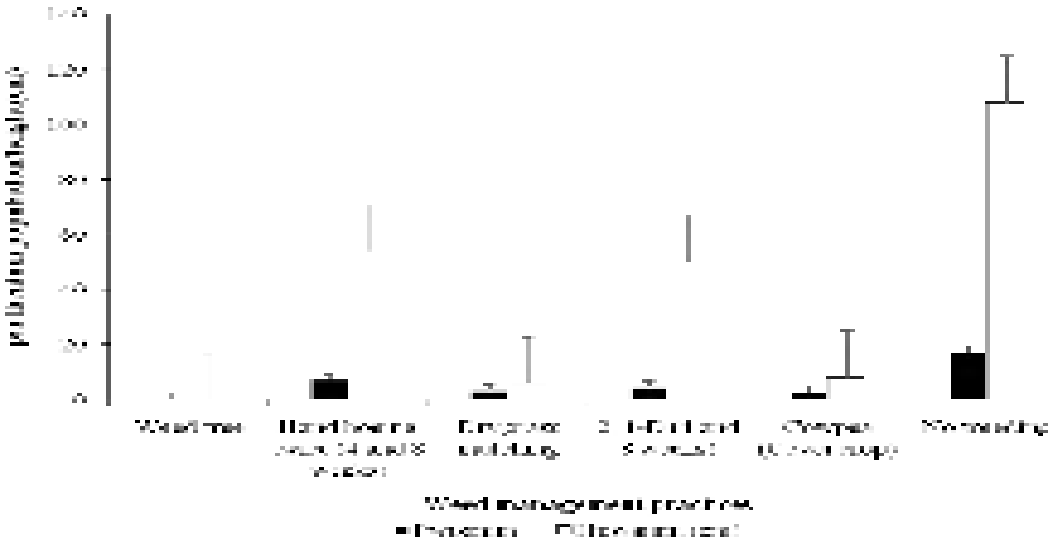
Statistical differences were observed to be significant ($p<0.05$) among treatments in

parthenium weed population and height at maize maturity (Fig. 2). A plot treated with cowpea as cover crop had lower parthenium weed population followed by cover crop plots and 2, 4-D plots while higher parthenium weed population was observed in the un-weeded plots (Fig. 2). Lowest parthenium weed height was recorded in dry grass mulched plots while the highest height was observed in the un-weeded plots.



(Ppbf2, 4-Da – Parthenium weed population before first weeding and 2, 4-D application, Hpwbf2, 4-Da – Height of Parthenium weed before first weeding or 2, 4-D application)

Figure 1: Effect of control method on parthenium weed population and height before first weeding or 2, 4-D application



(Pwpamm – Parthenium weed population after maize maturity, Hpwamm – Height of parthenium weed (cm) after maize maturity

Figure2: Effect of control method on parthenium weeds population and height (cm) after maize maturity)

Effect of control method on plant height, number of leaves, leaf length and leaf width at flowering

Plant height was not significantly affected by the applied management practices of the parthenium weed in the maize field (Table 1). The tallest maize plants were observed in plots with 2, 4-D while the shortest were observed in control plots (no weeding and weed free). Not only on plant height but also leaf length, leaf width and number of leaves were not statistically affected by the weeding methods. However number of leaves was slightly higher with 2, 4-D (Table 1).

Table 1: Effect of control method on plant height, number of leaves, leaf length and leaf width at flowering

Treatments	Plant height at flowering (m)	Number of leaves at flowering	Leaf length/plant (cm)	Leaf width (cm)
Weed free	1.43[a]	11[a]	13.37[a]	7.37[a]
Hand hoeing twice (4 and 8 weeks)	1.43[a]	11[a]	13.27[a]	7.59[a]
Dry grass mulching	1.49[a]	11[a]	13.46[a]	7.94[a]
2, 4- D (4 and 8 weeks)	1.57[a]	12[a]	13.46[a]	7.61[a]
Cowpea (Cover crop)	1.50[a]	12[a]	13.46[a]	7.89[a]
No weeding	1.45[a]	12[a]	12.16[a]	7.67[a]
Grand mean	1.48	11	13.38	8
SE±	0.068	0.3	0.8	0.4
P-value	0.296	0.131	0.26	0.702
CV (%)	7.9	3.9	2.7	6.9

*Means that share a letter within a column are not significantly different by Tukey mean separation test ($P \leq 0.05$)

Influence of control method on number of days to 50% tasseling, tassel length, number of days to 50% silking and number of days to milking

The parthenium weed management practices did not significantly affect number of days to 50% tasseling, tassel length, number of days to silking and number of days to milking in maize (Table 2). Maximum number of days to tasseling, silking and milking was observed from weed free plots. The data also showed that the maize variety used (SC 403) took almost 18 days to milking stage after silking.

Effect of control method on number of days to maturity and plant height

Results in Table 3 indicate that number of days to maize maturity was not significantly different among parthenium weed management practices. However, maximum number of days to maize maturity was recorded with dry grass mulch application while maize plants took relatively short days to mature when 2, 4-D was applied. The shortest maize plants at maturity were recorded in un-weeded plot while the tallest maize plants were noted in plots applied with dry grass mulch.

Table 2: Influence of control method in number of days to 50% tasseling, tassel length, number of days to silking and number of days to milking

Treatments	Days to 50% tasseling	Tassel length (cm)	Days to silking	Days to milking
Weed free	73.25[a]	27.93[a]	79.25[a]	94.75[a]
Hand hoeing twice (4 and 8 weeks)	71.25[a]	27.88[a]	78.00[a]	93.25[a]
Dry grass mulching	72.50[a]	27.98[a]	77.75[a]	93.75[a]
2, 4- D (4 and 8 weeks)	71.25[a]	27.50[a]	77.25[a]	93.00[a]
Cowpea (Cover crop)	71.25[a]	27.60[a]	77.75[a]	94.00[a]
No weeding	71.25[a]	26.85[a]	78.50[a]	93.75[a]
Grand mean	71.66	27.62	78.08	93.75
SE±	0.971	1.245	0.940	0.922
P-value	0.257	0.943	0.395	0.516
CV (%)	0.8	1.5	1.5	0.7

*Means that do not share a letter within a column are significantly different by Tukey mean separation test (P≤0.05)

Table 3: Effect of control method on number of days to maturity and plant height at maturity

Treatments	Days to 50% maturity	Plant height at maturity (m)
Weed free	142.8[a]	1.89[a]
Hand hoeing twice (4 and 8 weeks)	143.2[a]	1.94[a]
Dry grass mulching	152.5[a]	1.99[a]
2, 4- D (4 and 8 weeks)	142[a]	1.98[a]
Cowpea (Cover crop)	143[a]	1.93[a]
No weeding	142.5[a]	1.85[a]
Grand mean	142.67	1.93
SE±	0.553	0.067
P-value	0.333	0.314
CV (%)	0.3	4.1

*Means that do not share a letter within a column are significantly different by Tukey mean separation test (P≤0.05)

Effect of control method on number of plants harvested, number of ears and ear length.

Despite of many maize plants being harvested when hand hoeing was practiced and few plants harvested in weed free treated plots, these practices did not affect significantly number of maize plants and ears harvested. Additionally, Ear length and ear diameter were also not significantly affected by the weeding methods (Table 4).

Table 4: Effect of control method on number of plants harvested, number of ears and ear length

Treatments	Number of plants harvested	Number of ears harvested	Ear length (cm)	Ear diameter(cm)
Weed free	25[a]	25[a]	13.37[a]	4.89[a]
Hand hoeing twice (4 and 8 weeks)	27[a]	27[a]	13.27[a]	4.86[a]
Dry grass mulching	26[a]	26[a]	13.86[a]	4.79[a]
2, 4- D (4 and 8 weeks)	26[a]	27[a]	14.17[a]	0.048[a]

Cowpea (Cover crop)	26[a]	26[a]	13.46[a]	4.96[a]
No weeding	26[a]	26[a]	12.16[a]	4.61[a]
Grand mean	25.88	26	13.38	4.82
SE±	3.057	3.038	0.806	0.14
P-value	0.999	0.997	0.49	0.262
CV (%)	8.3	8.7	2.7	3.6

*Means that do not share a letter within a column are significantly different by Tukey mean separation test (P≤0.05)

Effect of control method on number of kernel rows, number of kernels/ha and grain yield (t/ha)

Maize variety (SC 403), produced ears with almost the same number of kernel rows since significant differences was not found as shown in Table 5. Same number of plants and ear size was also harvested to every plot (Table 4.5). In addition pollination succeeded in the same rate to every plot.

Results in Table 5 show that there were similar number of kernels per cob that resulted into similar maize yield (t/ha).

Table 5: Effect of control method on number of kernels row, number of kernels/ha and total kernels weight (t/ha)

Treatments	Kernel rows/ha	Kernels/ha	Grain yield (t/ha)
Weed free	37500[a]	73264[a]	5.27[a]
Hand hoeing twice (4 and 8 weeks)	37639[a]	75278[a]	6.12[a]
Dry grass mulching	36528[a]	81042[a]	6.27[a]
2, 4- D (4 and 8 weeks)	37917[a]	81875[a]	5.69[a]
Cowpea (Cover crop)	37500[a]	78264[a]	6.86[a]
No weeding	35208[a]	68681[a]	5.41[a]
Grand mean	37049	76400	5.94
SE±	1029.8	5777.8	1.293
P-value	0.145	0.246	0.827
CV (%)	6.6	3.6	14.8

*Means that do not share a letter within a column are significantly different by Tukey mean separation test (P≤0.05).

Discussions

These results indicate that dry grass mulching and cover crop were the best management practices in reducing parthenium growth over the control (no weeding) plot. Thus, Dry grass and cowpea (cover crop) covered almost the whole plot, therefore they hindered parthenium weed to emerge by inhibiting light reaching the weed. Thus insufficient light hindered parthenium weed establishment and growth. The parthenium weed seeds were able to germinate and emerge easily only in spots which were not well covered by mulch. These results are similar to those reported by Nishanthan *et al*. (2013) in which high parthenium weed density was observed from un-weeded plots and mulching suppressed its growth. Parthenium weed germinated and emerged where there was insufficient cover by the mulch (Nishanthan *et al*., 2013). Parthenium weed in the un-weeded plots had higher population and taller plants since they were not disturbed with any weed management practices. Dry grass and cover

crop mulches delayed parthenium weed emergence and even where they emerged maize crop was already full-established and provided shading effect to the weed which resulted into poor growth. Thus, grass mulch hinders parthenium weed growth and favors growth of maize plants by conserving soil moisture as well as suppressing growth of other weeds (Florence *et al*., 2015).

Additionally, application of 2, 4-D was the best management practices for reducing parthenium plant height over the control (no weeding). Thus, application of 2, 4-D two weeks after planting killed almost all parthenium weeds. New parthenium weeds that germinated were also killed when 2, 4-D was applied for the second time (8th week after planting).

Cover crop mulch (cowpea plants) could be used by farmers to manage parthenium weed since it reduced parthenium weed growth and population by inhibiting its emergence through shading effect. Apart from reducing parthenium weed population, also cowpeas plants fixed nitrogen in the soil and hence became available to maize plants (Papa *et al*. 2015). Similar results were reported by Haroon *et al*. (2012) who reported that 71-80% of parthenium weed was controlled four weeks after 2, 4-D application while un-treated plot could not provide a mean mortality of over 80% to parthenium weed (Goodall *et al*.,2010).

Maize emerged earlier than parthenium weed and thus out-competed the weed resulting in greater plant height, leaf length and width. Wajeeh *et al*. (2016) reported similar results. They noted weeding methods were not affecting significantly on maize plant height. Although many leaves were counted when 2, 4-D, cowpeas and dry grass mulches were observed. These could be due to the effectiveness of the applied weed management methods that provided a chance for maize to explore all available nutrients for its growth. This is similar to Larbi *et al*. (2013) who observed the greatest number of leaves with 2, 4-D application.

Weed management methods such as dry grass mulch, cover crop and 2, 4-D affected parthenium weed growth. However, it did not reach a level to compete with maize plants. Maize, being the first to emerge and establish, it cause the weed not to affect maize growth parameters such as number of days to silking, days to tasseling and milking. This concurs with the results of Nleya *et al*. (2016) who reported that kernel milk stage occurred approximately 18 to 22 days after silking.

In order for a weed to suppress growth of a plant it must out-compete the grown plant. Late parthenium weed germination even in un-weeded plot favored maize plant growth and hence caused applied weed management methods not to have statistical differences in plant height and number of day to maize maturity. Additionally, the results provide the information that maize variety used (SC 403) had almost the same ear length and diameter. This could be due to maize crop being the first to emerge before the weed and hence managed to use effectively the available resources such as moisture, oxygen and nutrients. These results were similar to those of Tesfay *et al*. (2014) who observed longest ears (16.3, 19.2 cm) with hand weeding and hoeing respectively, but not significant.

Factors such as plant population, ear size and success at pollination were not affected by the parthenium weed, that's why there was no significant difference in number of kernel rows and number of kernels per hectare. The number of kernel per hectare depends upon plant population, ear size and success at pollination (Jeff, 2010). These results may imply that, rate and duration of grain filling was unaffected by the parthenium weed. Parthenium weed did not out-compete the maize crop, thus not affecting grain yield. Maize emerged and well established before the weed from un-weeded plot hence dominated the cropped area and got all necessary requirements for its growth. Thus, they grew taller than parthenium weeds; hence maize had advantage of light over the weed. The weed should out-compete a respective crop in nutrients, moisture and air so that to alter its growth (Montserrat *et al*., (2004). Therefore, this made grain yield in the un-weeded plots to be similar to weeded ones. Grain yield is directly related to number of kernels per cob (Wajeeh *et al*., 2016). The number of rows per cob is a genetically controlled factor but environmental and nutritional level may alter the number of rows per cob (Muhammad *et al*., 2008). Thus, the grain yield being not affected despite of applying weed management practices could be attributed by environment and/or nutritional level of the soil which were not in favor of facilitating kernel rows emergence in a maize cob.

Conclusions and Recommendations

Conclusions

The study demonstrated that parthenium weed population can highly be reduced by applying 2, 4-D, dry grass mulches and cover crop mulching as weed management practices. Additionally, cowpea mulch and 2, 4-D treatments, dry grass mulch was noted to reduce height of parthenium weed. However, application of 2, 4-D reduced parthenium weeds population as compared to hand hoeing. Notwithstanding, after maize maturity, height of parthenium weed was observed to be highly reduced in plots treated with dry grass and cowpea mulches.

Recommendations

2, 4-D reduced parthenium weed more than mulching but should not be the first option due to its health hazards. Therefore researchers and farmers should go for other weed control options. This research work recommends the use of cover crop mulching (cowpea plants) to be the best option for farmers to manage parthenium weed since it was among the best practices in reducing parthenium weed growth and population by inhibiting its germination through shading effect provided by the large canopy of cowpea plants.

Resultsof this study were obtained from a single season experiment. Therefore, more research should be carried out in order to confirm current results and work on economically viable and environmental friendly control method of parthenium weed in maize field.

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Bamboo: A Potential Resource for Contribution to Industrial Development of Tanzania

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Abstract

Bamboo is an important non-timber forest product and a major wood substitute. Itcan be processed and fabricated into different products as a substitute for wood products at an industrial scale. However, the available information on bamboo resources availability, its properties and potential for contribution towards Sustainable Development Goals is limited. Therefore, this study aimed at determining the potentials of bamboo resources for sustainable industrial development in Tanzania. Specifically, the study aimed at exploringavailable bamboo resources, unique propertiesand its potential for contribution to Sustainable Development Goals in Tanzania. We conducted a comprehensive literature review in Tanzania mainland, supported by field visits to validate the National Forest inventory bamboo data. We used meta-analysis to generate descriptive statistics of the variables of interest. Results show that bamboo covers about 1,025,033 ha in Tanzania mainland, dominated by Yushania alpina, Bambusa vulgaris, Bambusa bambos and Oxytenanthera abyssinica. Bamboo has unique physical, chemical, and mechanical properties compared to wood, steel, cements and plastics, ithas many unique properties related to strength, elasticity and lightness, which could be used to contribute towards Tanzania industrial development ambitions.Use of bamboo resources can contribute to achievement ofsix of the 17 Sustainable Development Goals.

Keywords: Bamboo, Sustainable Development Goals, Tanzania, Potential Resource

Introduction

Bamboo is a fast-growing woody grass in the family Poaceae. Itcomprises of over 1642 species belongingto 91 genera worldwide (FAO 2007; Vorontsova*et al.*, 2017). Some of its members are giants, forming by far the largest members of the grass family. It is naturally distributed in the tropical and subtropical belt between approximately 46° north and 47° south latitude, and is commonly found in Africa, Asia and Central and South America. Some species may also grow successfully in mild temperate zones in Europe and North America. Bamboo grows naturally on the major mountains and highland ranges of Tanzania and other East African countries. Itis an extremely diverse plant, which easily adapts to different climatic and soil conditions (FAO, 2005; 2007; Chihongo*et al.*, 2000).

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Bamboo has proven to be a potential resource for industrialization and sustainable development in various countries (INBAR, 2015). It is an environmentally friendly building material, presentingadvantages such as physical properties comparable withsteel, high renewability with a rate of CO2 absorptiongreater than wood and thus a closed life cycle materialfor buildings; besides its social benefits (Losada, 1993; Janssen, 2000).Resource management and technical improvements can convert this fast-growing grass into a durable raw material for construction purposes and a wide range of semi-industrialised products (Li *et al*. 2004).

FAO (2007) estimated that bamboo forest coversmore than 36 million hectares(ha) worldwide. It is most abundant in the monsoon area of East Asia, especially in India with 11.4 million ha and China with 5.4 million ha. Over the last 15 years, the bamboo area in Asia has increased by 10 percent, primarily due to large-scale planting in China and India (Lobovikov *et al*., 2007). In Africa, Ethiopia, Kenya and Uganda possess most of the bamboo resources, according to the world bamboo resources assessment report (Lobovikov*et al*., 2007). Among the three countries, 86% of the African bamboo resource is distributed in Ethiopia (Kelbessa*et al*., 2000). Two indigenous bamboo species Yushania alpina (highland bamboo) and Oxytenanthera abyssinica (lowland bamboo) are commonly found in East Africa.

Bamboo is a long stick like non-wood forestproduct and sometimes used as wood substitute. Itis found any regions of the world and plays an importanteconomic role. Even though it is used for housing, crafts, pulp and paper, panels, boards, veneer, flooring, roofing, fabrics andvegetable (the bamboo shoot). The shoot of young bamboo grass can be processed into various delicious healthy foods and sometimes used as medicines. Young bamboo shoot is usually consumed as vegetable in curry and also as pickle. The nutritional value of bamboo shoots varies from species to species, harvesting procedure and growing environment (FAO 2007; Vorontsova*et al*., 2017). Generally, it is reported that bamboo has more than 1,500 documented uses andover 1,000 million people live in houses made of bamboo or with bamboo as the key structural, cladding or roofing element (Baksy, 2013; Khan *et al*, 2007).Products of bamboos are usingeverywhere and bamboo industries are now thriving in Asia andare quickly expanding across the continents to Africa andAmerica (FAO 2007).

There are four major bamboo species occurring naturally in Tanzania namelyYushaniaalpina, Oreobambosbuchewaldii, Hickelia sp. aff. madagascariensis and O.abyssinica (syn. Oxytenantherabraunii) (URT, 2008). Also, there are several introduced bamboo species in Tanzania namely Dendrocalamusasper, Bambusavurgaris var. Striata, Bambusa multiplex, Bambusa nutans, and Bambusa bambos exist (Kigomo, 1988; Chihongo*et al*., 2000). The dominant spp are Y. alpina, O. buchwaldii, and O. absyssinica (Chihongo*et al*., 2000).

In spite of the importance of bamboo, very little is known about bamboo resources availability, its properties and potential for contribution towards Sustainable Development Goals in Tanzania.As a non-timber forest product, bamboo is not

routinely included in forest inventories. According to the FAO (2001), statistical data on bamboo are available for the period 1954 to 2005 only. Currently, very few countries monitor bamboo supply and utilization at the national level. This might be due to difficultness of assessing bamboo resources and their use arises from: uncertainty associated with their taxonomy; the large number of, and wide variation in their uses at local, national and international levels; the fact that many bamboo products are used or marketed outside traditional economic structures; it lacks of common terminology and units of measurement (FAO 2001). It is evident from National Forest Monitoring and Assessment (NAFORMA) of Tanzania where bamboo resources were not reported.

Inadequacy of comprehensive and updated information onbamboo resources, its properties and potential for contribution towards Sustainable Development Goals in Tanzania hampers itsutilization and limits its potential to contribute to sustainable industrial development of Tanzania. Additionally, literature on the potential uses of bamboo resources to sustainable development of Tanzania is scarce. Therefore, this study aimed to explore the potential of bamboo resources for sustainable industrial development of Tanzania. Specifically, the study the study aimed determine the available bamboo resources, unique properties and its potential for contribution to Sustainable Development Goals in Tanzania.

Materials and methods

Study Area

Tanzania is located between 1° 00' S and 12° 00' S and between 30° 00' E and 41°00'E at an altitude between 358 m a.s.l. and 5,950 m a.s.l. Mainland Tanzania ischaracterized by tropical climate, which can be divided into four distinct climaticzones, namely, the hot humid coastal plain, the semi-arid zone of the central plateau,the high-moist lake regions, and the temperate highland areas. The country hasmean maximum day-time temperatures ranging from 10°C to 31°C and a meanannual rainfall ranging from 500 to 2,500 mm across the four zones (URT, 2017).The study was conducted on forestland in Tanzania Mainland which covers an estimated area of 48.1 million ha (MNRT, 2015).

Sampling design

Sampling design and data collected by National Forest Resources Monitoring Assessment (NAFORMA) (MNRT, 2015) were used in this study. The NAFORMA inventory adopteda two-phase stratified systematic cluster design with double sampling for stratification which was designed based on a simulation study described by Tomppo *et al*. (2014).The first-phase sample consists of clusters of plots on a 5 × 5 km grid over mainland Tanzania based on predicted growing stock, terrain of the area and time for cluster measurements, and results into 18 strata. The clusters in the first-phase contain a range of 6 to 10 plots, but the number of plots in cluster of the same stratum is the same.

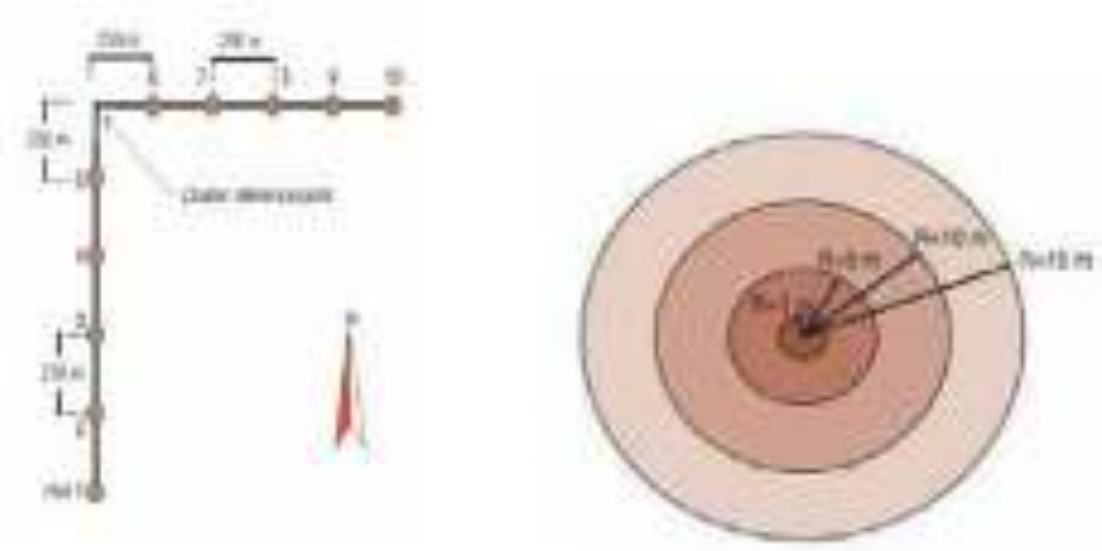

Figure 1:Cluster design used byNational Forest Resources Monitoring Assessment

The second-phase samples were systematically selected from the first phase sample, with different sampling intensities in each of the 18 strata following an optimal allocation procedure and with cost functions designed for each stratum. Greater sampling intensity was allocated to strata with large predicted growing stock and smaller sampling intensity to strata with small predicted growing stock. Thus, the second phase which is a sub-sample of the first phase were measured in the field.The distance between field plots within a cluster was 250 m, while the distance between clusters varied from 5 km to 45 km (Tomppo *et al*., 2014).

Data collection

Circular plots of 15 m radiuswere laid out. Bamboos present in the plots were identified, followed by measurements ofaverage diameter at breast height (Dbh), average height, and number of culm/stems in the plot. Also, vegetation type, land use, ownership, land cover, altitude, plot centre coordinates and coverwere recorded for the plots.

Additionally, we conducted comprehensive literature review on the properties of bamboo and how it can beused to achieve sustainable development goals in Tanzania.

Data extraction

Data was extracted from the NAFORMA database server located atSokoine University of Agriculture. The whole NAFORMA data set was imported to R software for the extraction of bamboo data and their related cluster and plot information. The extraction of the data was then done by performing Structured Query Language (SQL) queries within R software using sqldf package. After extraction, the data were subjected to validation, cleaning (removal of noisy data and data cleansing) and outliers' analysis (Son, 2011).

Data Analysis

Aspatial distribution map was generated from the plot center Global Positioning System (GPS) coordinate points. QGIS version 2.16.3 was used for mapping the spatial distribution of bamboo species across the country.The distribution was assessed by presence data of the bamboo species along the altitudinal gradient, across vegetation types and land uses(Whittaker, 1972).The altitudinal band of the 200 m band was adopted for this study. Samples within each altitudinal band were pooled and the number of species observed in each band was regarded as richness (Whittaker, 1972; Shimada and Wilson, 1985).

A relative abundance of bamboo species in various vegetation types was calculated as the ratio of the number of species found in each vegetation type and the total number of species recorded in all study vegetation types which according to May (1975), as cited by Magurran (1988) is:

$$[illegible]$$

Where:ni the abundance of the ith species,NT is the total number of individuals, andS is the total number of species.

Stand density (culms/ha) was determined based onthe formula of Philip (2004).

$$[illegible]$$

Whereby; N is the number of stems per ha, nicounts in ith plots, aiis the area of the of ith plots in ha and n is the total number of sample plots.

Land area estimation equation developed by NAFORMA was adopted to estimate area occupied by bamboo species.

$$[illegible]$$

Where:A_{ah} is area estimates of the land category

n_{ah} is the number of plots in the second phase sample on the land category n_h, l

n_{sa} is the total number of plots in the second phase sample on land on stratum h, n_h

A is estimated land area of the stratum from the first phase sample

Results

Distribution and coverage of bamboo resources

Bamboo covers about 1,025,033 ha in Mainland Tanzania. About 62% (636,545 Ha) of bamboos are found in the Southern zone (Lindi, Mtwara and Ruvuma) of Tanzania

(Table 1).Bamboo resources are distributed in eleven administrative regions of Arusha, Tanga, Morogoro, Lindi, Mtwara, Ruvuma, Njombe, Iringa, Mbeya, Katavi and Kigoma (Figure2). Bamboo were most abundant in Lindi, Ruvuma, Mtwara, Iringa and Njombe with 75.2% of total population. Less abundance of bamboos observed in Arusha, Mbeya, Katavi and Tanga that constitute to 7.9% of the total population. Most bamboo species were distributed in low altitudes compared to high altitude, and about 85.2% of bamboos distributed below 1500 m.a.s.l. (Figure3).

Bamboo has been distributed in all land use types (Figure4). They are widely distributed in production forest, protection forest and Wildlife protected areas, which all together forms the public forests and contributes about 65% of the total distribution of bamboo across different land use(Table 2).

Additionally, bamboo species were observed to be distributed across all vegetation types in Tanzania (Figure5). The highest proportion of occurrence is in woodland, cultivated land, and forest, with 66% 12% and 10% respectively. Most of the bamboo species area distributed on woodland, especially in open woodland with 10-40% of the canopy cover. Despite bamboo species being distributed across all types of land use, though species richness found at each land use tends to vary.More bamboo stems were observed in lower Dbh class (<4cm) as shown in diameter distribution (Figure 6). Bamboo forest is composed of many small diameter culms and very few large diameter culms, thus making an inverse J structure.

Table 1: Coverage of bamboo species across zones/regions of Tanzania

Zone	Regions	Coverage (Ha)
Southern zone	Lindi, Mtwara and Ruvuma	636545
Southern highland zone	Iringa, Njombe and Mbeya	165030
Western zone	Kigoma and Katavi	128129
Eastern zone	Morogoro	77903
Northern zone	Arusha	17426
Total area		1025033

Table 2: The coverage of bamboo species across land use types in Tanzania

S/n	Land use type	Coverage (ha) (000)
1.	Production forest	458.189
2.	Protection forest	98.403
3.	Wildlife protected areas	118.903
4.	Shifting cultivation	116.854
5.	Agriculture	199.881
6.	Grazing land	3.075
7.	Built up areas	16.401
8.	Water body/wetland	4.1
9.	Others	9.227
Total		1025.033

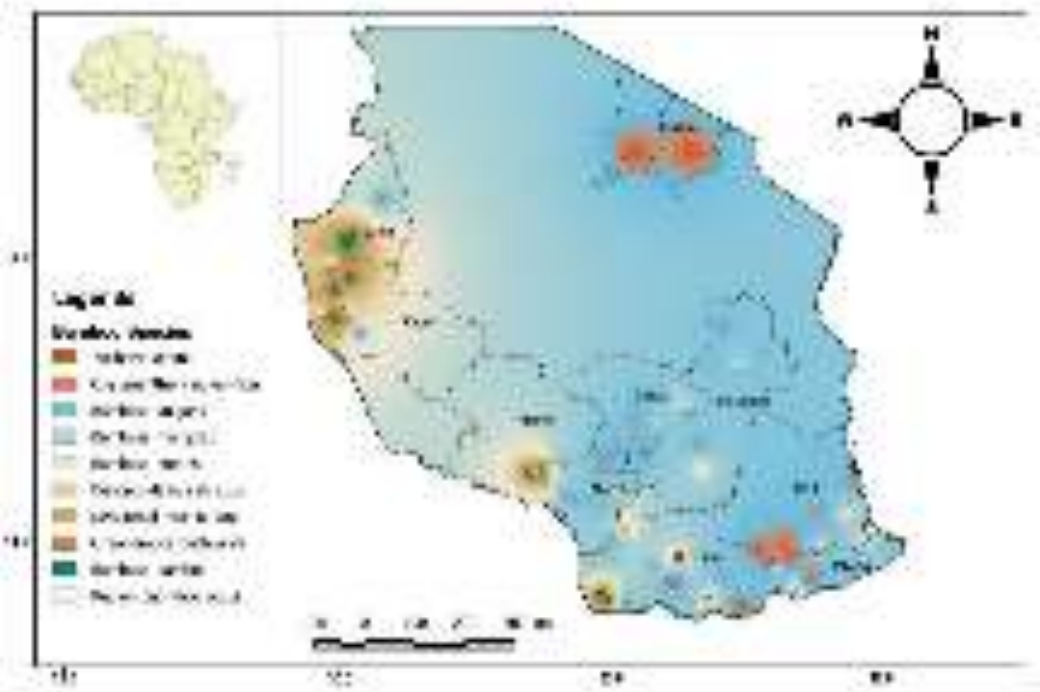

Figure 2: A map of bamboo species distribution in Tanzania

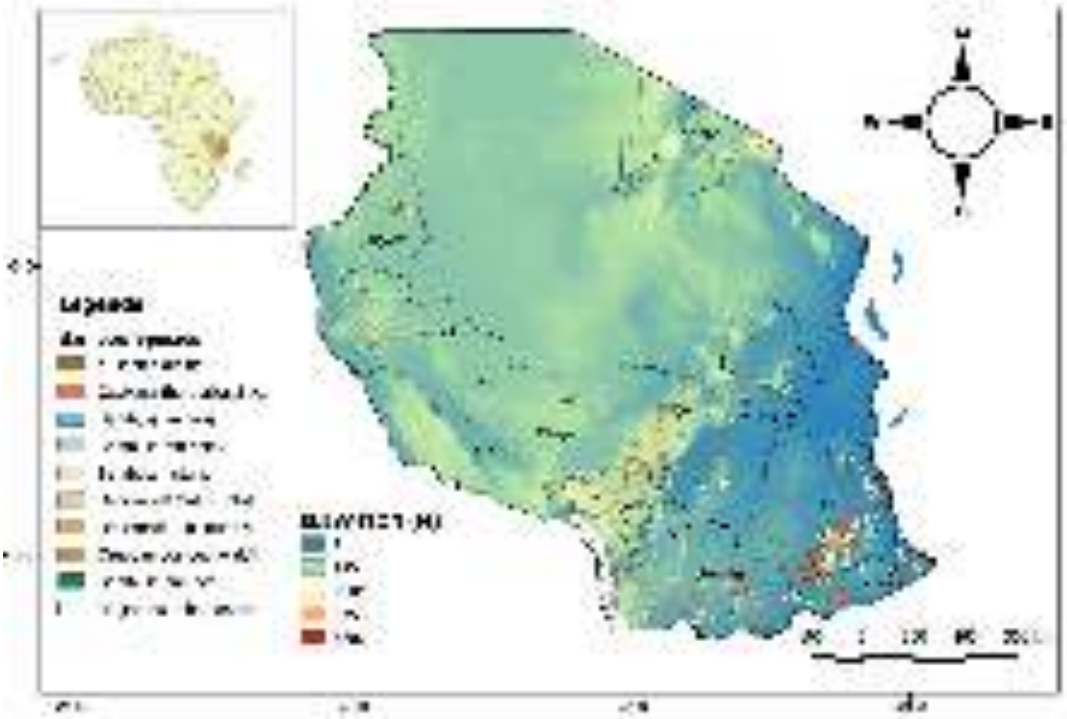

Figure 3: A map of bamboo species distribution along elevation gradients in Tanzania

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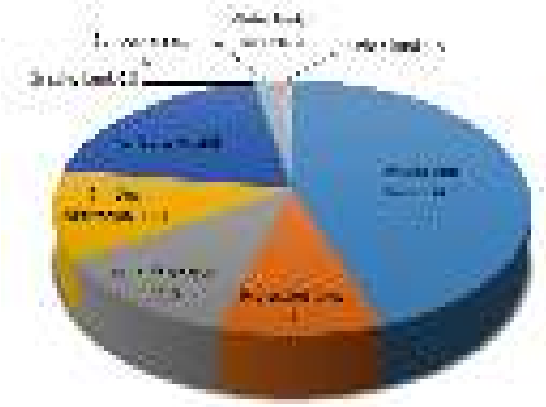

Figure 4: Distribution of bamboo species across land use types in Tanzania

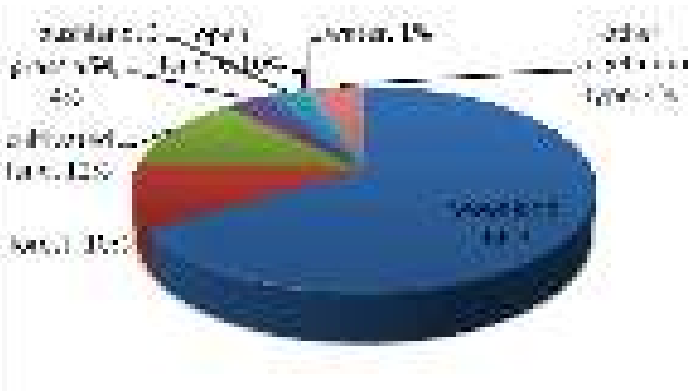

Figure 5: The distribution of bamboo species across vegetation types

Figure 6: Diameter class distribution of bamboo species in Tanzania

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Bamboo species composition and richness in Tanzania

A total of 11 bamboo species were identified and recorded in Tanzania (Table 3). These bamboo species are distributed in 5 genera within two tribes of Arundinarieae and Bambuseae, both of which are woody bamboo. The identified bamboo species include three indigenous species and eight exotic species.

Table 3: A list of bamboo species identified in Tanzania

s/n	Species name	Genera	Status
1.	*Yushania alpina*	Arundinarieae	Indigenous
2.	Bamboo spp.	-	-
3.	*Bambusa bambos*	Bambusa	Exotic and Naturalized
4.	*Bambusa multiplex*	Bambusa	Exotic
5.	*Bambusa nutans*	Bambusa	Exotic
6.	*Bambusa spp.*	Bambusa	Exotic
7.	*Bambusa vulgaris*	Bambusa	Exoticand Naturalized
8.	*Dendrocalamusstrictus*	Dendrocalamus	Exotic
9.	*Dendrocalamusnutans*	Dendrocalamus	Exotic
10.	*Oreobambosbuchwaldii*	Oreobambos	Indigenous
11.	*Oxytenanthera abyssinica*	Oxytenanthera	Indigenous

Production forest had the highest richness of bamboo species observed with eleven species, among which the most abundant are Y. alpina, O. abyssinica, B.bambos and B. species (Table 4). Protection forests and shifting cultivation land use type have also high bamboo species richness with eight bamboo species. Bamboo richness of agriculture land use type is seven species, while the most abundant specie is O. abyssinica. Wildlife protected areas land use type is six species withY.alpina being the most abundant. Lowest species richness wasobserved in grazing, built-up area, water and swamp area and other land use types.

Table 4: The richness of bamboo species across land use types in Tanzania

S/n	Land use type	Number of bamboo species
1.	Production forest	11
2.	Protection forest	7
3.	Wildlife protected areas	4
4.	Shifting cultivation	6
5.	Agriculture	6
6.	Grazing land	2
7.	Built up areas	1
8.	Water body/wetland	1
9.	Others	3
Total		11

The richness of bamboo species along the altitudinal gradient differs (Figure 7). There is an increasing trend in total species richness from 76 m.a.s.l to 500 m. a. s. l., then followed by decrease in richness from 500 m.a.s.l to 2600 m.a.s.l. Thus, the high bamboo species richness in Tanzania is between 400 m.a.s.l and 800 m.a.s.l with a maximum value at 500 m.a.s.l (Figure 7). This falls within the general pattern of an initial increase in species richness with altitude followed by a peak and then a decline with further increased altitude.

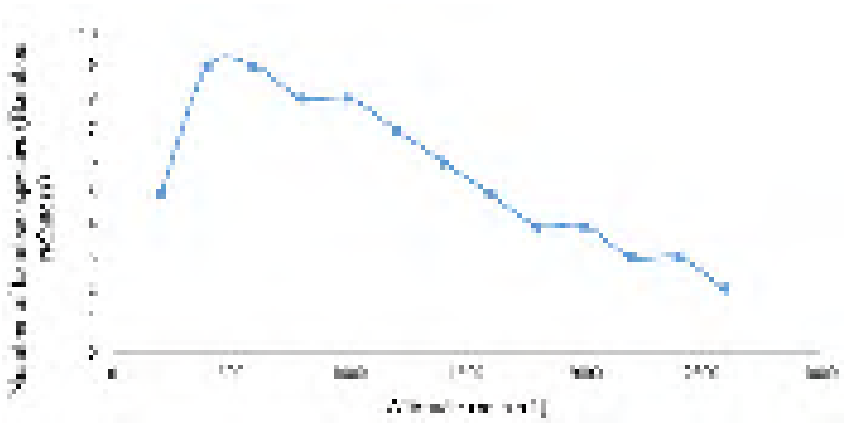

Figure 7: Bamboo species richness along altitudinal gradient in Tanzania

Abundance and Density of Bamboo in Tanzania

The most abundant bamboo species were Y. alpina, B. vulgaris, B. bambos and O. abyssinicawhich altogether constituted to 73.2% (Table 5) of the total bamboo abundance in the country.Results from the study show that the mean stand density of bamboo was 2660.18 culms/ha (Table 6). There is a great variation in culm density for different bamboo species that ranges from 1247 culms/ha for Bambusa vulgaris to 3622 culms/ha for Bamboo spp.

Table 5: The relative abundance of bamboo species in Tanzania

S/n	Scientific name	Relative abundance	Percentage (%)	Ranking
1	*Yushania alpine*	0.213	21.3	1
2	*Bambusa vulgaris*	0.207	20.7	2
3	*Bambusa bambos*	0.165	16.5	3
4	*Oxytenanthera abyssinica*	0.147	14.7	4
5	*Bambusa spp.*	0.109	10.9	5
6	Bamboo spp.	0.069	6.9	6
7	*Dendrocalamusnutans*	0.027	2.7	7
8	*Dendrocalamusstrictus*	0.019	1.9	8
9	*Bambusa nutans*	0.017	1.7	9
10	*Bambusa multiplex*	0.016	1.6	10
11	*Oreobambosbuchwaldii*	0.011	1.1	11

Table 6: The stand (culm) density of bamboo species in Tanzania

S/n	Species name	Stand density (culms/ha)	Ranking
1	*Bamboo spp.*	3622	1
2	*Bambusa nutans*	3211	2
3	*Bambusa multiplex*	3029	3
4	*Oreobambos buchwaldii*	2972	4
5	*Bambusa spp.*	2852	5
6	*Oxytenanthera abyssinica*	2790	6
7	*Yushania alpine*	2656	7
8	*Dendrocalamus strictus*	2519	8
9	*Bambusa bambos*	2368	9
10	*Dendrocalamus nutans*	1996	10
11	*Bambusa vulgaris*	1247	11
Average		2660.18	

Bamboo properties

Bamboo has unique physical,chemical, and mechanical properties

Physical properties

Specific gravity, moisture content and dry shrinkage

The specific gravity of bamboo ranges between 0.5 and 0.8 g/cm3 (oven-dry weight). This value increases from the central parts to the peripheral parts of the culm and from the bottom to the top (Liese 1985).

Moisture content influences the utilization of bamboo in a similar way like that of wood. The moisture content of bamboo depends on: 1. Bamboo species: the different species have a different amount of parenchyma cells which correlate to the water holding capacity (Liese and Grover, 1961). 2. Culm zones: the base has a higher value than the top. The inner part of the culm cross section has a higher value than the outer part. 3. Nodes or internodes: the nodes have a lower value than internodes (up to 25%). 4. Seasons: at the end of the rainy season it is much higher than at the end of the dry season; 5. Age of the cane: the young culm has a higher and more uniform moisture content than the mature one (Dunkelberg, 1985). After the harvesting the moisture of bamboos can be influenced by the humidity and dryness of the environment.

Chemical properties

The chemical properties influence the growth and the mechanical properties of bamboos. Through the chemical analysis more information on the taxonomical identification and propagation can be obtained. The chemical composition of bamboos also has an influence on deciding what kinds of bamboos with which kind of material in

combination is suitable for the utilizations. Bamboo consists mainly of cellulose, lignin and hemicellulose which are not different to that of trees (Table7). The difference lies in the percentages of each component and their micro structures. Some minor chemical components are resins, tannins, waxes and inorganic salts. This chemical composition changes according to the species, the age and the parts of bamboo. The variation of bamboo's chemical composition has a big influence on the physical and mechanical properties of bamboos and therefore the treatment and utilization of bamboos (Liese, 1985).

Table 7: Chemical compositions of bamboo and softwood (Source: Janssen, 1981)

Material	Cellulose (%)	Lignin (%)	Hemicellulose (%)
bamboo	55	25	20
softwood	50	25	25

Mechanical properties

The studies on bamboo mechanical properties are commonly based on laboratory tests of the strength of bamboo (tensile strength, bending strength, compression strength, shear strength and modulus of elasticity) (Atrops, 1969; Janssen, 1981; Dunkelberg, 1985). These tests show remarkable differing values when changing species, ages, moisture content, locations, soil and climatic conditions. The variation of mechanical properties is similar to wood, but even more remarkable (Table 8).

Table 8: Material mechanical properties concrete, steel, wood and bamboo (Janssen, 1981)

Material	Working stressσ (N/mm2)	E (N/mm2) Modulus of lasticity	Working strain ε(10-6)	Strain energy stored	
				J/m3	J/kg
concrete	8	25000	300	1200	0.5
steel	160	210000	800	64000	8.2
wood	7.5	11000	700	2600	4.3
bamboo	10.7	20000	500	2500	4.2

The research by Janssen (1981) shows that compared to concrete, steel and wood bamboo has excellent mechanical properties with reference to material efficiency for strength (working stress per volume unit) and stiffness (E modulus per volume unit) (Table 9).

Table 9: Material efficiency for strength and stiffness (Janssen, 1981)

Material	Working stress/Weight by volume	E/Weight by volume
concrete	8/2400 = 0.003	25000/2400 = 10
steel	160/7800 = 0.02	210000/7800 = 27
wood	7.5/600 = 0.013	11000/600 = 18
bamboo	10/600 = 0.017	20000/600 = 33

Bamboo and Sustainable development goals

Bamboo is among unique resource which can be used to address Sustainable Development Goals (SDGs). This study found six of the 17 SDGs can be achieved through sustainable use of bamboo resources in Tanzania (Table 10). Thought sustainable use of bamboo, several targets can be achieve including poverty reduction; energy; housing and urban development; sustainable energy production and consumption; climate change and land degradation.

Table 10: Sustainable Development Goal can be contributed through using bamboo resources

S/No	Sustainable Development Goal (SDG)
1	SDG 1 (End poverty in all its forms everywhere)
2	SDG 7 (Ensure access to affordable, reliable, sustainable and modern energy for all)
3	SDG 11 (Make cities and human settlements inclusive, safe, resilient and sustainable)
4	SDG 12 (Ensure sustainable consumption and production patterns)
5	SDG 13 (Take urgent action to combat climate change and its impacts)
6	SDG 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss)

Discussion

Distribution and coverage of bamboo resources

The found distribution and coverage of bamboo resources in this study contradict with the study by Kigomo (1988) and Chihongo*et al*. (2000) who reported that bamboo species distributed in Arusha, Tanga, Morogoro, Iringa, Mbeya, Lindi, Ruvuma, Kigoma, Kilimanjaro, Coastal and Kagera regions, though the proportional of distribution differs completely. The study reveals that there is no longer existence of bamboo in Coastal and Kagera regions which previously reported to exist. Also, there is occurrence of bamboo in Katavi and Mtwara regions which previously were not reported. The difference could be attributed by introduction of bamboo species in different areas after previous studies, the reported over-exploitation of bamboo resources in the country that cause depletion of bamboo (Chihongo*et al*., 2000). Also, the difference attributed by methodological approach. Previous researches were based on remote sensing (FAO, 2007). According to FAO (2007) reported that remote sensing technology that does not recognize bamboo as a separate class. Also, there is a contradiction in differentiating the refractive index of bamboo and other species like sugarcane (Chihongo*et al*., 2000; FAO, 2007; Liese and Köhl, 2015) that may cause bamboo not recorded its occurrence. On other hand, the findings of this study on distribution of bamboo across different land use agree with the study by Chihongo*et al*. (2000) reported that bamboo species are widely distributed in public forests.

Bamboo species composition and richness in Tanzania

The identified 11 bamboo species include three indigenous species and eight exotic species contradict with the study by Kigomo (1988); Chihongo*et al*. (2000); Bystriakova

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et al. (2004); FAO (2007) and Oyen (2011) reported that, four indigenous bamboo species exist in Tanzania, namely *Yushaniaalpina*, *Oxytenanthera abyssinica*, *Oreobambos buchwaldii* and *Hickelia africana*, and five exotic bamboo species namely *Bambusa bambos, Bambusa vulgaris, Bambusa multiplex,Chimonobambus ahookeriana and Bambusa nutans*. The difference in the species richness could be attributed by the intensity of the survey, since NAFORMA was the first compressive and most detailed survey conducted in Tanzania that included bamboo (MNRT, 2015) and previously bamboos were not included in the National Forest Inventories. Also, the difference might be contributed by the fact that other species were introduced. According to IUCN (2013) reported that *Hickelia africana* is under risk of extinction, its absence in this survey might mean that the species is very rare and would need a special survey to assess its status.

Three bamboo species that exist in Tanzania namely *Bambusa bambos*, *Bambusa vulgaris* and *Dendrocalamus strictus* fall under prioritized bamboo species for sustainable development and potential materials for industry. The group consists of twenty bamboo species considered as bamboo of high value globally (Rao *et al*., 1998). Other bamboo species existing in Tanzania like Yushaniaalpina, OxytenantheraabyssinicaandBambusa nutans falls under the category of proposed high value taxa of bamboo. This group constitutes a total of 21 bamboo species (Rao *et al*., 1998). Therefore, six bamboo species among eleven bamboo species exists in Tanzania are bamboo of high value globally.

The found richness of bamboo in this study contradicts with the study by Kigomo (1988) and Chihongo*et al*. (2000) who reported that the maximum richness of 8 bamboo species occurred in Tanga mostly confined to Amani arboretum. Other regions of Arusha, Iringa, Morogoro, Lindi, Kagera, Mbeya, Kigoma and Coast had a richness of 1, 2, 4, 1, 1, 2, 1, and 2 respectively (Chihongo*et al*., 2000). The differences could be attributed by difference in methodological approach. Also, the difference might be contributed by the fact that other species were introduced in other areas after the two studies. Most bamboo species were distributed in low altitudes compared to high altitude, and about 85.2% of bamboos are distributed below 1500 m.a.s.l. This agrees well with other studies as most of bamboos found in Tanzania were under tribe Bambuseae, genera Bambusa that prefer altitude below 1500 m.a.s.l. (Seethalakshmi and Kumar, 1998; Judziewicz*et al*., 1999; BPG, 2012). Therefore, altitude should be considered as an important factor for the selection of exotic bamboo species for the establishment of bamboo plantation in Tanzania.There is an increasing trend in total species richness from 76 m.a.s.l to 500 m. a. s. l., then followed by decrease in richness from 500 m.a.s.l to 2600 m.a.s.l. Thus, the high bamboo species richness in Tanzania is between 400 m.a.s.l and 800 m.a.s.l with a maximum value at 500 m.a.s.l. This falls within the general pattern of an initial increase in species richness with altitude followed by a peak and then a decline with further increased altitude. This, observed hump -shaped species richness patterns of bamboo species are in accordance with the hypothesis of productivity and optimum resource combination in the intermediate portion of the altitudinal gradient (Lomolino, 2001; Gerytnes and Vetaas, 2002). The indicated inverse J shaped showed that culms frequencies decreasing with an increase

in DBH. This implies that bamboos are developing and regeneration is taking place. This situation also indicates that there is severe disturbance which is characterized by presence of smaller diameter culms (Smiet, 1992).

Abundance and Density of Bamboo in Tanzania

The found abundance of bamboo in this study differ from study by Chihongo *et al*. (2000) which found that the relative of *Yushania alpina, Oxytenanthera abyssinica, Oreobambos buchwaldii, Bambusa vulgaris* and other bamboo species were 0.497, 0.348, 0.149, 0.006 and 0.0002 respectively. The difference in abundance might be attributed by the reported over-exploitation, gregarious flowering of bamboos which lead to mass death and the introduction of more bamboo species in different areas. Also, the difference in abundance could be attributed by the research methodologies between studies, since Chihongo *et al*. (2000) estimate bamboo resources by the use of remote sensing data. According to FAO (2007) remote sensing does not recognize bamboo as a separate class since most of bamboo exists as understory, thus recommend for a more detailed ground survey. Specifically, the difference in abundance for *Oxytenanthera abyssinica* especially on public land could be attributed by over-exploitation of the species as it is more preferred by the community for different uses (Chihongo*et al*., 2000). Moreover, for Yushania alpina the difference in abundance especially the increase is due to the fact that the species mostly distributed in protected areas where there is intensive management hence little disturbance.

Furthermore, the study reveals that indigenous bamboo species were more abundant with a total of 62.9%, while the exotic bamboo species constituted to 37.1 % of the total bamboo abundance in Tanzania. These findings concur with the findings by Chihongo *et al*. (2000) reported indigenous bamboo species are the most abundant, though the level of abundance for the two studies differ. The difference of the percent which is 99.4% of the study by Chihongo *et al*. (2000) and 62.9% in this study the difference relies on methodological approach, the introduction of other exotic bamboo species over-exploitation of indigenous bamboo species especially from public land. This informs decision makers to intensify the management of bamboo resources.

The results showed that there is a great variation in culm density for different bamboo species that ranges from 1247 culms/ha for *Bambusa vulgaris* to 3622 culms/ha for *Bamboo* spp. The low stocking of bamboos attributed by the fact that bamboos are mixed with other tree species, difference in preference for different species and variation in management efforts to different area where species found. Also, bamboos are under severe pressure from over-exploitation, grazing, wild fire, expansion of agricultural activities and other human disturbances cultivation (MNRT, 1998; Chihongo *et al*., 2000; MNRT, 2015). This overemphasize the need for conservation efforts on bamboo to meet the demand in Tanzania and global as the whole.

Properties of Bamboo

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The study found bamboo has many advantages like strength, elasticity and lightness compared to wood, steel, cements and plastics (Yu, 2007). The material properties of bamboo are the sum of the substances plus the structure of the substances. As material bamboo means mostly the culm, when the material properties of bamboos are discussed it mostly means the properties of the culm. The material properties will explain how the bamboo plant changes to bamboo material (Li *et al*. 2004).

Cellulose: Cellulose (C6H10O5)n is a carbohydrate. It forms the primary structural component of green plants. For the plants the primary cell wall is made of cellulose and the second cell wall is made of cellulose with a varying amount of lignin. Cellulose is also the most abundant form of living terrestrial biomass in the world, which in combination with lignin and hemicellulose can be found in all the plants (Crawford, 1981). It is also the major constituent of paper and for the synthesis of the plastics celluloid (Li *et al*. 2004).

Lignin: Lignin is an integral part of the cell walls of plants, especially in tracheids, xylem fibers and sclereids. It is the second most abundant organic compound on earth after cellulose. Lignin makes up about one-quarter to one-third of the dry mass of wood. The lignin fills the cell wall of the plant in the space among the cellulose, hemicellulose and pectin components. It confers mechanical strength to the cell walls and thus the whole plant. It is important in conducting water in culms. Because it is difficult to degrade it helps to build a barrier to defend the plant against the invasion of pathogens and enhances the durability of the plant. The high lignified wood is durable and yields more energies than cellulose. But it is a detrimental for paper making and therefore should be removed by pulping (Li *et al*. 2004).

Hemicellulose: Hemicellulose is similar to cellulose but is less complex. Hemicelluloses bind with pectin to cellulose to form a network of cross-linked fibers in plants. The hemicellulose in bamboo has its main component xylan between that of the hardwood and softwood (Li *et al*. 2004).

Unlike wood, bamboo begins to shrink from the beginning of drying (Liese and Grover 1961). The process is not regular and will stop at about 40% moisture content. After the bamboo is cut, its moisture content decreases and the shrinkage begins. The shrinkage varies in different directions. It is reported the dry shrinkage of phyllostachyspubescens, when the moisture lost is 1%, the average shrinkage rate is: lengthwise 0.024%, tangential 0.1822%, radial 0.1890% (on node parts 0.2726%, on inter node part 0.1521%) (Zhang *et al*., 2002). The dry shrinkage also increases from inner to outer parts. The dry shrinkage of the outer part of bamboo in length direction can be neglected, but the crosswise shrinkage is large (Li *et al*. 2004).

Some researchers triedto analyze and calculate bamboo's mechanical properties by studying its molecularstructure. Janssen (1981)developed a mathematical model of cells of bamboo culm to calculate the mechanical properties, whose principle has been used in the research on mechanical properties of cell walls in wood. Ye (1995) studied the different mechanical properties in the outer, middle and inner parts of the bamboo culm by studying the distributions of vascular bundles in these areas. These studies reveal

arelationship between the micro structure of bamboo and its properties and help to form a better understanding of the mechanical properties of bamboo (Li *et al*. 2004).

Bamboo and Sustainable Development Goals (SDG) in Tanzania
SDG 1 (End poverty in all its forms everywhere)

Bamboo exploitation and utilization have yielded direct and immediate micro level benefits to economically disadvantages of rural communities in many Asian, South and East African countries. In Tanzania, Bamboo has been employed as a veritable poverty fighter, replacing timber wood, iron, plastics, increasing wealth in rural livelihoods and even for exports, and most particularly contributing to decrease environmental footprints in carbon sequestration. It also plays a vital role of build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental disasters.The planting and cultivation of bamboo, it will help to achieve poverty reduction; energy; housing and urban development; sustainable energy production and consumption; climate change and land degradation and SDG1. Bamboos can be grown on marginal land, which may not be under cultivation, and may not have existing land tenure. Promoting the cultivation of bamboo therefore helps to provide the poor with natural resources that they have access to and ownership over (INBAR, 2013).

SDG 7 (Ensure access to affordable, reliable, sustainable and modern energy for all)

Bamboo provides energy when it is burned as firewood, processed into chips or pellets, or carbonized as charcoal. Recent studies in China, Ethiopia and Ghana reveal that the calorific value of bamboo charcoal is similar to that of the most suitable woods used for charcoal. At an industrial scale, bamboo can be used to fire generators and power stations, and research is progressing in Indonesia, Japan and Spain to study how to establish large-scale power generation based on bamboo plantations. Bamboo can also be the raw material for biogas systems, and research is now starting to define the properties for bioethanol and biodiesel. The starting point for this value chain is that managed bamboo stands give a long-term, sustainable source of raw material for bio-energy that helps to avoid deforestation (INBAR, 2015).

SDG 11 (Make cities and human settlements inclusive, safe, resilient and sustainable)

For affordable housing and dwellings that can be rapidly erected to respond to floods or other natural disasters, bamboo is emerging as a flexible construction material of choice for many uses. A number of documented cases testify how bamboo structures better withstand natural disasters than concrete housing, which is largely destroyed. Bamboo's unique properties of being sustainable and with high tensile strength, point to a revolution that is waiting to happen. In the world of high design, more top architects and designers are specifying bamboo for their creations in urban development (INBAR, 2015).

SDG 12 (Ensure sustainable consumption and production patterns)

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Bamboo is a "woody grass", not a tree and is selectively harvested without harming the ecosystem, or contributing to deforestation. Bamboo poles, fibre and engineered bamboo can be used for most purposes where timber is used today, and in some cases offers better performance than some timber products. In its cultivation and production life cycle, no part of the bamboo plant is wasted. Shoots are harvested for food; branches for poles used for many applications; the main bamboo pole for fibres for pulp or charcoal production and the lower trunk for construction uses or flooring and engineered bamboo products (INBAR, 2015).

SDG 13 (Take urgent action to combat climate change and its impacts)

Bamboo like other plants, also absorb CO2, and research in China has shown that a managed bamboo Moso bamboo forest absorbs more CO2 than an equivalent woodlot of Chinese fir. Unlike trees, bamboo is harvested selectively (in the case of Moso, only >3-4 years old culms are cut) and continues to store carbon for a longer term. Once products are made from bamboo, the carbon is locked up and is prevented from escaping into the atmosphere for the product lifetime. Bamboo therefore provides a secure carbon sink (INBAR, 2013; 2015).

Bamboo can help rural communities become less vulnerable as the plant's rapid growth allows frequent harvesting. Bamboo's excellent adaptability and resilience to natural disasters, allows farmers to adapt their landscape management practices, using bamboo, to respond to the changing weather patterns. At the same time. Bamboo can help to build resilience against changes in climate and related loss of livelihood options (INBAR, 2015).

SDG 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss)

This SDG is particularly relevant for bamboo as it includes targets related to the conservation, restoration and sustainable use of terrestrial ecosystems and their services; the implementation of sustainable management of all types of forests, restoring degraded forests and substantially increasing afforestation and reforestation globally; restoration of degraded land and soil; reducing the degradation of natural habitats; and integrating ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts.

SDG 15 also introduces measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species. In some cases, often inadvertently bamboo has been labelled an 'invasive species. It is important to clarify the invasiveness character of bamboo and identify which species carry a risk and which species are harmless in this respect.

Bamboo is used to rapidly restore severely degraded landscapes in Mbeya, Tanzania. With its over 1642 species, bamboo offers a range of characteristics for different uses and survival from wet to dry seasons of Tanzania suitable for a range of restoration and

land use planning needs. Bamboo grows rapidly, regenerates annually through an extensive root system and very good adoption to poor soil or climate conditions, and helps bind soil. These properties make it a unique and effective tool to control erosion and slope stability. Several countries use bamboos along river banks to maintain slope stability and restrain erosion. Additionally, to the soil conservation and climate change mitigation opportunities, ecosystem services provided by bamboo include biodiversity conservation, recreation and green spaces for wellbeing. However, the values of these various natural services are not well understood, and in most cases not reported (INBAR, 2015).

Conclusion

The study found 11 bamboo species that include three indigenous and eight exotic species exists in the country. Production forest had the highest richness of bamboo species observed with eleven species, among which the most abundant are *Y. alpina, O. abyssinica, B. bambos* and B. species. Results from the study show that the mean stand density of bamboo was 2660.18 culms/ha in Tanzania.The abundance and stocking of bamboo species is relatively low, since most of the bamboos in Tanzania are distributed in woodland, especially open woodland that follows under category of production forests which are under severe pressure from over-exploitation, wildfire and livestock grazing. Therefore, proper management intervention is required for the sustainability of bamboo resources in the country.

Bamboo species are distributed in eleven administrative regions of Arusha, Tanga, Morogoro, Lindi, Mtwara, Ruvuma, Njombe, Iringa, Mbeya, Katavi and Kigoma. Bamboo were most abundant in Lindi, Ruvuma, Mtwara, Iringa and Njombe with 75.2% of total coverage.

Bamboo has been distributed in all land use and vegetation types. They are widely distributed in production forests, protection forests and wildlife protected areas. More bamboo stems were observed in lower DBH class (<4cm) and very few large diameter culms, thus making an inverse J structure.

This study found bamboo has unique physical, chemical, and mechanical properties compared to wood, steel, cements and plastics, ithas many unique properties related to strength, elasticity and lightness, which could be used to contribute towards Tanzania industrial development ambitions.Use of bamboo resources can contribute to achievement of six of the 17 Sustainable Development Goals. Through sustainable use of bamboo, several targets can be achieved including poverty reduction; energy; housing and urban development; sustainable production and consumption; climate change and land degradation. Bamboo can make a positive contribution to addressing food security, women's empowerment, economic growth and technology.

Bamboos should be considered as a resource with great potential for sustainable industrial development of Tanzania. There is a need of more effort to create awareness about the available bamboo resources and its potential uses in Tanzania. Therefore, bamboos should regularly be included in the national forest inventory (NFI) in order to update information and monitor trends on the richness, coverage, abundance, density,

distribution and its role to address national concerns in the country.

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Natural Antioxidants from Clove for Protecting Omega-3 Fatty Acids in Sardines (*Rastrineobola argentea*) during Deep Frying Process

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Abstract

Sardines (Rastrineobola argentea), popularly known as "dagaa" is one of the leading commercial fish species of Lake Victoria. The fatty fish species are attracting great attention because they are good source ofomega-3 polyunsaturated fatty acidswhich are vital for a wide range of biological functions and are implicated in the prevention of numerous diseases. While nutritionally valuedomega-3 fatty acids are highly susceptible to oxidation during fish processing due to their unsaturated nature. Oxidation reactions result in loss of omega-3 fatty acids and production of undesired off-flavours which discourage consumption and limit diversification of sardine products.Synthetic antioxidants may be used to prevent lipid oxidation but have been claimed to becarcinogenic at higher levels. The replacement of synthetic antioxidants with ones of natural origin is now in demand. In this study, natural antioxidants rich extracts from clove buds were applied on sardines in a bid to impede lipid oxidation during deep frying process.Lipid oxidation was assessed by peroxide value (PV), volatile compoundsand fatty acid profilesusingGas chromatograph (GC-MS and GC-FID).The results showed that natural antioxidants from clove buds reduced peroxidation and protected highly unsaturated omega-3 fatty acids from oxidation during deep frying process.Total polyunsaturated fatty acids amounted 7.30 % in pre-treated deep fried sardines.Retention of omega-3 fatty acids was 0.70 % more in pre-treated than untreated fish. Significantly lower amounts of representative volatile compoundswere produced in sardines pre-treated with clove extracts. The study demonstrated feasibility to pre-treat sardines with natural antioxidants for protecting omega-3 fatty acids against oxidation during deep frying.

Key words: Omega-3 fatty acids, natural antioxidants, lipid oxidation, *dagaa*, Lake Victoria

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Introduction

Sardines (Rastrieobolaargentea), popularly dagaa in Tanzania, aretiny, fatty freshwater fish species of commercial importance in Lake Victoria. The species provide 72.30 % of the total landings by weighton the Tanzanian side of the Lake (URT, 2015).Their proximate composition varies due to environmental factors including the change of seasons and the resultant change of food supply in the Lake(Kilema-Mukasa, 2012;Abdulkarim*et al*., 2016). Sardinesare attracting great attention because they are good source ofpolyunsaturated fatty acids (PUFAs) including omega-3 which are vital for a wide range of biological functions. Omega-3 fatty acids are implicated in the prevention of numerous diseases such as cardiovascular diseases, inflammation, high blood pressure, atherosclerosis, thrombogenesis, cancer, skin diseases and are necessary

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for the brain development in fetuses(Finley *et al*., 2001;Sidhu, 2003; Minhane *et al*., 2008; Gladyshev *et al*., 2012).

Sardines are perceived negatively and considered as an inferior food for poor and pro-poor communities despite its economic and nutritional values. This may be attributed to poor handling and processing technologies along the sardine value chain. Roberts *et al*., (2014) found that dagaa is richer in omega-3 fatty acids than *Oreochromis niloticus*,*Tillapia zilliii* and *Lates niloticus* of Lake Victoria. Sun dried and fresh dagaa are reported to contain 18.50 to 20.88 % and 13.5 to 21.2 % omega-3 fatty acids respectively (Mwanja*et al*., 2010; Masa *et al*., 2011; Chaula *et al*., 2019).

Dagaa can be preserved by open sun drying, smokingand deep frying processes. The traditional open sun drying of dagaa has significant effect on the composition and hence quality of the dried product.Owaga*et al*.(2010) reported a significant decrease in total fat content(from 14.8 to 13.9 %) of dagaa after sun drying.Open sun drying process promotes lipid oxidation and in some instances the production of secondary lipid oxidation products in sun dried sardines exceeds acceptable levels with regard to development of off-flavour (Chaula *et al*., 2019). Off-flavours emanating from lipid oxidation discourage consumption and limit diversification of sun dried dagaa products. Deep frying has emerged as an important sardine value addition process. Deep frying involves immersion of sardines in hot oil, typically at temperatures ranging from 165 to 195 °C. At such high temperatures, frying oils and lipids in fish undergo chemical reactions including oxidation, polymerization and decomposition, resulting in off-flavours, nutritional loss and other deteriorative changes (Naz *et al*., 2004; Secci*et al*., 2016).Lipid fraction of deep friedsardinescontains significantly lower amounts (16.56 and 8.46 %)than sun dried (29.29 and 20.88 %) of PUFAs and omega-3 fatty acids respectivelyindicative of oxidative damage of PUFAs during deep frying process (Chaula *et al*. 2019).

Commercially available synthetic compounds such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), and tert-butylhydroquinone (TBHQ) are known to be strong antioxidants. However, different regulatory authorities such as the United States Food and Drug Administration (FDA), the European Food Safety Authority (EFSA), and the World Food and Agricultural organization (FAO) have placed limits on the amount of synthetic antioxidants allowed for use in foods typically to levels at or below 200 ppm, due to their potential toxicity (Ito *et al*., 1986; Zheng and Wang, 2001). Such relatively low concentrations allowed do not provide sufficient protection against oxidative damageof PUFAs under frying conditions.Due to safety concerns and increased consumer interest in natural products,nontoxic natural antioxidants of plant origin could potentially be used at higher concentrations than 200 ppm for better protection of PUFAsduring frying process.Therefore, the development of strong antioxidants that suppress oxidation and protect the nutritional quality of highly reactive PUFAs is now in demand. In this study, natural antioxidants rich clove (Szygium aromaticum)extracts were applied on sardines in a bid to impede lipid oxidation during deep frying process.

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3.0 Materials and methods

3.1 Materials

Fresh whole *dagaa* (25Kg) were collected directly from fishermen at Kijiweni landing site at the shore of Lake Victoria, Tanzania placed in ice in insulated boxes and transported to the National Fish Quality Control Laboratory, Nyegezi, Mwanza for experiment. Dry clove*(Szygium aromaticum*) buds were obtained from a local market in Zanzibar, transported at ambient temperature to Mwanza and kept at 5 to 10°C in a refrigerator.

3.1.1 Preparation of clove water extracts

For water extraction, 5, 10 and 20 g grounded powder(to pass through a 250µm sieve) of clove buds were mixed with 1 L boiling water with continuous stirring to make 5, 10 and 20 g L^{-1} concentrations of extracts.Themixtures were boiled for 15 min and subsequentlycooled to0-5 °C in a refrigerator thereafter gravity filteredto remove the particles present.

3.1.2 Preparation of deep fried *dagaa*

Fresh *dagaa* intended for deep frying were washed with portable water thensoaked in clove extracts (1:1 *w/w*) for 40 min and spread on wire mesh to drip dry in open sun for three hours, thereafter deep fried in hot sunflower oil at 135-180 °C for 5 minutes. Fish samples without clove pre-treatment were prepared in similar way and used as control. Each treatment experiment consisted of four replicates. For each treatment experiment 100 g portion of whole fish was made into mince using a mixer (MoulinexMoulinette S type 643 02 210, Hamburg, Germany).The fish mince was then stored at -40°C awaiting analysis.

3.2 Methods

3.2.1 Dry matter content and lipid extraction

The dry matter content for fish samples was determined by weighing after drying a sample of approximately 2 g of homogeneous fish mince at 105 °C for 18 h according to the AOAC (2012) and results expressed as a percentage dry matter.

Lipids were extracted following the Bligh and Dyer method (1959) with modifications according to Iverson *et al*., 2001. The sample (5 g of fish mince) was homogenized in chloroform, methanol, and water mixture (1:1:0.8 v/v) at the speed of 15,000 rpm for 90 sec using an Ultra Turrax homogenizer (T25 Homogenizer, Staufen, German).The homogenate was centrifuged at 2,800 rpm at 18°C for 10 min using a centrifuge (Sigma 4K15, Osterode am Harz, German) to obtain the extract (Chloroform phase).The lipid content was determined by gravimetry after evaporation of chloroform and expressed as percentage of dried fish sample

3.2.2 Primary and secondary lipid oxidation products

Peroxide values (PV) of the lipid extracts were determined according to the method of Shantha and Decker (1994) based on the formation of an iron−thiocyanate complex. The

colored complex was measured by spectrophotometer (Shimadzu UV1800, Shimadzu Scientific Instruments,Columbia,MD) at 500 nm. The analysis was done in duplicate, and the results were expressed in millequivalent peroxides/Kg oil (meq O_2/Kg oil).

The secondary oxidation products were determined as volatile compounds from fish mincecollected using the dynamic headspace technique. The procedure was carried out using 1 g of fish mincein which 30 mg of internal standard, 4-methyl-1-pentanol were added and mixed with 15 mL of distilled water. The volatiles were collected in Tenax GR tubes at 37 °C by purging withnitrogen for 30 min at 150 mL/min. The tubes were flushedwith nitrogen at 50 mL/min for 20 min to remove water. The trapped volatiles were desorbed from theTenax tubes by heat (200 °C) using an automatic thermal desorber(ATD-400, PerkinElmer, Norwalk, CT), cryofocused on a cold trap(−30 °C), released again at 220 °C, and led to a GC an Agilent 5890IIA model (Palo Alto, CA, USA) equipped with a HP 5972 massselective detector.Separation was done on a DB1701 column (30 m × ID 0.25 mm × 0.5µmfilm thickness, (J&W Scientific, Folsom, CA).The carrier gas used washelium atflow rate of 1.3 mL/min. The oven temperature was rising by 2.0 °C/min from initial temperature of 45 °Cto80 °C followed by an increase of 3.0 °C/min to 150 °C and finally increased by 12.0 °C/min to 240 °C. The individual compounds were identified by MS-library searches and addition of the internal standard. Quantification was done through calibration curve made by adding the standard directly on the Tenax tubes as described by Nielsen *et al*. (2007). For the quantification, a stock solution of 19 volatiles was prepared and a calibration curve was conducted in a range from 0 to 1.2 mg/g. The analysis was carried out in triplicate.

3.2.3 Free fatty acids and fatty acid profiles

Free fatty acids (FFAs) content was determined by acidometric titration of the lipid extract using NaOH (0.1 M). The FFAs content was calculated as oleic acid according to the AOCS (1998) and results were reported as % oleic acid.

The fatty acid profiles of deep fried sardines were determined as fatty acid methyl esters (FAMEs)according to the American Oil Chemists' Society (AOCS) officialmethod; Ce 1i-07 (AOCS, 2009).1g of oil extract was evaporatedto dryness under nitrogen.Thereafter, 100µL of internal standard solution (2% w/v C23:0in heptane), 200 µL of heptanes, 100 µL of toluene and 1 mL of boron trifluoride in methanol (BF3-MeOH) were added.Methylation was done in microwave oven (Microwave 3000 SOLV, Anton Paar) for 10 min at 100°C and 500Wand cooled down for 5 min. 1 mL of saturated salt water (NaCl)and 0.7 mL of heptane with BHT were added. The upper phase of thesample (around 0.7 mL) was transferred into vials. Samples were analyzed by gas chromatographysystem (HP-5890 A, Agilent Technologies, Santa Clara, CA, USA). FAMEswereseparated and detected by the GC column Agilent DB-wax (10 m x100µ m x 0.1µm), from Agilent Technologies (CA, USA). The carrier gas was helium with a flow rate of 0.38 mL/min and an inlet pressure of 51psi. The oven temperature program for separation was from 160 to 200°C, then from 200 to 220°C and from 220 to 240°C at 10.6°C /min. All analyses were done in duplicate. The result of each fatty acid

was expressed as g fatty acid/100 g lipid.

3.2.4 Antioxidant activity of clove water extracts

3.2.4.1 Total phenolic content

The total phenolic compounds of the extracts were determined using Folin–Ciocalteu reagent by a procedure described by Farvin and Jacobsen (2013) in which gallic acid was used as a standard. The standard curve was prepared in distilled water at a concentration range of 0–125 µg/mL. The original extracts were diluted with water as necessary to fit within the standardcurve. The absorbance was read at 725 nm using UV-vis spectrophotometer and resultsreported in µggallic acid equivalent (µg GAE)/mL ofclove water extracts. All measurements were performed in duplicate.

3.2.4.2 Free radical scavenging ability

The free radical scavenging activities of clove water extracts were measured by utilizing the stable radical, 1,1-diphenyl-2-picryl-hydrazil (DPPH) as described by Yang *et al.*, 2008. The solutions of prepared extracts were diluted with water *(*1:1 *v/v)*.Diluted solutions (100µL) were added to the microplate and mixed with 100µL of 0.1 mM DPPH in ethanol (96%). The mixtures wereshaken vigorously and maintained for 30 min at ambient temperature in the dark. Theabsorbance of mixtures and the control (100µL DPPH solution + 100µL BHT)was measured at 517 nm against a reagent blank by using a UV–Visspectrophotometer. The scavenging activity was calculatedas inhibition percent by using thefollowing equation:

$$\text{Inhibition } (\%) = \left(1 - \frac{A_s - A_b}{A_0}\right)$$

Where A_s is the absorbance of DPPH after reaction with antioxidant, A_0 is the absorbance of antioxidant and ethanol (blank) and A_b is the absorbance of water and DPPH(blind).

3.2.4.3 Iron (Fe^{2+}) chelating ability

The ferrous ion chelating activity of clove extracts was measured as described by Farvin *et al*. (2010) with 20 µL of 0.5 mM ferrous chloride and 20µL of 2.5 mM ferrozin being mixed with 100 µL of clove extracts. The mixture was allowed to equilibrate in the darkness at room temperature for 10 min before measuring the absorbance. The decrease in the absorbance at 562 nm of the iron (II)-ferrozin complex was measured. EDTA was used as the positive control and the ability of the extracts tochelate $Fe^{2+}$was calculated using theequation:

$$Fe^{2+}\ chelating\ activity = \left(\frac{A_{blank} - (A_{sample} - A_{blind})}{A_{blank}}\right) \times 100$$

A_{blank} is the absorbance of blank (only iron chloride and Ferrozin), A_{sample} is the absorbance of sample and $A_{blind}$is the absorbance of blind(only antioxidant).

4.0 Statistical analysis

Data were analyzed using IBM SPSS (SPSS for Windows Version 20.0, 2013, IBM, Bethesda, MD, USA). Data were reported as mean ± standard deviation. Differences between means were determined using one-way analysis of variance (one-way ANOVA) with Tukey's HSD post hoc test, according to the equal variance of different groups. The correlations among variables were determined using a two tailed Pearson correlation coefficient. A p-value <0.05 was considered statistically significant.

5.0 Results and Discussion

5.1 Antioxidant activity of clove water extracts

The clove water extracts analyzed in this study had total phenolic content levels in the range from 18.18 -28.75 µgGAE/mL (Table 1). As expected the 20 g L^{-1} extracts had significantly higher total phenolic content than that of 5 and 10 g L^{-1}.The total phenolic content did not increase linearly with the amount of dry clove extracted in 1 L of water. This suggests that longer time periods might be needed for efficient extraction of phenolic compounds when larger amounts of clove powder are used. The recovery of phenolic compounds from plant matrices during aqueous extraction is known to depend on factors such as temperature, extraction time and solvent to solid ratio (Çam and Aaby, 2010). The ability of clove extracts to donate hydrogen to the DPPH radical, ranged from 93 to 95 % .This could be due to higher phenolic content in clove extracts.There was no linear relationship between total phenolic content and DPPH suggesting presence of compounds other than phenolics (e.g flavonoids) that contributed to the antioxidant activity of clove extract.

Table 1: Antioxidant capacity of clove water extracts

Extracts (g/L)	Total phenolic content (µgGAE/mL)	DPPH scavenging (% inhibition)	Fe^{2+} chelating activity (%)
CL 5	$18.18^{a} \pm 1.29$	$93.33^{g} \pm 0.21$	$14.74^{p} \pm 0.21$
CL 10	$25.94^{b} \pm 2.62$	$95.59^{h} \pm 1.44$	$20.87^{q} \pm 0.43$
CL 20	$28.75^{c} \pm 1.35$	$94.34^{i} \pm 0.38$	$22.24^{r} \pm 0.32$

CL: Clove, GAE: Gallic acid,5,10 and 20:Grams of clove extracted in 1 L water. Means marked with different letters in a column are statistically significant.

The DPPH decreased from 95.59 to 94.34 % when the amounts of clove extracted in one litre of hot water was increased from 10 to 20 g .This could be due to decrease in extraction efficiency of phenolics in boiling water at concentration above 10 g/L (Slavin *et al.*, 2016). Clove water extract has been found to contain substantial amounts of phenolic compounds and powerful antioxidant activity in linoleic acid emulsion with

itsiron chelating capacity beingdependant on concentration and type of solvent used (Gülçin *et al.,* 2004). Essential oils of clove have been tested in omega-6 and omega-3 fatty acids enriched food supplements and found to have high radical scavenging activity, iron-chelating properties and higher hydrogen donating power than the standard antioxidants BHT and α-tocopherol (Bag & Chattopadhyay, 2017).

5.2 Fat, free fatty acids and dry matter content

The dry matter content of clove was 86.40 % and there was no significant difference in mean dry matter content of treated and untreated sardines (Table 2). Fat content in the samples ranged from 39.42 to 41.69 %. Such high fat content in deep fried sardines is because during the process oils tend to replace water in the product and thus, there is a correlation between initial water content and oil uptake(Dana and Saguy, 2006).Free fatty acids in all samples were less than 1% suggesting limited lipolysis because Lipolytic enzymes might have been inactivated at high temperatures during deep frying process.

Table 2: Fat, free fatty acids and dry matter content in deep fried (DCL) sardines pre-treated with clove water extracts

Sample	Fat content (%)	Free fatty acids (%)	Dry matter (%)
DCL 0	$39.99^{e} \pm 0.36$	$0.48^{f} \pm 0.09$	$92.33^{h} \pm 1.13$
DCL 5	$41.69^{e} \pm 0.89$	$0.87^{g} \pm 0.06$	$89.78^{h} \pm 4.90$
DCL 10	$39.42^{e} \pm 0.04$	$0.15^{i} \pm 0.01$	$90.93^{h} \pm 0.10$
DCL 20	$39.95^{e} \pm 0.15$	$0.18^{i} \pm 0.02$	$90.68^{h} \pm 1.60$

5,10 and 20:Grams of clove extracted in 1 L water. Means marked with different letters in a column are statistically significant

5.3 Primary and secondary lipid oxidation products

The peroxide value(PV) and the volatiles analyses were used to determine the primary and secondary lipid oxidation products in pre-treated fish and the control sardine samples. From

Figure 1, it can be seen that peroxidation was more pronounced untreated than pre-treated deep fried sardines. The control sampleshad significantly higher peroxide values and concentrations of most ofrepresentative volatile compoundsthan the clove pre-treated samples (Figure 1&2).The peroxide values and the concentrations of volatile secondary oxidation products among clove treated samples decreased as the amount of clove extracted in 1 L of water increased indicating the effect of extract concentration on lipid oxidation.Soaking sardines in 5, 10 and 20 gL^{-1} clove water extracts for 40 min prior to deep frying resulted in respectively21.20, 10.70 and 11.20 % reduction of peroxide values in products relative to the control samples.

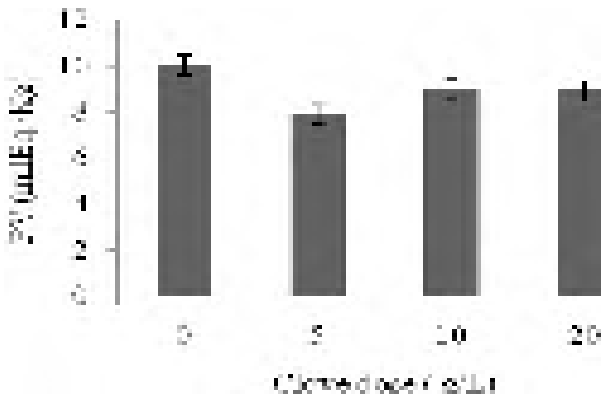

Figure 1: Peroxide value(PV) in deep fried sardines pre treated with different doses of clove extracts.

The pre-treatments resulted into remarkable decrease in concentrations of individual volatile compounds, including 4-heptanal and t, t-2, 4-heptadienal (Figure 2) which are recognized as decomposition products of EPA and DHA (Venkateshwarlu*et al*., 2004).These observations indicate that lipid oxidation reactions were more pronounced in untreated than in clove treated sardines. The peroxide value reduction and lower concentrations of volatile compounds in clove treated samples suggest that phenolic compounds in the extracts played an anti-oxidative role during processing.The anti-oxidative effect of phenolic compounds can be through different mechanisms such as scavenging of free radicals, singlet oxygen quenching, oxygen scavenging, metal chelation and inhibition of oxidizing enzymes (Shobana and Akhilender, 2000; Dudonné *et al*., 2009).The use of whole spices and herbs or their extracts with strong antioxidant activity (Gachkar *et al*. 2007) can control lipid oxidation in muscle food such as mullet fish, frozen chub mackerel and smoked rainbow trout (Emir Çoban *et al*. 2014). Clove essential oils have been applied in smoked and vacuum packed rainbow trout (*Oncorhynchus mykiss*) during refrigerated storage (at 2° C)resulting in reduction of peroxide values(Emir Çoban and Patir, 2013).

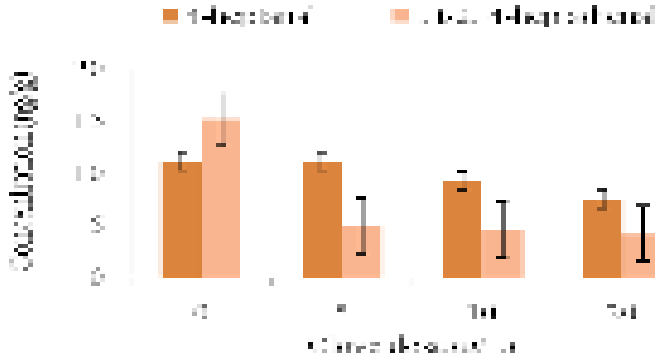

Figure 2: Concentration of representative volatile compounds in deep fried sardines pre-treated with different doses of clove extracts

5.4 Polyunsaturated fatty acids

Lipid fractions of untreated sardines, contained significantly lower amounts (P<0.05) of PUFAs(6.95 %) than those from sardines pre-treated with clove extracts with 7.03- 7.61 % PUFAs (Figure 3). Clove pre-treatment prior to deep frying processes resulted into 0.67 %more retention of total omega-3 fatty acids in the final products relative to untreated fish. With respect to individual omega-3 fatty acids pre-treated samples had significantly higher content of DHA, 2.96 – 3.12 % in pre-treated deep fried than the control (untreated) which had 7.77 %ofDHA.

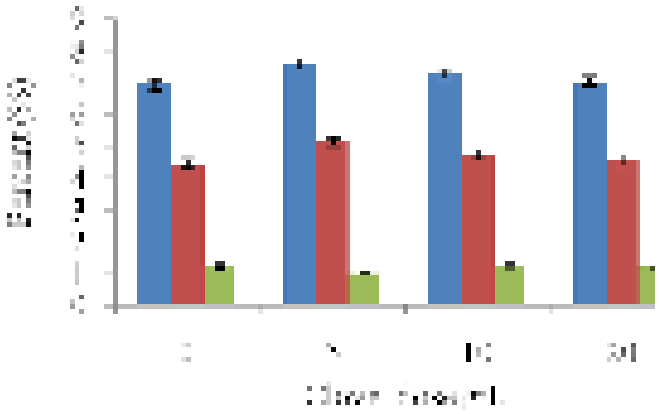

Figure 3: Fatty acid profiles in deep fried sardine pre-treated with different doses of clove extracts. PUFAs; polyunsaturated fatty acids

Higher proportions of DHA and total PUFAs in lipid fractions of treated sardines are evidences that natural antioxidants in clove extracts exert protective effect against lipid oxidation during deep frying process.

Clove has been reported to have high phenolic content and antioxidant components with high thermal stability (Shobana and Akhilender, 2000; Shan *et al*., 2005). The use of spices like clove as natural antioxidant to protect lipids in meat and fish oil has been demonstrated (Falowo *et al*., 2014; Shah *et al*., 2014). Improved retention of long chain polyunsaturated fats and preservation of omega-3 fatty acids in oven dried sardine (*R.argentae*) pre-treated with clove water extracts has also been shown (Slavin *et al*., 2016).Water extracts of clove are also reported to have as strong peroxidation inhibitory effect as ethanol extract in linoleic acid emulsion (Gülçin *et al*., 2004).The antioxidant activity of clove extracts may be attributed to strong hydrogen donating ability, metal chelating ability, and effectiveness as free radicals scavenger. The major phenolic compounds in clove are phenolic acids such as flavonol glucosides, phenolic volatile oils and tannins, recovery of which is highly dependent on extraction conditions, differences in solvent and extraction method (Wu *et al*., 2004; Shan *et al*., 2005; Dudonné

et al., 2009).

6.0 Conclusion and recommendations

The present study evaluated the efficacy of clove water extracts to retard lipid oxidation during deep frying of sardines. Pre-treatment of sardine with clove water extracts resulted in improved retention of nutritionally valued long chain PUFAs, including the omega-3 fatty acids DHA.However, the success of these pre-treatments to impede lipid oxidation may partly be attributed to small size and weight of sardine fish.Further researches on other sources of antioxidants from edible plant sources are needed. The researches should include investigation on the effects of natural antioxidants applications on sensory attributes of pre treated sardines. The information would be of interest during sardine product diversification through its incorporation into other food product formulation at industrial scale.

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Factors Determining Crop Farmers' Willingness to Pay for Agricultural Extension Services in Tanzania: A case of Mpwapwa and Mvomero Districts

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Abstract

As a result of the rapid changing situation of agriculture in African countries, inability of public agricultural extension services (AESs) to be responsive to the needs of farmers and changing of policy environment, new paradigm is emerging. The focus of this new paradigm is pluralism, the emergence of multiplicity of actors providing AESs, and the participation of farmers in the financing of AESs with the aim of making extension less burdensome to the governments, and relevant to farmer needs. In Tanzania, although not formally established, experience shows that, in some areas, farmers are paying for or contributing to the cost of providing AESs. This study thereforeaimed at assessing crop farmers' willingness to pay for AESs and to identify factors influencing their willingness to pay for AESs. Data were collected from 292 randomly selected crop farmers' households between December 2017 and February 2018 using a questionnaire throughface-to-face interviews. Datawere analyzed using frequency counts, percentages and Tobit regression model. The study found that 92 percent of the respondents are willing to pay for AESs. It was also found that farmer's age, education attainment, farming experience, distance from farm to the nearest important road, income (both farm and nonfarm) and attitude towards AESs are significant determinants of farmers willingness to pay for AESs. The study recommends that these variables be given proper policy consideration by the government and other stakeholders in the design and the implementation of a workable fashion of privatizing extension services for the expected impact of improving extension services and farmers' productivity hence improved quality of life.

Key words: extension services, willingness to pay, crop farmers, Mpwapwa, Mvomero

Introduction

The importance of Agricultural Extension Services (AESs) in agricultural and rural development is widely acknowledged, particularly in a developing country like Tanzania. Mutimba (2014) opined that agricultural extension is a vehicle for modernizing agriculture in many sub-Saharan African countries. The author adds that it is that discipline of agriculture charged with the responsibility of, as the late 1970 Noble laureate, Norman Borlaug said, '*taking it to the* farmer'. Through an educational process, AES provides farmers with the agricultural information in the form of knowledge and skills to build their capacities and influence their attitude so as to enable them take effective farm management decisions regarding their daily agricultural practices (Swanson and Rajalahti, 2010; URT, 2013). According to Birner *et al.* (2006), agricultural extension entails training of farmers, dissemination of new technologies, assisting farmers to organize themselves, market their agricultural products and create networks with various institutions in order to improve productivity in agriculture and

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livelihoods. Additionally, AES links farming communities with research where farmers' problems are brought to the attention of research and solutions communicated back to farmers.

Financing and delivery of AESs

In most of developing countries, AES has in the past been, and still remains, almost entirely financed by the public sector, although this may vary from purely public to nearly private services (Ameur, 1994). As more governments face severe financial difficulties, funds are curtailed for support services to agriculture, including extension. In such circumstances, decision-makers usually opt for one or both of the following: (i) to save on the overall cost of public extension; and/or (ii) to gradually privatize extension services, leaving the private sector and users to take on increasing responsibility including covering the cost of service provision (Agbamu, 2000; van den Ban, 2000; Katz, 2002).

Agricultural extension in Tanzania: history and reforms

Agricultural extension service in Tanzania dates back to British colonial rule and has been funded and delivered by thegovernment since independence in 1961 (Mvuna, 2010). Since then several agricultural extension systems and approaches have been implemented which include the gradual improvement in farming methods, the transformation approach,the settlement scheme (Schneider, 2004), and the Training and Visit (T&V) system (1980s-1990s). Thenthe decentralization of AESs to the Local Government Authorities (LGAs) in 1999 (Rutatora and Mattee, 2001).In addition, several initiatives have been recently taken by the government to improve the agricultural sector as indicated in Table 1.

Table 1: Initiatives taken by the government to improve the agricultural sector

Policy initiative	Time frame	Area of focus
KILIMO KWANZA	2009–No time bound	Ten Pillars: National Vision; financing; Institution reorganization; Paradigm shift; Land; Incentive; Industrialization; Science and Technology; Human resource improvement; Infrastructure and Mobilizing Tanzanians
SAGCOT	2010-2030	It seeks to focus on public and private intervention to engage the smallholders in commercial farming
BRN	Originally three years 2013-2016	Three KPI: Promoting 25 commercial farming deals; Enhancing 78 smallholder rice irrigation schemes; and 275 COWABAMA
ASDP II	2016/17-2024/25	Increase productivity, profitability and farm incomes; Promote private sector investment; and address cross-cutting issues

Source: Authors' own compilation, 2019

Privatization of extension services in Tanzania

Although not formalized, experience shows that, farmers in some areas of Tanzania are, in one way or another, already paying for or contributing to the cost of providing AESs.Isinika (2000) reportedsome examples on attempts to commercialize/privatize

AESs: (i) The use of paraprofessionals as an extension strategy. The Mogabiri Agricultural Training Center in Tarime District uses paid (in cash or in kind) Farmer Motivators to assist village extension officers to train groups of farmers. (ii) In Mbozi District under the Agricultural Development Project Mbozi Trust Fund, costs for food are shared where farmers contribute to the cost of training programmes by providing maize flour while the project contributes beans. (iii) In Kondoa District, the Establishment of Plant Protection Brigades project trained young farmers whocharged for service provided to other farmers;and (iv) FAIDA-SEP project that is supported by SNV which trains farmers on business awareness and charges them a subsidized rate of 2000/= per course as a cost sharing policy.A more recent study by Lameck (2017) reported that extension agents in Morogoro Municipal and Hai District Councilscharge for their services in terms of recovering the cost for transport and the drugs the extension agents use when treating livestock and controlling crop diseases.

According to Schwartz (1992), commercialization of traditionally publicly provided AESs raises several related issues including whether the"fee for service" systemwould necessarily lead towards greater efficiency and equity. Similarly, Katz (2002) posits that a decision to introduce financial participation should be preceded by a thorough assessment of its feasibility and desirability, which include assessing users' willingness to pay (WTP) for the service. Although several studies have assessed farmers' WTP for AESs in different countries (Abraham *et al*., 2012; Temesgen and Tola, 2015; Uddin *et al*., 2016; Aydogdu, 2017) information on crop farmers' WTP for AESs and types of services they are willing to pay for is not well documented in Tanzania. This study therefore aimed at assessing crop farmers' WTP for AESs.Specifically, the studydescribedcrop farmers' demographiccharacteristics, ascertained farmers' willingness to pay for AESs and the amount they are willing to pay, and identified the factors influencing farmers' WTP for AESs.

Materials and Methods

Study area

The study was conducted in Mvomero, a District in Morogoro Region located and Mpwapwa, a District in Dodoma Region. Selection of the study sites was informed by criteria such as agricultural potential and climatic conditions of the two Districts. Mvomero District has a higher agricultural potential while Mpwapwa District has a relatively lower agricultural potential (Phelan *et al*., 2011). The difference in agriculture potentiality is associated with the difference in agro-ecological zones, Mpwapwa in a semi-arid zone characterized by rolling plains and low fertility susceptible to water erosion and Mvomero in a mixture of highlands and mountains, miombo woodland and savannahriver basin zones, which allow the production of wide range of food and cash crops. Equally important, the main economic activity in both districts is agriculture; so the majority of people are farmers (Sife *et al.*, 2010). This study therefore wanted to establish if there exists any differences in terms crop farmers' feelings about AESs and hence their WTP for the services based on agricultural potential.

Sampling procedure and sample size

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The study adopted a multi-stage sampling technique. First, the two districts were purposively selected (reasons stated above). One ward was randomly selected form each of the two districts, Dakawa and Lupeta in Mvomero and Mpwapwa Districts respectively. Then in each ward one village was randomly selected, Wami-Luhindo in Dakawa and Makutupa in Lupeta. 300 households (Yamane, 1967) were randomly selected using sampling proportional to size. That is 137 and 163 from Wami-Luhindo and Makutupa village respectively. Thesampling unit was the household while the target respondent was the household head.

Instrumentation and data collection procedure

This study adopted the interview guide (semi-structured questionnaire) as the main data collection instrument. The study followed a Contingent Valuation Method (CVM) using open-ended elicitation techniquethrough face-to-face interviews with heads of household.The CVM uses survey questions to ask respondents to directly value the good or service in a hypothetical market, which, by means of an adequately designed questionnaire, is described where the good or service in question can be traded (Guo *et al.*, 2006). Crop farmers' WTP for AESs was determined by the amount each respondent is willing to pay for a particular item associated with extension service. Any amount other than zero indicated WTP. The items included: agent's travel cost; advice on control of crop diseases; advice on control of crop pests; advice on crop value addition; and advice on crop marketing. A respondent was considered to be willing to pay for AESs if he/she stated the amount other than zero for at least one of the assessed items. A comparison was made between food and cash crops as defined by respondents in the study area.

Data analysis

The collected data were summarized, coded and entered in the International Business Machines (IBM SPSS) Statistics Version 20 and STATA version 12 for analysis. Descriptive statistics such as mean, percentages, minimum and maximum, and standard deviations were computed while Tobit regression model was used to determine the factors that influence crop farmers' WTP for AESs.Tobit model, according to Tobin (1958), is designed to estimate linear relationships between variables when there is either left-or-right-censoring in the dependent variable. In our case, the respondents were to express their WTP for transport cots of extension agent and each of the five categories of extension services (advice on general practices of crop production, disease control, pest control, crop value addition and marketing of crops). A respondent was free to choose to pay for none or any number out of the six choices, making an index score ranging from 0 to 1.

The Tobit model was based on the hypothesis that the likelihood of willingness to pay, y_i depends on a vector of known variables (X_i) and a vector (β, coefficient) of unknown variable.

The standard Tobit model is defined as $y_i^* = x_i\beta + u_i$…..(1);

$$y_i = \begin{cases} a \text{ if } y_i^* \le a \\ y_i^* \text{ if } a < y_i^* < b \\ b \text{ if } y_i^* \ge b \end{cases} \quad \ldots\ldots(2)$$

where; the subscript i = 1,.., N indicates the observations, y_i^* is an unobserved ('latent') variable, x_i represents vector explanatory variables, β is a vector of unknown parameters, ε_i is the error term which is assumed to be independently normally distributed: $\varepsilon \sim N(0, \sigma)$ (and therefore $y \sim N(X\beta, \sigma)$), a is the lower limit of the dependent variable, b is the upper limit of the dependent variable.

Estimation of the model

The Tobit model is usually estimated by the Maximum Likelihood (ML) procedures (Verbeek, 2008). Assuming that the error terms are normally distributed with mean 0 and variance σ^2, the log-likelihood function of the model is

$$\log L = \sum_{i=1}^{N} \left[I_i^a \log \Phi\left(\frac{a - x_i'\beta}{\sigma}\right) + I_i^b \log \Phi\left(\frac{x_i'\beta - b}{\sigma}\right) + (1 - I_i^a - I_i^b)\left(\log \phi\left(\frac{y_i - x_i'\beta}{\sigma}\right) - \log \sigma\right) \right] \quad \ldots(3)$$

where: $\phi(.)$ and $\Phi(.)$ denote the probability density function and the cumulative distribution function, respectively, of the standard normal distribution, and I_i^a and I_i^b are indicator functions with $I_i^a = \begin{cases} 1 \text{ if } y_i = a \\ 0 \text{ if } y_i > a \end{cases}$ ……(4); and $I_i^b = \begin{cases} 1 \text{ if } y_i = b \\ 0 \text{ if } y_i < b \end{cases}$ ……(5)

Note that the log-likelihood function of the censored regression model can be maximized with respect to the parameter vector (β', σ)' using standard non-linear optimization algorithms (Gujarati, 2004). The variables included in the Tobit model and their expected relationships are discussed in the following section. Selection of these variables was based on the review of relevant theories and studies similar to the present study. The description of variables and their hypothesized effects are presented in Table 1.

Table 1: Variables description, coding and expected sign of relationship

Variable name	Variable description	Expected sign
WTP	**Dependent variable (yes/no response to items of WTP). This is continuous variable taking values ranging from 0 to 1**	
Age	Age of respondent in years	-
Sex	Sex of respondent. 1 if respondent is male, 0 otherwise	+
Education	Was a dummy variable indicating whether a respondent had attended formal education or not (1 if attended formal education, 0 otherwise)	+
HHSize	Number of individuals in the household	+
HHLand	Total household land in hectares own by the household	+
FarmExp	Number of years the household has been engaged in crop production	+/-
FarmDistance	Distance in kilometers from farm to nearest important road	-
HHIncome	Total annual net income of household in Tanzanian shillings	+
ComCrop	Degree of commercialization of crop enterprise - proportion of crops sold	+
Attitude	Attitude towards AESs. Dummy variable taking value of 1 if favourable	+

	and 0 otherwise

Results and Discussions

Socio-economic characteristics of respondents

As indicated in Table 2, of all the 292 respondents, 77.2% were males while 22.8% were females. These results are slightly lower than the national statistics which indicated that female-headed households (FHHs) in Tanzania account for 25.0% of households nationally and for 24.0% in rural areas (FAO, 2014). This indicated that majority of crop farming households in the study area were headed by males.This is common in most African countries, where male farmers culturally dominate as the heads of families from the hierarchical pattern of family structure. This provides males the opportunity most times to embrace new innovations when they are introduced in the community more than their fellow female counterparts. It is argued by Tolera *et al*. (2014) that demanding advisory services on payment requires sufficient resources, such as land, livestock, etc., which female headed households usually lack. Comparison of sex distribution of respondents between the two districts did not indicate a significant difference (χ^2 = 1.187, ρ = 0.276).

Respondents' age ranged between 21 and 75 years, with mean and standard deviation of 44.5 and 12.43 respectively indicating wide variation in the age of respondents. Findings reveal that a large proportion (about 70%) were 49 years old or less (Table 2).The higher percentage of young to middle-aged farmers showed that most farmers were still energetic to carry out the strenuous activities that accompany farm work in Tanzania where the hand hoe is still the dominant farming tool. Farmers' mean age of 44.5 years further attest to the fact that they were still active. Ogundele and Okoruwa (2006) asserted that only those farmers within the productive age group of 20-50 years are likely to possess the necessary strength to carry out farming operations. However, chi-square analysis revealed that age distribution of respondents slightly differed significantly between the two districts at 10% level of significance (χ^2 = 8.515, ρ = 0.074).

Table 2: Demographic characteristics of respondents (n=292)

Variables		Distribution of respondents by district						χ^2	ρ-value
		Mvomero (n=133)		Mpwapwa (n=159)		Total (n=292)			
		F	%	F	%	F	%		
Sex	Male	110	79.7	115	74.7	225	77.2	1.187	0.276
	Female	28	20.3	39	25.3	67	22.8		
Age (years)	Below 28	12	9.0	8	3.1	20	5.8		
	28 to 38	34	24.1	54	34.6	88	29.8		
	39 to 49	46	34.6	54	35.2	100	34.9	8.515	0.074**
	50 to 60	25	19.5	31	18.9	56	19.2		
	Above 60	16	12.8	12	8.2	28	10.3		
Marital status	Unmarried	12	9.0	11	6.9	23	7.9		
	Married	91	68.4	131	82.4	222	76.0	10.315	0.016*
	Divorced	17	12.8	13	8.2	30	10.3		
	Widowed	13	9.8	4	2.5	17	5.8		
Education level	No formal education	7	5.3	15	9.4	22	7.5		

Primary school	112	84.2	135	84.9	247	84.6	6.365	0.095**
Secondary school	13	9.8	6	3.8	19	6.5		
Beyond secondary	1	0.8	3	1.9	4	1.4		

*and ** means significant at the 5% and 10% levels respectively; F = Frequency;

Over two thirds (76.0%) of respondents were married; 10.3% divorced; 7.9% unmarried; and 5.8% were widowed. Distribution of respondents by marital status varied significantly between the two Districts at 5% level of significance ($\chi^2 = 10.315$, $\rho = 0.016$). The findings show that there were more married respondents in Mpwapwa (82.4%) than in Mvomero (68.4%); and more widowed respondents in Mvomero (9.8%) than in Mpwapwa (2.5%). Marital status determines an individual's decision to demonstrate a mark of social responsibility and also indicates a readily available source of labour input (Adah *et al.*, (2016). Adegeye and Dittoh (1985) declared that small-scale farmers could only be successful if they were married especially when they had to rely on family labour.

With regard to education, the findings show that majority of respondents (93%) had formal education and therefore probably were able to read and write, an attribute that enables them to understand issues and therefore can make informed decisions including a decision regarding paying for extension services (Sebadieta *et al.,* 2007). Tolera *et al*. (2014) suggest that farmers who learned more may need farm specific information to manage their farm effectively on fee-for-service basis rather than confining themselves to general public goods.

Crop farmers' willingness to pay for agricultural extension services and the amount they are willing to pay

Willingness to pay for AESs

Of the 292 respondents, 88.0% were willing to pay for AESs associated with food crop production while 92.0% were willing to pay for AESs associated with cash crop (Figure 1 and Table 3). These findings are in line with other studies conducted in different parts of the world. Ackah-Nyamike (2003), for example, in a similar study conducted in Ghana reported that 82.0% of farmers were willing to pay for extension services while a study by Ozor *et al.* (2007) reporting that 80.6% of farmers in Nigeria were positively disposed to cost sharing in Nigeria.

However, these findings differ from some other studies. For example, in a study conducted in the three states of India, Sulaiman and Sadamate (2000) found that about 48.0% of farmers expressed a WTP for agricultural information. In Zimbabwe, Foti *et al.* (2007) found that only 4.6% of farmers were willing to pay for extension service, and 95.4% of the farmers were not. Ali *et al*. (2008) in Iran reported that only 24.7% of farmers were willing to pay for extension services and 75.3% were not willing to pay. Similarly, Francis *et al*. (2010) indicated that in Uganda 35.0% and 40.0% were willing to pay extension services related to crops and animal husbandry respectively. These findings show that the willingness to pay for AESs was higher for crop farmers in

Tanzania compared to their fellow counterparts in these other countries. This could be attributed to various strategies and initiatives taken by the government to improve the agricultural sector for the recent years.

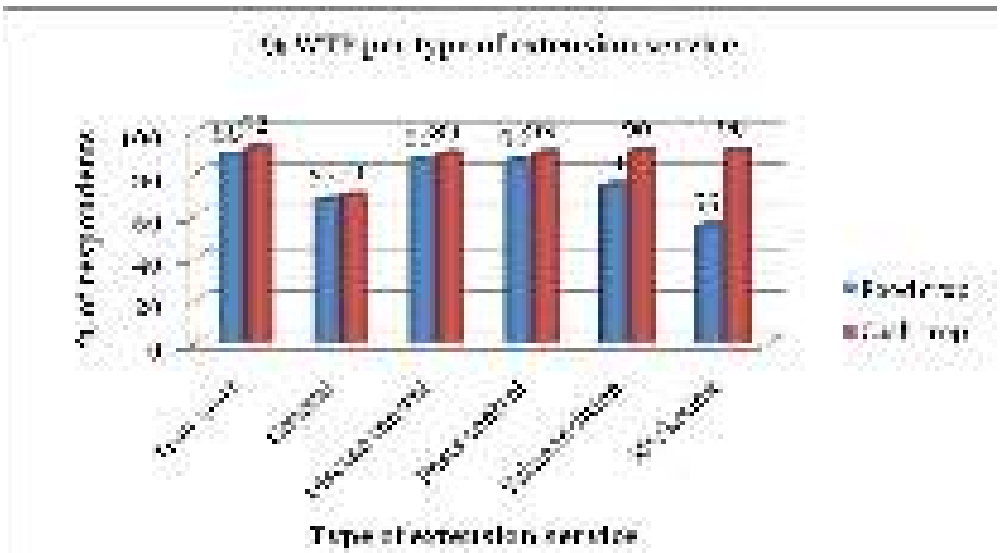

Figure 1: Percentage distribution of respondents by their WTP for AESs

Considering the six items that were assessed, although the difference might not be significant, findings show that more farmerswere willing to pay for advice on value addition and marketing as compared with other items (Figure 1). Also farmers are more willing to pay for services targeting cash crop than food crop indicating that farmers attach more value to cash crops than they do to food crops.This demonstrates that there is a conceptual change among the farmers from production orientation to market orientation. This sends a signal for AESs to cover the whole agricultural value chain.

Amount crop farmers are willing to pay

The willing respondents were alsoaskedto state the amount of money they would be willing to pay for AESs (Table 3). The cost for AES was estimated per visit made by the extension agent. Zero was not considered as the amount but rather as an indication of unwillingness to pay hence not included in the computations. On average farmers are willing to pay between Tanzanian Shillings (TAS) 3422 and 4582 per visit by extension agent for each of the six items associated with AESs. These findings reveal that farmers attach a certain value to extension service and at least are willing to pay something for the service. It is important therefore for extension administrators in Tanzania to actually estimate the total cost of providing extension service and then reconcile it with the amount farmers are willing to pay as revealed in this study in order to come out with a meaningful, achievable and sustainable figure prior to the introduction of a full-scale cost-sharing approach as a government policy.

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Table 3: Respondents' stated WTP amount (Tanzanian Shillings-TAS)

	Type/category of extension service											
	Extension agent's Transport costs		**General agronomic practices**		**Diseases control**		**Pests control**		**Crop Value addition**		**Marketing of crops**	
Type of crop	Food	Cash	Food	Cash	Food	Cash	Food	Cash	Food	Cash	Food	Cash
Frequency	258	261	197	197	251	252	250	253	217	255	161	256
Percent	88.4	92.2	67.5	69.6	86.0	89.0	85.6	89.4	74.3	90.1	55.1	90.5
Mean (x100)	34.22	34.08	35.43	33.45	37.31	36.98	37.90	38.21	35.52	42.92	34.88	45.82
Minimum	1000	1000	1000	1500	1000	1000	1000	1000	1000	1500	1000	2000
Maximum (x100)	60	60	100	100	150	150	150	150	100	100	200	200
SD x100	13.30	12.92	21.14	17.01	25.39	23.22	26.34	25.30	19.80	27.21	26.02	30.60

N = 292 (food crop) and 283 (cash crop); SD = Standard Deviation

Factors influencing crop farmers' WTP for AESs

WTP was regressed against a set of independent variables as indicated in Table 2. A Tobit regression model was estimated using STATA 12 computer programme. Robustness test results (Table 4) for the Tobit model revealed that the log-likelihood value (-246.62492), the pseudo R^2 (0.0559), and the chi-square value (28.95) were significant at $P \leq 0.0003$. The smaller p-value from the Likelihood Ratio (LR) test would lead us to conclude that at least one of the regression coefficients in the model is not equal to zero.

Seven out of ten factors were found significantly influencing farmers' WTP (Table 4). They include age of household head ($p \leq 0.034$), formal education attainment ($p \leq 0.039$), farming experience ($p \leq 0.001$), distance from farm to the nearest important road ($p \leq 0.000$), total household income ($p \leq 0.002$), commercialization of crop enterprise ($p \leq 0.037$) and attitude towards AESs ($p \leq 0.003$). Age was found to have a negative association with farmers' WTP for AESs which means that as the farmer grows older, his/her WTP for AESs decreases. These results conformtoother studies (Gautam, 2000; Mezgebo *et al.*, 2013). It is believed that older people prefer to keep tradition and therefore they are less likely to support the idea of paying for innovation. The implication of this is that if change is not required then the there is no need for improved extension services and therefore no need to pay for it.

Findings (Table 4) show a positive association between attendance to formal education and WTP. These findings are according to what was hypothesized and are consistent with other studies (Ulimwengu and Sanyal, 2011; Ajayi, 2016).It is assumed that an educated farmer knows the importance of AESs hence should be more willing to pay

than the uneducated one. Likewise, Tolera *et al*. (2014) argues that educated farmers may need farm-specific information to manage their farms effectively on fee-for-service rather than confining themselves to general public free goods.

Farming experience was positively associated with WTP for AESs, indicating that WTP increases with farming experience. These findings contradict Tolera *et al*. (2014) who reported that the average years of farm experience were 21.9 and 28.6 for the willing and non-willing respondents respectively. Possible explanation for this could be that experienced farmers have accumulated more knowledge that they would not be ready to spend their money for something they already know.Our study did not predict a priori the direction of relationships between experience in growing crops and WTP because farming experience can have different effects to the farmer's decision to pay for AESs.

Willingness to pay was negatively associated with distance from farm to nearest important road. This is consistent with Francis *et al*.(2010) and Mwaura *et al.* (2010) who reported that WTP for AESs was less for those residing furthest from the main road. Possible explanation for this could be that farmers find it more expensive to cover transport costs for extension agent as he or she visits distant farm than it is for the near farm.

Incomewas positively associated with WTPmeaning that household's WTP for AESs increased with total annual income. These findings are in line with prior expectation and consistent with many other studies (Tolera *et al*., 2014; Temesgen and Tola, 2015; Ajayi, 2016; Aydogdu, 2017). Possible explanation for this could be that more income means that a farmer has more funds to spend and can decide to experiment with the idea of sharing the cost of extension delivery. Also available income for the household is expected to reduce household's poverty and thus increase its ability to pay for AESs. On the other hand, poverty reduces a household's willingness and ability to invest in agricultural technologies (Holden and Shiferaw, 2002).

Degree of commercialization for crop enterprise and attitude towards AESs were both positively associated with an increased probability of WTP. This implies that farmers are more willing to pay for extension if they derive greater benefits from the services. Umali and Schwartz (1994) argue that demand for agricultural extension services depends upon the expected net benefits from investment in new information. This also means crop farmers' WTP for AESs increases as their attitudes towards AESs changes from unfavourable to favourable state.The person's attitude towards an item is important in determining a person's intentions to or not to purchase the item (Ajzen and Fishbein, 1980). Findings further show that sex, household size and land size are not among the factors that influence crop farmers' WTP for AESs.

Table 4: The maximum likelihood estimates of the Tobit model

Variables	Coef.	Std. Err.	T	p>|t|
Age	-0.009526	0.003540	-2.69	0.034**
Sex	-0.04597	0.152584	-0.30	0.763
Education	0.462554	0.1907644	2.06	0.039**
HHSize	0.015322	0.018974	0.81	0.420
Landsize	0.003833	0.004318	0.89	0.375
FarmExp	0.024759	0.007225	3.43	0.001*
Distance	-0.657281	0.172043	-3.82	0.000*
HHIncome	0.45201	0.142917	3.16	0.002*
ComCrop	0.401422	0.160132	2.51	0.037**
Attitude	0.500259	0.166638	3.00	0.003*
_cons	1.421772	0.339317	4.19	0.000
/sigma	0.7786914	0.068409		
Model chi-square value	40.09			
Log likelihood	-246.625			
Prob>Chi^2	0.000			
Pseudo R^2	0.0559			

*Significant at 1% and **Significant at 5%

Conclusion and Recommendations

This paper assessed the factors that influence crop farmers' WTP for AESs in Mpwapwa and Mvomero Districts. It concludes that farmers are willing to pay for AESs and their willingness is positively influenced by education, farming experience, income and attitude towards AESs and negatively influenced by age and distance to the nearest important road. Therefore designing of initiatives for paying for extension service for sustaining the AESs should pay attention to these factors.Farmers' WTP for extension service therefore is an indication that the introduction of fee-for-service AESs is feasible in Tanzania, especially in the study area.

The study recommends that: the government through AESs should design and implement an effective adult education program in order to increase the farmers' level of education; and through TARURA should ensure rehabilitation of rural roads especially feeder roads that connect crop farms to the main roads. It addition, the government in partnership with other stakeholders should design programmes that are targeted at increasing the farmers' household incomes so that they can pay for extension services; through AESs it should work on improving service delivery in order to ensure farmers' positive attitude AESs.

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Harvesting Vegetables from a Kitchen Garden: An Educative and Sustainable Approach to Improve Dietary Practices and Nutritional Status among Rural Families in Tanzania

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Abstract

Undernutrition continues to inflict significant social, health and economic consequences in developing countries, Tanzania inclusive. The aim of the present study was to implement, monitor and assess the impact of bag gardening and household nutrition education on dietary practices and nutritional status in rural villages in Tanzania. Nutrition education covered various gaps observed in a preceded nutrition survey (baseline). Bag gardening practical demonstrations and hand on implementation skills were carried out to the participating 120 households. McNemar and marginal homogeneity tests were conducted to compare the baseline to endline results for each section of the questionnaire. Results indicated that at baseline only 27% of households had a high Dietary Diversity Score as compared to 52% at endline. Daily and weekly consumption rates increased by 10-50% from baseline to endline periods.There were significant differences in knowledge aspects of factors influencing inclusion of vegetables in a meal, knowledge of bag and cultivation of vegetables in a bag garden, receiving nutrition education before, knowledge of foods that increase intake of fibre, knowledge of food groups and iron deficiency anaemia between the baseline and endline time points with $p<0.05$.The intervention increased consumption of green leafy vegetables, dietary diversity and nutrition knowledge of participants in the topics covered including general nutrition, nutrition requirements for specific groups, preparation and preservation of foods, improving nutrition through kitchen gardens and tips for improving health. We recommend progressing this type of intervention further by selecting foods containing high vitamin A amounts to be included in bag gardens.

Keywords: Kitchen garden, bag kitchen garden, green leafy vegetables, consumption patterns, household, nutrition education

Introduction

Micronutrient deficiencies in human diets continue to impose significant social, health and economic consequences in the world. This may be due to poor nutritional practices, low availability of foods rich in micronutrients, poor agricultural practices leading to micronutrient depleted soils and inadequate knowledge about nutrition and food (Burchi *et al*., 2011). The consequences of poor nutritional status include reduced work capacity due to growth retardation, impaired cognitive function and immunity, complications in pregnancy leading to poor pregnancy outcome and increased risk of morbidity and mortality mainly in children and women (Caulfield *et al*, 2006). In Tanzania as for other developing countries, micronutrient deficiencies are common. Strategies to combat micronutrient deficiencies at national level mainly involve supplementation and fortification with specific micronutrients such as iron, folic acid and vitamin A. However, attainment of success is limited because the approach

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strongly relies on international aid (Fiedler *et al*., 2003), lacks communication with all at risk populations as logistics of delivery are usually undependable and conflicting. In addition, supplementation and fortification mostly target only sub groups of the population, usually children under five years of age and women of reproductive age (Gautam *et al*., 2008). An alternative sustainable approach is a food based one to increase consumption of micronutrient rich foods. This can be done by introducing kitchen gardens of green leafy vegetables and small animals/livestock rearing. Kitchen gardens are a cheap local strategy that is broadly practiced by local communities using limited resources.Such gardens are a part of the agriculture and food production systems in many developing countries and are widely used to complement production of cereals and pulses (Gautam *et al.,* 2006). A kitchen garden approach assures prolonged sustainable supply of micronutrient rich vegetables through production at the door step. Kitchen gardens can help to improve the diets through increased consumption of a variety of vegetables. In rural areas of Bangladesh for example, households with a kitchen garden had children of better nutritional status (Talukder *et al*., 2010). Even with these positive observations, another study (Thompson & Amoroso, 2010) indicated that the kitchen garden approach alone may not be a total solution for reducing micronutrient deficiencies. Therefore, in order for kitchen gardens to be effective in improving nutritional status, other supporting interventions such as nutrition education to improve knowledge on adequacy of the diet and skills on healthy food preparation methods should accompany it.

This study adopted the approach of a household based nutrition education in the targeted households in order to impose the maximum effect of equal participation of the intervention activities towards improving the nutrition situation and ensuring maximum retention of knowledge and skills at household level. The aim of the present study was therefore to identify the need, develop, implement and assess the impact of kitchen gardens coupled with household nutrition education program on consumption patterns, dietary diversity and nutritional status of rural household members.

3.0 Materials and Methods

Study location

The study was conducted in two different agro-climatic zones in Tanzania namely: sub humid Morogoro region and semi arid Dodoma region. The two regions Morogoro and Dodoma were selected because they represent two different food systems and have sufficiently diverse environmental and socio-economic conditions for investigating causative factors for food and nutrition insecurity thus allowing for the transfer of results to other regions of Tanzania with similar characteristics.A cluster sampling method was used to select four villages in Kilosa and Chamwino districts.In Morogoro region, Kilosa district was selected and Changarawe and Ilakala villages were selected and in Dodoma region, Chamwino district was selected and Ilolo and Idifu villages were selected. The majority of the population in the study villages depends on farming as their main livelihood activity.

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Study population, sampling procedure and design

The population comprised all household members including women, care givers, men, the youth and children in the sampled households. This study followed a one group pre test-post test design to determine the effects of the intervention by comparing the pre test and post test results. A baseline survey was conducted and then follow-up with the same households and participants at endlineafter twelve months. Baseline and end-line data collection was done through a face to face administered questionnaire and anthropometric measurements. A sub sample of 30 households with children below five years of age was purposively selected from the main sample of each village to be included in the study making a total of 120 households. Verbal and written consent was obtained from participants and ethical clearance was obtained from the Tanzania National Institute for Medical Research (NIMR/HQ/R.8a/Vol.IX/2226).

Baseline and end line surveys

A face to face interviewer administered questionnaire was used to collect demographic and socioeconomic information and to identify knowledge gaps of mothers'/caregivers' in nutrition and kitchen gardening in the selected households. Data on household dietary diversity was collected using a dietary diversity questionnaire developed by Food and Agriculture Organization of the United Nations (FAO) with twelve food groups and was used to assess household dietary diversity scores (HDDS) which is defined as the number of different food groups consumed by households over 24 hours. The results of the baseline survey indicated that nutrition knowledge, practices and attitudes particularly those related to general nutrition, nutrition requirements for specific groups, preparation and preservation of foods, importance of kitchen gardens in improving nutrition status and basics for improving health through nutrition were poor and required the most improvement (Mbwana*et al*., 2016).

Nutrition training program

The household nutrition training materials were developed based on the knowledge gaps and needs identified from the nutrition baseline survey conducted in the study areas. One training module with five topics was developed. The topics included: General nutrition and consumption of micronutrient rich foods within households, nutrition requirements for specific groups, preparation and preservation of food, improving nutrition through kitchen gardens and finally tips for improving health through nutrition.

Content validity of the materials developed was done by a panel of five experienced nutritionists who are researchers and academicians. The experts validated the accuracy of the information presented and the cultural sensitivity of the materials. The materials were also presented to project members during a meeting. The meeting participants were requested for general comments and suggestions which were later incorporated to improve the materials. Training was done once every month for three months consecutively. Two training sessions per day were done at the central demonstration household with a total of 30 men, women and the youth from the study households. The vegetable cooking demonstrations included actual cooking and eating. One training

session lasted for about 3 hours. A total of 15 hours were used to cover the whole module of training.

Kitchen gardening

One central household in each village was identified as a demonstration site for the kitchen gardens. Bag gardens were selected to be implemented in this study because they are space sparing, efficient in terms of using water, suitable for areas with little or no healthy soils (as the soil in the bag is contained) and they require only low physical labour. Bag gardens, also known as "vertical farms or gardens", are tall bags filled with a mixture of soil, sand and manure from which plant life grows. The bag is filled with a centre column of gravel which allows for drainage and water distribution throughout the bag. Slots made on the vertical sides of the bags enable plants to grow but vegetables can also be planted on top of the bag. A model bag kitchen garden was established on one site in each village, and then all participating farmers were required to implement the same at their households. Types of vegetables planted included Chinese cabbage, collard greens, spinach, sweet potato leaves and amaranth as suggested by the farmers themselves.

Monitoring of interventions

A number of indicators were developed which were used to monitor the performance of the intervention on a bi-monthly basis. A simple researcher administered tool with the indicators was administered to all participating households after every two months.

Nutrition status assessment

The height (in cm) and weight (in kg) of children and their caregivers in the sampled households were measured. Weight was measured to the nearest 0.1 kg using a SECA electronic bathroom scale (A SECA, Vogel and Haike, Hamburg, Germany). Height was measured using a stadiometer (Shorr Productions, Perspective Enterprises, and Portage, Missouri, USA).

Data analysis

All analyses were performed using IBM SPSS Statistics for windows, Version 21 (IBM Corp., Armonk, New York, USA). Data were presented using frequencies, percentages frequencies, means and standard deviations. Food consumption patterns and practices were compared before and after intervention. Emergency Nutrition Assessment (ENA) was used to classify the study children into categories of nutritional status into z-scores which were used to define stunting, underweight and wasting in children.For women, Body Mass Index (BMI) was used to define nutritional status. Paired t-test was used to compare the nutritional status of children and their caregivers at baseline and endline periods. The dichotomous categorical data for assessing differences in responses to nutritional knowledge in the baseline and endline time points were analysed using McNemar test. The marginal homogeneity test was used for categorical variables with more than two responses to assess the marginal frequencies. Significance was considered when $p < 0.05$.

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4.0 Results

A total number of 120 households were involved at baseline and 100 households at endline. Household size ranged between 6-8 persons at baseline (48%) and endline (44%). The proportion of female headed households was 15% at baseline and 23% at endline. The respondents who had not attained any formal education were 33%. The demographic information of the households and respondents are presented in Table 1. Majority of the children were in the age group of 42-53 months with mean weight of 14 kilograms and height of 95.9 centimetres at baseline. At the endline the majority of children were in the age group of 30-41 months with average weight of 11.8 kilograms and the height of 86.5 centimetres.

Table 11: Physical and demographic characteristics of households

Characteristics	**Baseline (n=120)**		**End-line (n=100)**	
	Mean	Standard Deviation	Mean	Standard Deviation
Age of respondents (years)	44.33	17.086	41.95	12.156
Weight of caregivers (kg)	54.76	11.788	54.13	11.551
Height of caregivers (cm)	153.29	6.872	153.56	12.628
	n	**%**	**n**	**%**
District of origin				
Chamwino households	60	50	53	53
Kilosa households	60	50	47	47
Sex of household head				
Male	102	85	77	77
Female	18	15	23	23
Marital status of household head				
Married-monogamous	73	60.8	58	58.0
Married-polygamous	9	7.5	5	5.0
Widowed	18	15.0	11	11.0
Divorced	5	4.2	10	10.0
Single	4	3.3	3	3.0
Cohabitation	11	9.2	13	13.0
Level of literacy of caregiver/mother				
Not able to read or write	53	44.2	35	35.0
Can read and write to some extent	25	20.8	11	11.0
Can read and write	42	35	54	54.0
Occupation of respondent				
Farmer	113	94	98	98.0
Employed formal sector	2	1.7	1	1.0
Self-employed/other	1	1.0	1	1.0
Other	4	3.3	0	0.0
Education level of respondent				
No education	40	33.0	36	36.0
Primary education	74	62.0	58	58.0
Secondary education	4	3.2	3	3.0

Adult Education	2	1.8	3	3.0

Kitchen garden knowledge and practices

Within three months of first demonstrations, all study households had established one or more gardens; planting various types of green leafy vegetables. The water sources used for growing bag gardens in the study villages were well water, rain water and household waste water. Further results regarding questions asked on kitchen gardening are presented in Table 3.

Nutrition knowledge of respondents

Knowledge on balanced diet increased by 35% during the two periods as more respondents could provide right responses to the questions on balanced diet.Table 2 indicates nutrition knowledge of participants during the baseline and endline surveys.

Table 2: Nutrition knowledge of respondents at baseline and endline periods

Question asked	n	%	n	%	Effect of knowledge	P-valuea
	Baseline		Endline			
Have you received any training about nutrition before					↑	0.005MN*
Yes	28	23.3	82	82.0		
No	92	76.7	18	18.0		
How often should children 2-5 years be fed					↑	
Once	2	2.1	5	5.0		0.065MH
Twice	67	55.8	15	15.0		
Thrice	38	31.2	68	68.0		
More than three times	11	8.8	11	11.0		
Do not know	2	2.1	1	1.0		
How many servings of fruits and vegetables a day are advised for people to eat					↔	0.081MH
One	35	28.8	14	14.0		
Two	42	34.8	46	46.0		
Three	27	22.5	32	32.0		
Four	1	1.1	2	2.0		
Five	1	1.1	1	1.0		
Do not know	14	11.7	5	5.0		
What is a balanced diet					↑	0.349MH
a diet rich in protein	6	5.2	5	5.0		
a diet poor in fat	2	1.8	2	2.0		
a diet containing all nutrients in proper quantities	17	13.8	49	49.0		

Do not know	95	79.2	44	44.0		
Do you know foods that increase intake of fibre					↑	0.083
Yes-with correct example	7	5.4	34	34.0		
Yes -with wrong or no example	8	7	18	18.0		
No	105	87.6	48	48.0		
Do you know any kinds of food groups					↑	0.008[MN]*
Yes with correct examples	18	14.8	95	95.0		
No	102	85.2	5	5.0		
Have you ever heard about iron deficiency anaemia						
Yes	94	78.3	90	90.0	↑	0.023[MN]*
No	26	21.7	10	10.0		
Can you list examples of foods rich in iron						
Organ meat	3	2.3	3	3.0	↑	0.078[MH]
Flesh meat	3	2.3	10	10.0		
Dark green leafy vegetables	50	41.3	55	55.0		
Beans	3	2.3	20	20.0		
Insects eg grasshoppers	1	1.4	2	2.0		
Fish and sea foods	1	1.4	2	2.0		
Does not know	59	49	8	8.0		
May I see the salt used to cook the main meal eaten by HH members						
Iodized	55	46.2	50	50.0	↑	0.069[MH]
Not iodized	61	51.1	39	39.0		
No salt at home	4	2.7	11	11.0		

[MN]McNemar test, [MH]Marginal homogeneity test* Significant at $p<0.05$

Household dietary diversity and consumprion of green leafy vegetables.

At baseline only 27% of households had a high HDDS as compared to 52% at endline.Figure 1.About 68% of households reported to have consumed green leafy vegetables in the previous 24 hours prior to the survey day. Daily consumption of different green leafy vegetables during the baseline and endline periods was observed to increase.

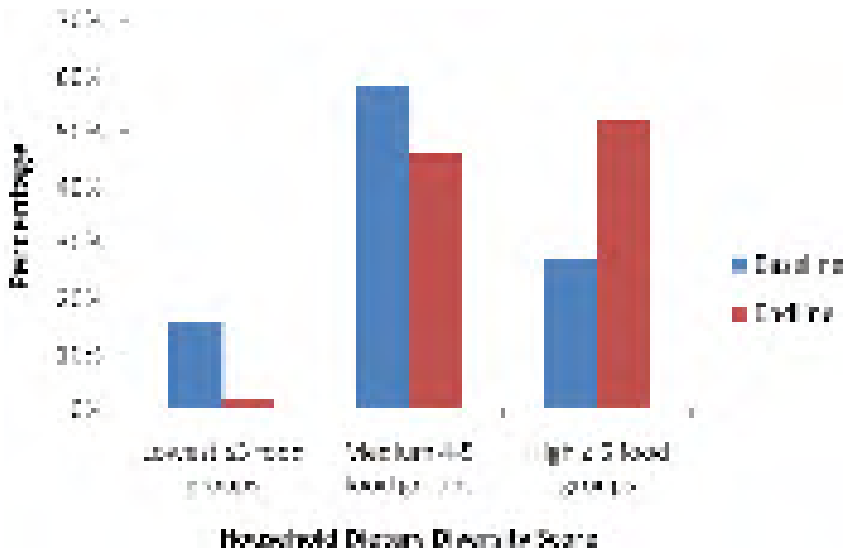

Figure 1: Dietary diversity classification

Nutritional status of children and mothers/ caregivers

The overall prevalence of stunting based on HAZ/LAZ for the total sample was 41% and 40.2% at baseline and endline respectively. The prevalence of underweight and wasting based on HAZ, WAZ and WHZ are indicated on Figure 2.

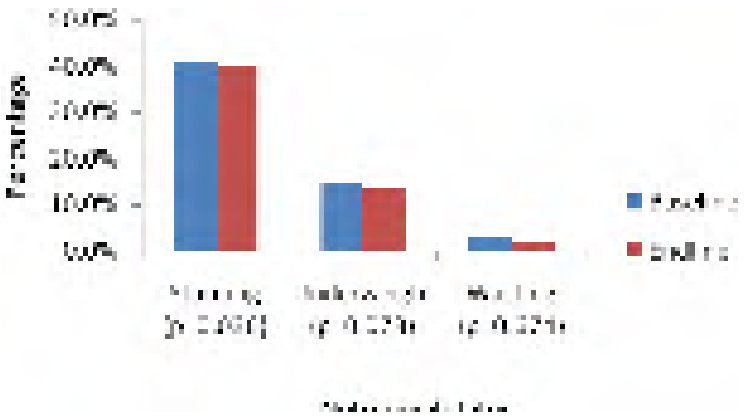

Figure 2: Child nutritional status

5.0 Discussion

The semi longitudinal nature of this study allowed researchers to measure change over time, thus permitted to prove causality between taking part in the nutrition and kitchen gardening education program and the improved nutrition knowledge, consumption patterns and dietary practices of the participating households. In the current study,

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there was a substantial increase in the performance indicators used to monitor the intervention such as improved nutrition knowledge, increased vegetable production, increased frequency of green leafy vegetable consumption and dietary diversity. On the part of nutritional knowledge, significant increases between the baseline and endline responses were seen on the aspects related to have received any nutrition training before, how often should children below five years be fed per day, knowledge about foods that increase intake of fibre, knowledge of food groups and the use of iodised salt at household level. Increase in knowledge was also observed on aspects of a balanced diet, iron deficiency anaemia and examples of foods rich in iron.

Reported practices of nutrition were better during the endline period as compared to the baseline period. This may indicate that the information supplied during the trainings was maintained by the participants for the whole period until the endline time and probably they will implement throughout their lives. Significant improvements in knowledge were found in various aspects. Other studies also reported improvements in nutrition knowledge after the implementation of nutrition education and kitchen gardening (Cannoosamy, Pem, Bhagwant, and Jeewon, 2016; Pillai, Kinabo, and Krawinkel, 2016). Comparable results were also reported by Powers, Struempler and Parmer (2005)where people in the nutrition education intervention group revealed significantly better improvement in nutrition knowledge. However, there are conflicting findings where knowledge scores did not increase significantly from the baseline to the endline(Garcia-Lascurain, Kicklighter, Jonnalagadda, Boudolf, and Duchon, 2006), which may be caused by disparities in the coverage of nutrition information, family environment, and food availability and accessibility or using a not applicable way of knowledge transfer (Shariff *et al*., 2008).

The consumption of introduced vegetables such as amaranth, collard greens, spinach and Chinese cabbage increased at the endline and the proportion of households using these vegetables was higher at the endline than in the baseline survey. Such improved diversity in green vegetable consumption is crucial to guarantee enough intakes of important vitamins and minerals for optimal growth and development (Burchi *et al*., 2011). In other developing countries, home gardening increased production and consumption of vegetables in the beneficiary households as compared to the controls and also vegetable diversity was reported (Talukder *et al*., 2010). In addition, the nutritional contribution of animal foods to dietary diversity is unquestionable. The majority of the households in rural areas of developing countries have low HDDS and foods from animal sources are uncommon in the household's diets (Ruel, 2003; Workicho *et al*., 2016). Therefore animal source foods should be equally consumed because they are a good source of nutrients that are needed for growth and that sustain the immune system (Darapheak, Takano, Kizuki, Nakamura, and Seino, 2013).

The small income obtained from sale of surplus vegetables is also used to buy other food items such as tomatoes, salt, sardines and cooking oil, which in turn increased diversification of the family's nutrition (Acham, Oldewage-Theron, and Egal, 2012; Sanusi, 2011; Talukder *et al*., 2010). Other studies also documented improvement in dietary diversity, nutritional knowledge and increased consumption of vegetables

(McAleese & Rankin, 2007; Pillai *et al*., 2016; Schreinemachers *et al*., 2016). The combined bag gardening and nutrition education in this study also indicated a slight positive effect on aspects of nutritional status such as child stunting, underweight, wasting and BMI of mothers/caregivers. Variable information regarding improvement of nutrition status is reported by various studies. Studies by Schipani *et al*., 2002 and Sheikholeslam*et al*., 2004, found a positive and significant impact on stunting and wasting prevalence after a gardening and nutrition education program whereas Malekafzali*et al*., 2000 and Masvongo*et al*., 2012 reported a reduction of underweight.

Regarding the performance indicators, the study experienced many optimistic outcomes. The number of bag gardens per household showed a positive outcome. At the beginning of the intervention, majority of households had one to two gardens, but at twelve months after the intervention, the majority had two to three gardens and all households had at least one garden. Similarly, in other areas, water shortage was also reported to be a major constraint for the development of gardens, especially in semi-arid areas (Galhena etal., 2013; Merrey and Langan, 2014). The problem of pests and diseases was solved by providing hands on skills on application and use of organic pesticides. Another study which examined component relations and productivity of the home garden system in India reported diseases and pests to be among the chief constraints (Pandey, Rai, Singh, and Singh, 2007).

Conclusion and Recommendations

One of the most positive outcomes of the study was a vast response towards the bag garden intervention. Many households within the intervention villages and also from the neighboring villages wanted to take part at the kitchen garden training. Our results demonstrate that the bag garden and nutrition education approach has the probability to improve dietary diversity, consumption patterns and micronutrient status of communities in rural areas such as Kilosa and Chamwino districts. The kitchen garden/nutrition education approach is a simple and sustainable approach for addressing the problem of micronutrient malnutrition. Even though the results of this study are encouraging the contribution of the program to overall nutrition and food security may be studied in inclusion of: A control study design may be needed to evaluate the impact of a blend program of nutrition education and kitchen garden on combating specific micronutrient deficiencies such as iron and vitamin A deficiencies, implementing this blend of intervention with other interventions such as de-worming and water, sanitation and hygiene and establishment of an improved point for seed and seedling sale in the localities. This can also involve empowering local communities to produce and distribute seedlings.

Conflict of interest

The authors declare that they have no conflict of interest.

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The Hidden Potential of Green Resources Products Trade Contributions to Industrialization in Tanzania

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Abstract

Tanzania is endowed with more than 1000 medicinal plants species which makes a core entity to Green Resources Products (GRPs) trade in the country. However, its potential contribution to industrialization is yet to be realized. This study aimed at examiningthe GRPs market to unveil their potential to value addition industries. The hybrid of ethnopharmacology and market mix reconnaissance methodology was conducted in two phytogeographical areas of Eastern Arc Mountains, Somali-Maasaiand one market hub. Two regions of Iringa and Morogoro for Eastern Arc Mountains, and Arusha and Manyara for Somali-Maasai were purposively selected, while Dar es Salaam was selected as a market hub. Ethnopharmacology covered traditional medicine types and usage while market analysis employed market mix in terms of product, place, price and promotion. A total of 426 products were surveyed in five categories of anti-malarial (31%), anti-bacterial (39%), anti-diabetic (8%), pain killers (12%), and anti-impotence (20%). The promotion of the products was mainly conducted for anti-impotency category. The highest price recorded was for anti-diabetics category. The places for conducting trade were practitioners' homes (78%), traditional clinics (3%), shops and street vendors (19%). About 21% of the products were sold in crude form while 54% and 25% of the products were sold in semi processed powdered form and liquid form respectively. Only 6% of the products were packed in specific containers with labels. Therefore, more value addition is required in order to produce more medicinal products in the finished form rather than selling in crude and in semi processed forms. This can be achieved through mobilization of practitioners in groups of ten members, or in business partnerships and provide them business development and support services hence increase their competitiveness. .

Key words: GRPs trade, potential, industrialization, formalization

Introduction

Livelihood improvement has been a global agenda through the Sustainable Development Goals (SDGs) and is well captured by Tanzania Vision 2025, although the latterwas developed before SDGs. These development strategies emphasize on proper utilization of human, financial and natural resources for betterment of lives (FAO 2017, URT 1999). Medicinal plants are one of natural resources which are utilized by majority of the Tanzanians.

Tanzania is endowed with more than 1000 medicinal plant species used to produce various medicinal plant products, referred to as Green Resources Products (GRP). The GRP can be categorized as traditional medicines, home based personal care products

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and nutraceuticals. Compared to other categories, traditional medicines dominate the GRP trade (FAO 2008).

The GRPs trade is a buoyant intra trade in Africa and Tanzania in particular. The value of trade in 2017 was estimated to be 200,000 USDfor non-powdered products at Kariakoomark*et al*one (Posthouwer, 2018). Various ethnobotanical and ethnopharmacologicalsurveys revealed a large number of GRP traded in Tanzania (Hilonga*et al*. 2018, Posthouwer*et al*.2018, Nahashon, 2013). These researches reveal thatGRP trade is informal which is not only in Tanzania case, but also in Africa at large (Cun-Sanchez *et al*.2017;Williams*et al*.2007).

Currently, Tanzania's policies and their implementations plans have put the industrial development agenda at forefront for realization of the semi industrial economy as speculated in Tanzania Development Vision 2025 (URT 2018, URT 1999). In financial year 2017/18 Tanzania had 53,876 industries of different sizes whereby those categorized as large industries were251, medium industries were173, small industries were 6957 and micro industries 46 495 (URT 2018). This was the increase of 6.13% since 2016 (URT 2018). In addition, Tanzania produces only 12% of the national medicine requirements per year (URT 2018) making the country a net importer of medicines.

However, despite of the prioritization of the industrial agenda and the demand for medicines in Tanzania, the industrial value addition of GRPs is still low and is dominatedby informal market. Moreover, market researches done on GRPs were on conservation purposes and they did not adopt the market mix components which gobeyond the product contents (Saleemi 2007). That is, market mix approach can characterize the product determined as informal to unveil the potential for value addition. Therefore, this study used the hybrid of ethnobotanical and market mix based survey to study the status of GRP trade in Tanzaniain order to explore its industrial development potential.

Materials and Methods

Study sites

The survey was conducted in two phytogeographical areas of Eastern Arc Mountains and Somali-Maasai in the case of production and one of the GRPs market hubs (Figure 1). These are two out of five phytogeographicalareas in Tanzania (Nahashon, 2013). Two regions of Iringa and Morogoro for Eastern Arc Mountains were purposely selected, while Arusha and Manyara were selected for Somali-Maasai regions. Dar es Salaam was selected as a market hub for the GRP. The areas were strategically selected as the main sources of the GRP in the country compared to other phytogeographical areas as well as largest market in Tanzania (Chacha*et al*.2018, Nahashon, 2013, Mabiki *et al*.2011)

Figure 1:Tanzania Map showing the study areas

Market survey

The market survey involved the hybrid of ethnopharmacologyand market mixapproaches. The ethnopharmacologycovered the traditional medicine type and usage while market mixcomponent assessed the product, place, price and promotionelements. Market mix uses the controllable factors to influence the purchase of the products (McCarthy and Perreault, 1987). It is strategically used by firms to penetrate various markets to increase sales (Saleemi 2007, McCarthy and Perreault, 1987). This implies that analysis of market mix of products can reveal product design, and its strength and weakness in capturing the target market. The approach was used to elaborate further the GRP products identified in the market, their nature and how they have penetrated the market despite of the persistence claim of informal nature (Vasisht*et al*.2016, Dzoyem*et al*.2013).

Place observation wasbased on the primary location where the practitioners reach their target customers. Price observation was based on the amount or valueof money that is exchanged with the productand the promotion was intended to show how the practitioners docommunicate about the products to their potential customers.

The Regional Traditional and Alternative Medicine Coordinators in each region were consulted and guided the districts selection. The District Traditional and Alternative Coordinators were requested to guide the identification of theservice centres. The service centres were classified as home based, clinics and shops or vendors.For each centre type, systematic random sampling was conducted to get a representation from each centre type after preparation of sampling frame. Finally, products were purchased from the selectedtraditional and alternative medicine practitioners.For each product, the therapeutic indications, package, dosage form, price and marketing authorizationwere

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noted. The practitioners were also enquired of the promotions strategy of their products.

Data analysis

The market mix components were described qualitatively based on the observed practices. The percentages were calculated based on the total observation of the particular component. The prices, dosage form packaging and promotion strategies were compared among regions. The content analysis was used to summarize the qualitative information. Further, the speculation of industrialization potential was done through guideline of micro and small enterprises by the Tanzania SME Development Policy 2003.This was done by comparing the requirements to establish micro and small industries and the observed capacity of practitioners.

Results

A total of 426products were purchased from 86 practitioners by the researchers. The purchased GRPwere categorized into five uses of anti-malarial, anti-bacterial, anti-diabetic, pain killers, and anti-impotency. Each components of the market mix is further explained in subsection 3.1 to 3.4below:

Products

The distribution of the five categories was as shown in Figure 2 below. Among them anti-bacterialdominated the markets. This can be contributed by the many infections treated by this category such as UTI, typhoid, and cholera, respiratory and sexually transmitted infectionsand other diarrheal diseases, which are the major health challenges in sub Saharancountries (Magesa *et al*. 2001; Global Antibiotic Resistance Partnership—Tanzania Working Group, 2015). The least was anti-diabetics.

The product breath, individual having all products categories, was 38%while the products depth, in terms of size differentiation, was 10% (Cite the Figure No. before presenting it). Most of the products packed in dosage, where a customer can purchase the small amount at a time.

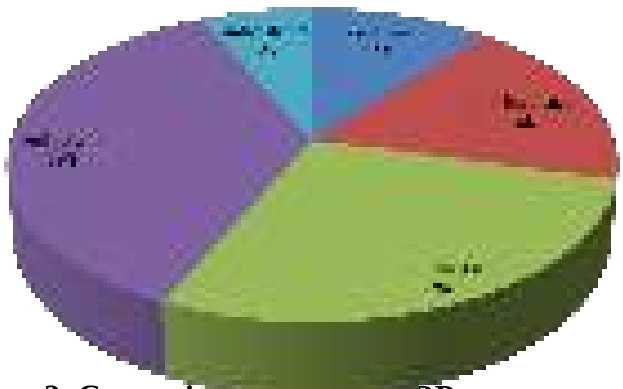

Figure 2: Categories of surveyed GRP

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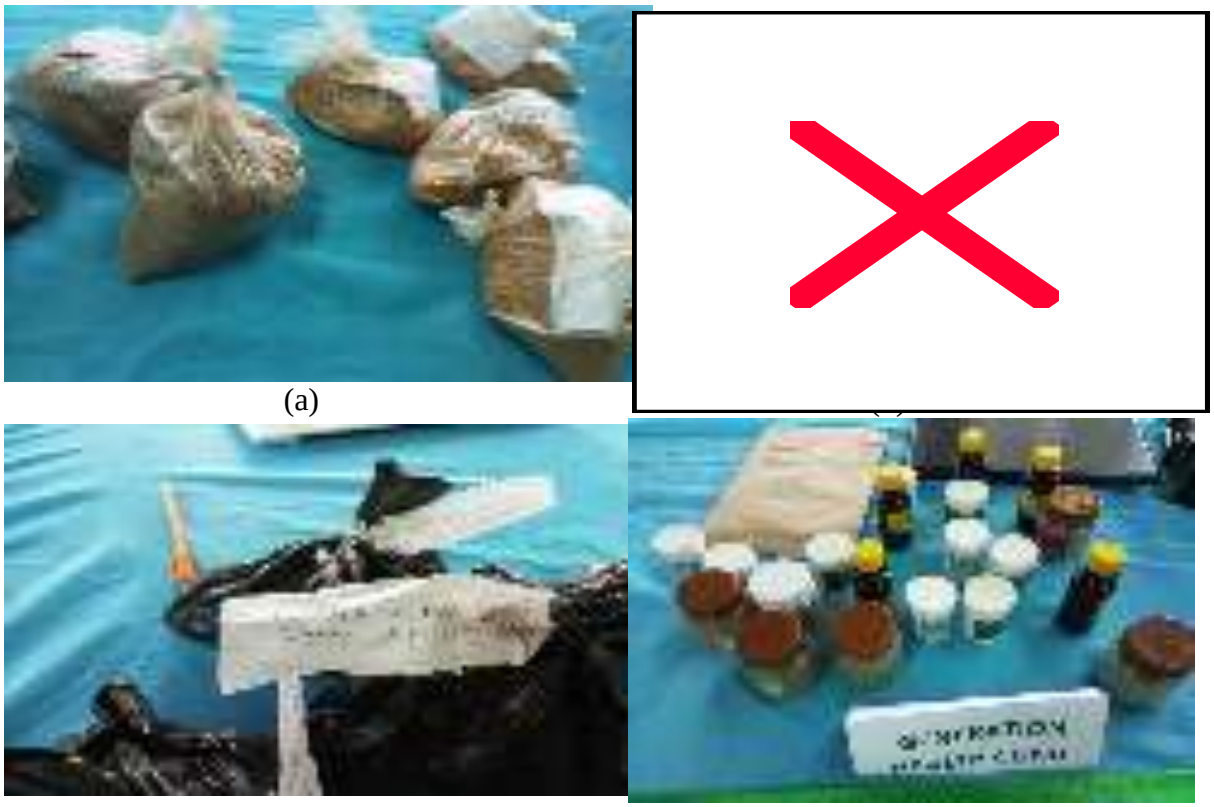
The processing status of the products was analysed in three states crude (21%), semi processed powder (54%) and semi processed liquid forms (21%). In most cases the crude products were harvested on arrival of customers. About 6% of the products were packed in specific containers and labelledas shown in Plates 1a to 1d. Others were packed in plastic bags and used containers of water, soda, petroleum jelly and conventional drugs.



(a) (c) (d)

Plates 1 a-d: Various packaging of GRP

Price

Prices of the products were almost homogeneous from all four sourced regions. The price was about 30% more in Dar es Salaam. This can be explained as the operational cost increase as most of the raw materials wereobtained outside this market hub. The most expensive category was anti-diabetics whereby the doses were up to 600 000 TZS (260 USD). The price was much influenced by the packaging of the products where well packed GRP were more expensive than unpacked. The well packed products exceeded more than 57% of the price of the same unpacked product.

Place

The observed places for dispensing the GRPs were the practitioners' homes (78%),

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shops and vendors (19%), and traditional clinics (3%). There were correlation of the product packaging and the place, where the shops and vendors' products were conveniently packed compared with practitioners conducted at home and traditional clinics.

Promotion

Communications of the products to customers were done through one to one communication. About 98% of the practitioners use such method to make their GRPs known to other customers. Other 2% uses posters and some other devices like brochures and business cards. Most of herbalist and vendors fall in this category. Due to this promotionapproach, it was normal to see the practitioners operating on the same circle of customers at the same geographical location.

Industrial potential of GRPs

In Tanzania micro industries are defined by having 1 to 4 employees and capital of less than 5 000 000 TZS and small industries having 5 to 49 employees and capital of 5 000 000 to 200 000 000 TZS (URT 2003). About 38% of the practitioners had all categories of products, and based on the product prices, their business had a capital of more than 5 000 000 TZS. The 62% of practitioners had business with a capital of less than 5 000 000 TZS.

Almost 78% of practitioners offered their servicesat home and mainly depended on family labour of about four people. The 19% operated in shops and vendors, mainly operated by individual owners with one to two assistants. The 3% operated traditional clinics, having more than four assistants. Taking into account capital and labour force of the 86 surveyed practitioners, the distribution of industries that can be formed is shown in table 1.In addition, individual practitioners can be mobilized to form groups for effective operation in their newly adopted practice of industries. For that matter, about eight small industries can be formed by groups of ten practitioners without experiencing capital and labour constraints. (Present difference between Eastern Arc and Masaai-Somali

Table 1: Micro and small industries that can be formed

Industry category	Number of Industries	
	Capital Base	Labour Base
Micro industries	59	83
Small industries	27	3

Discussion

The market mix analysis of GRPs indicated low profile of the products, place and promotion at given prices. The prices were relatively high compared to the profile of other components of market mix. High prices of GRPs with improved products, place and promotion show that GRPs trade can create more income.

Most of the products had little value addition. Value addition could be processing the products into tablets, syrups and gels, and creams. Value addition processes necessitate

the introduction ofvarious categories of industries. This will caterfor the national industrialization agenda as well as reduce the burden of importing medicines.

The GRPs industrialization have been possible in India where by 2013 they had about 14 well-recognized, 86 medium scale and 8000 small scale manufactures of herbal drugs on record (Nirmal*et al*.2013). These industries were besides of other thousands traditional practitioners who have their own miniature manufacturing facilities (Nirmal*et al*.2013). In Africa, countries like Ghana and South Africa have improved the processing and value addition to the extent of some of GRPs are registered and controlled by the Food and Drug Authorities (Gibson 2018, Komalaga*et al*.2015). Therefore, this indicates the possibilities of Tanzania to industrialize its GRPs production.

Conclusion and Recommendations

The marketed GRPs were of low profile with little value addition. Despite their relatively high price, products were poorly presented in the market and missed modern promotion strategies. Therefore, there is a potential of micro and small industries for value addition. In addition, individual practitioners can form groups to start micro and small industries, so as to pull together resources and distribute risk for inexperienced industry running.

It is recommended to sensitize the practitioners on the potential benefitsof adding value to their products. On the other hand, value addition requires industries of different types. Furthermore, the assessment of most appropriate type of required industries and typical products to start with is important.

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Facilitating Democratic Processes for Sustaining Environmental Education in Primary Schools: A case study of Ilonga Teachers' Training College in Tanzania

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Abstract

The paper is based on the authors' experience of a project aiming at the improvement of Environmental Education (EE) in teacher training colleges and thus in primary schools within Tanzania. Through participatory action research (PAR) in collaboration with a teacher training college, nine primary schools, and local community members, we developed examples of, and arenas for, facilitating a democratic process to influence the active teaching of environmental topics. The study was guided by one research question: What are the learning outcomes of participatory action research as an approach to facilitate the democratic process for sustaining environmental education in primary schools. We collected data through Focus group discussion, interviews, and observations and analyzed the data following the content analysis approach. The increased teaching competences among participating student teachers, sustenance of established EE activities, democratic organization of teaching and the support for environmental conservation by stakeholders were the key findings. However, the transfer of teachers and education leaders was the main challenge were the threats to sustaining positive change. We discuss the findings in terms of institutionalized top-down power structures that characterize Tanzanian educational governance. We argue that the contextualization of teacher education curriculum through participatory action research and action learning strategies grounded on democratic principles is the gateway toward environmental sustainability in Tanzania. We thus recommend the inclusion of participatory action research and action learning in the teacher education curriculum.

Keywords: Environmental education; Educational governance; Democratic processes Participatory action research; Teacher education

Introduction

The education of teachers is a focal point when it comes to initiating the active teaching approaches that are relevant when teaching environmental topics. Education for self-reliance, which is also founded on experiential learning, has been a core foundation of the revitalization of active teaching in Tanzanian teacher education (Dewey, 1938; Freire, 1970; Nyerere, 1967). An important aim is to educate professionals who can spearhead educational transformation, enabling the citizens to face the demand for improving local life within a democratic society (URT, 2001, 2010). Thus, teacher education emphasizes participatory teaching and practical activities (URT, 2001).

Thus, the Tanzanian government initiatives in teacher education have focused on teaching participatory teaching methods in the hope of educating professionals who can spearhead participatory teaching approaches and democratic ideals within schools and out into the wider community (URT, 2001). The government has taken these initiatives further in a number of ways. For instance, by expanding teacher training colleges

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through the opening up of more mid-career teacher training colleges, by introducing teacher educational programs into public universities, by expanding student loans to include more of student teachers, and by introducing private teacher training colleges with the aim of increasing the number of teachers educated in participatory approaches. These initiatives have increased the enrolment rates of trainee teachers. However, the quality of teaching in teacher training colleges and within schools, as a result, is also still poor. According to Bhalarusesa, Westbrook, and Lussier (2011), the teaching in teacher training colleges relies on lecturing and memorization, and the approaches are then transferred into practice teaching and later into schools when the teachers become employed.

Since 2005, the government of Tanzania has taken further initiatives to strengthen in-service training programs by introducing teacher professional development (PD) programs, seeking to strengthen the connection between teacher training colleges and primary schools. The initiatives work through the decentralized education systems, where district authorities together with the teacher resource centres (teacher training colleges, primary schools, and local communities) coordinate teachers' learning activities, aiming at improving the quality of teaching and learning. These efforts provide a possibility for teachers to reflect upon the assumptions, concepts, and belief systems that guide teaching practice.

However, according to Mosha (2012), the hierarchical power systems characterizing educational governance that are ingrained into the culture of Tanzanian political governance are still the main challenge in terms of achieving interactive teacher development systems. In the same way, the relationship between the Ministry of Education, the district authorities, universities, teacher training colleges, primary schools, and the local communities seems to build upon hierarchical power relations. Mosha (2012) maintains that the decisions among stakeholders are normally top-down and are quite often not consensual. Hierarchical power relations might demotivate and thus negatively affect the sustainability of interactive teacher development systems.

Considering the foundation of, and experiences with, Tanzanian teacher education and educational policy and its relevant research on environmental education (EE), we regard the government initiatives as an appropriate point of departure for strengthening the EE within current-day Tanzania (Fine &Tilbury 1996; Hardman *et al.*, 2015; Sterling, 2010; URT, 2010; Wals, 2017). The vitalization and achievement of democratic relations and decision-making systems among and between the stakeholders on different levels is a possible gateway for initializing cooperative and participatory approaches in teacher education for environmental sustainability.

Thus, our strategy involved connecting the teacher training programs with the environmental realities of primary schools where the student teachers practised the teaching. The intention is to create the best examples of teaching practice that promotes the constant interaction with, and the refreshment of, the connections between teacher training colleges and the realities of teaching practice in primary schools, using student teachers as agents of change (Stenhouse, 1975). According to Sterling (2010), initializing EE in a teacher training college can facilitate the transfer of knowledge and therefore

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enable systemic change in terms of environmental sustainability through the transferring of best practices by educational professionals.

Though teacher education curriculum emphasizes participatory teaching of environmental topics, the teaching in practice is based on lecturing (Bhalarusesa, Westbrook, & Lussier, 2011). As alluded to above, to enhance the learning outcome of EE participatory pedagogy need to be followed. Thus in this paper, we share our experience on how to facilitate the democratic process and to which degree the introduction and implementation of democratic processes in teacher training programs increase the different stakeholders 'abilities to manage and negotiate environmental challenges and the resilience of the local communities.

In the following section, we will elaborate on the theoretical perspectives surrounding the tension between hierarchical and democratic power in the Tanzanian education and teacher education systems.

Hierarchical power and democracy

Our main theoretical perspective on societal power structures and on the maintenance and functioning of such structures expands on Bourdieu's (1986) theory that connects societal power structures with cultural practices. In addition, we use Dewey's (1916, 1938) perspectives on democracy and experiential education and Freire's (1970) perspectives on conscientization to discuss the potential influence on existing power structures through strengthening democratic processes.

Bourdieu (1986) suggests that the legitimacy of hierarchical power relations demands the existence of a societal Doxa that often consists of an undisputable socially constructed worldview and of uncontested and institutionalized social and cultural practices. Doxa appears to us as the unchangeable natural order of the society in accordance with its given rules, procedures, and the power of the authorities. On the other hand, democratic power relations represent discourses and a dynamic worldview in terms of the tentative state of the changes that move us toward constructing a better world. The two major types of power relations, namely hierarchical power relations and democratic power relations might exist simultaneously and side by side in the same society (Quicke, 1995). While hierarchical power relations espouse centralized, bureaucratic, and top-down decision making to achieve efficiency and cultural stability, democratic power relations espouse distributed power through majority decision making in order to achieve autonomy, self-control, distributed power relations, and cultural progression (ibid).

Normally the two types of power relations tend to compete for domination of the social practices, each legitimizing its position through the acquisition of relevant capital and thus gaining the power to squeeze, push, and establish said social practices (Bourdieu,1986). When a hierarchical power structure dominates, as indicated in Table 1 with the black arrow pointing downwards, emotional reactions characterized by disempowerment seem to prevail. The key issue to understand is what might happen in the right column when the right arrow becomes stronger.

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Table 1: Power transaction between hierarchical and democratic power systems

Hierarchical power systems Top/down system for decisions The supremacy of the central government Coercion, obeying, conformity, stable culture and rules, efficiency, control, competition, and individualism	**Democratic power systems** Distributed power through majority decisions Negotiable distribution of power to decide between municipalities, regional, and central authorities Negotiation, discussion, ability to change through majority decisions, autonomy, cooperation, collaboration, group activities
Prevailing emotions when hierarchical power systems are dominant • Apathy • Aggression • Othering • Resistance • Withdrawal	**anticipated development of emotions when democratic power systems are dominant** • Feeling competent • Experiencing relatedness • Increased community resilience

Drawing from the hierarchical power and democracy perspective, we discuss the potential of the democratic organization of EE in teacher training colleges, in primary schools, and in their surrounding local communities. Kalungwizi *et al*. (2017) document that reliable leaders who facilitate democratic decisions can motivate both student teachers to include EE in their practice schools and members of local communities to implement environmentally friendly practices. Still, hierarchical power is an obvious part of the current hierarchical leadership in Tanzania, but even within this power structure, the facilitators might realize democratic processes within a framework of confidence and make room for self-determination among the participants. When the arrow turns rightwards, participants' self-esteem, self-efficacy, and united problem-solving capacities seem to increase.

Considering the remaining tradition of self-reliance within Tanzanian education and its experiences with experiential learning and conscientization (Dewey, 1938; Freire, 1970), we suggest that two interdependent gateways be employed in order to extend and expand the student teachers' and, in the next phase, the local inhabitants' situated freedom in order to, in turn, develop EE within the framework of the Tanzanian hierarchical power structure. We think cultivating an awareness of the power structures and the strengthening of the members' trust and confidence by demonstrating significant results from EE could be a stepping-stone in terms of addressing sustainable environmental activities (Kalungwizi, Sigrid, Krogh, Mattee & Ahmad, 2017).

Materials and Methods

Research design and context

The project followed a participatory action research approach (Reason and Bradbury, 2008) inspired by Freirean and transformative learning perspectives (Freire, 1970; Nyerere, 1957). The approach advocates the ideas of critical reflection and co-learning to ensure that stakeholder participation is intentional, inclusive and critical (Reason and Bradbury, 2008). Therefore, we wanted to involve all participants on equal terms, to secure that all voices contributed to the process of change (Kemmis, 2001). As

facilitators, our roles were to assist stakeholders in discovering their own abilities and understanding of the situation, encouraging them to take ownership and control of the problem definitions as well as finding solutions. When the participants control the process of knowledge production from problem definition to the creation of solutions, they are more likely to develop capacities that influence their future actions (Gaventa and Cornwall, 2001). Thus, raising critical consciousness among the stakeholders is important for community transformation (Freire, 1970).

We used the emancipatory learning perspective as a meta-theoretical lens to explore the extent to which the process provided participants with a chance to examine, question and review their perceptions and experiences. Thereafter we examined to which degree the changes in perception transformed their orientation and actions. We implemented the project into three interlinked phases: a preparatory, planning and an implementation phase. The initial preparatory phase started with collaborative practice mapping where everyday practices at the school were examined. Thereafter, we arranged formal and informal meetings with the stakeholders to collect their experiences of the EE practices and their understanding of the situation.

The activities both strengthened and developed mutual learning, relationships and confidence in each other (Bowen & Martens, 2005). Then we arranged a dialogue conference to facilitate dialogues and reflections oriented towards a change of EE teaching and learning practice. We presented our mapping of the ongoing practices during the dialogue conference. This exposed the participants to the practice at the college and schools facilitated the sharing of experiences and ideas. In Freire's (1970) spirit, mutual consciousness about challenges on the practices provided a platform for the development of an action plan based on democratic interaction between the stakeholders.

Theoretically, the plan is founded on John Dewey's concept of 'education as life itself'; experiential learning' (Kolb, 1984); and Paulo Freire's 'humanizing education' (Freire, 1970). Pragmatically, the plan rests on the policy of Education for Self-Reliance that calls for context-based pedagogy (Nyerere, 1967). The plan aimed to build capacities of stakeholders to be able to link formal learning with community experiences, everyday life and local realities. The implementation phase, which is the focus of this article, ran for ten months. In collaboration, researchers and local actors implemented most of the planned actions but made some adjustments were made during reflective meetings.

Data generation and analysis

In order to explore to what extent the beginning of the democratic process prevailed; the first author undertook a follow-up study one year after the formal closure of the project. He participated as co-evaluator with the teachers and the tutors of the action research project and documented the successes and challenges that the participants had experienced and the strategies they used to address said challenges. In addition, we conducted focus-group discussions (Yin, 2014) involving environmental committees from the participating primary schools, and the teacher training college. One focus-group discussion took place in each the three school and one at the college. In addition,

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we interviewed the head of the teacher training college and the heads of all participating primary schools, village leaders, and gardeners, as well as the administrators of the teacher training college. To get a broader insight, we also observed outdoor activities and analyzed the teaching plans at each school. The first author took notes and then transcribed all the audio recordings, organizing them into themes and reflecting on our research question (Miles & Huberman, 1994).

Results

Influence of PAR on environmental learning outcomes

Increased teaching competences among participating student teachers

The results indicated that student teachers had committed to environmentally friendly practices and democratic principles. They were able to facilitate both environmental care within the local communities and surrounding practice teaching schools and stimulate discussions with school and college leaders. In one of the schools, the student teachers and pupils supported the local community members in reflecting on their environmental problems. The discussions resulted in the establishment of home gardens among the interested parents, teachers, and tutors. In another school, the student teachers facilitated the community members to discuss a conflict in their village between farmers, pastoralists, and school leaders. Through their joint efforts, they decided to plant fodder for their animals as a means to reduce conflicts resulting from lost pastures due to drought in the area. The community members enjoyed the activities and volunteered to fence the school garden in return. Dialog and mutual problem solving reduced the level of hostility between the involved stakeholders and (probably) founded a future sense of democratic cooperation and enhanced community resilience. Throughout the program, the student teachers learned to be both active participants in their local communities and how to create learning spaces for other actors.

After an initial perception of disempowerment and a feeling of a loss of control over their learners' discipline, the student teachers gradually began to enjoy their projects. In addition, they reported that pupils were more participative and responsive during teaching and learning and that the community members participated actively in the process. As future school leaders, the student teachers learned to organize meetings, to lead group discussions, and to listen to diverse ideas. They also learned to promote equal participation among people from various ethnic groups, hence, to promote ethnic inclusion in democratic discussions. As a result, the teachers started to acknowledge student teachers and pupils as co-learners within their community and ultimately valued their contributions during the teaching sessions.

Sustenance EE activities developed following a democratic process

During the follow-up study, only one of the practice schools had continued to plant trees, whereas all continued to care for the trees that were planted. Gardening predominated in all the sites that we visited, with vegetable cultivation as the dominant crop. The teachers, pupils, and the student teachers visiting the schools from the teacher training college (during practice teaching) conducted the gardening nearby or within

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the tree plot established at the participating primary schools to facilitate the simultaneous learning of tree care and gardening. Gardening generated raw materials for their own school lunches, which motivated the student teachers and the pupils to further participate in the gardening activities and in taking care of the planted trees. We also found new activities such as creating ornaments and plant pots for beautifying the school.

On all four sites (the practice teaching schools and the teacher training college), student teachers, together with tutors, teachers, and the pupils, had started to use animal manure and decomposed organic wastes to fertilize the soil in their gardens. In the schools we visited, gardening, tree care, and soil fertilization had become major arenas for the teaching of environmental topics. The teaching had become oriented toward practical activities that addressed the community's needs. This change is contrary to the conventional teaching and learning approaches of Tanzania—approaches that emphasize the passing of examinations only (O-Saki, 2012)—and yet it is in line with the curriculum.

Democratic organization of teaching and the support for environmental conservation: concrete evidence of power balance

During field visits, it was observed that in the study schools, the EE activities were organized according in collaboration between students and teachers unlike before were mainly teachers did plan and organize. This show that they now EE learning activities were organized according to the democratic principles of power-sharing and mutual support as espoused by Eikeland (2012). Furthermore, through focus group discussions it was reported that the teacher training college had organized planning and reflection workshops with primary school teachers and local village leaders in order to discuss the participatory supervision of the student teachers and to explore how both the teachers and the local communities could contribute further toward improving teacher education at Ilonga Teachers college. Thus, the locals' participation continued to ensure access to local resources that aided the practical teaching of environmental topics and led to enhanced student-teacher experiences of teaching environmental topics. It also enacted itself as a positive contribution toward environmental sustainability in the surrounding communities, the schools and the college. The practice sessions enhanced the learning experiences among student teachers. In return, both the student teachers and the pupils had been teaching tree planting and gardening within their communities, showing that they had acquired a sense of self-confidence and a sense of responsibility and autonomy during their previous activities. In the pupils' homes (which the first author visited), the members who were trusted by the community reported that the pupils had become very supportive, especially in terms of helping to establish vegetable gardens and in helping to manage pests and diseases.

On top of that, the teachers and tutors reflected on the possibility of becoming learners themselves as one of the teachers acknowledged that she herself had learned about tree planting since her school days: Only after she had participated in the project, however, had she acquired the ability to do the gardening practically. This shows that the participants realized the power of working together and learning from each other

(Gaventa &Cornwall, 2001). The democratic organization of EE learning seemed to be interesting to both teachers and pupils in the study area since it encouraged autonomy and supported academic learning in the classrooms—as one of the teachers said: "The pupils seem to feel freer in the classroom. Now, they perceive us as friends."

Possible challenge threatening the democratic process

Transfer of teachers:

The existing hierarchical power structure in Tanzania—such as the regular transfer of teachers and school headmasters by central government authorities—threatened the project. The transfer of teachers jeopardized the acquired knowledge and skills of both the pupils and the teachers, as well as the cultural capital necessary to sustain the development of EE. The district authorities had transferred most of the teachers who participated in the participatory project, from the beginning up until the point when the first author conducted the follow-up study. However, there were still a few teachers left to keep on teaching new participants. Even when headmasters who had supported the process were transferred, other teachers took responsibility. The planning and implementation of EE activities continued through the active participation of pupils and student teachers.

The pupils decided on the outdoor activities they wanted to implement and discussed their ideas with local community members in their student clubs, which met regularly. The pastoral communities participated in the activities, contributing both materials and labour to the process.

Discussion of the findings

In line with the contextualized theoretical model, findings show the potential of PAR and action learning strategies in terms of sustaining the democratic teaching of environmental topics within the context of hierarchical structures. We have indicated that despite the hierarchical authorities regularly removing headmasters and college administrators, creating inaccessibility to key resources due to feelings of disempowerment and weak access to relevant decision-making members of their faculties, the teachers were not demotivated. Instead, they encouraged new teachers to join the process of change in the hope of spreading these teaching and learning strategies to more teachers in the neighbouring schools, therefore expanding their newly-created learning community. Teachers and local communities alike demonstrated a growing ability to improve EE by engaging both the learners and the community members, sharing their knowledge and skills with pupils and student teachers. This ability is promising in terms of the communities' development of resilience against not only environmental degradation but also against the devastating conflicts among certain groups within the community. The transition toward democratic relations in EE seems to rely on an awareness of local environmental conditions, dynamic teacher identities, a sense of solidarity, and committed local leader.

The awareness of the power structures of educational governance seems to be a necessary element of cultural capital for sustaining democratic power relations

(Bourdieu, 1986; Chevalier & Buckles, 2013). In line with Freire (1970), Ahmad (2016), and Jäckle (2016). The findings seem to suggest that the increased awareness of the dominant power structures of the EE practice and educational practice, in general, can promote and stimulate community members' commitment to democratic processes that improve learning situations. The awareness stimulates self-determination, commitment, and the willingness to try new strategies, and can even foster the formation of dynamic teacher identities.

According to Wenger (1998), the knowledge that is based on real-life experiences shapes human identity through the redefinition of the members' roles in the community of practice. This knowledge of the power structures seems to shape the identity of teachers, increasing the readiness of teachers to become learners: Teaching became a dynamic process that also involved learning. One of the tutors commented on this transformation, saying she had been learning tree planting since her school years but that it was during this project that she learned how to do it practically at home—there were opportunities to learn from experienced student teachers. Such an identity transformation is important in the power-sharing process and thus in sustaining democratic relations. It can become a source of solidarity for the learners and the teachers alike, who are connected by the demand for the fulfilment of their personal, as well as their communal needs.

Sense of collective solidarity is important in realizing collective actions among marginalized communities who want to use research to realize social change (Nyerere, 1967, Nkulu, 2005, and Noffke, 1997). Collective actions and solidarity seemed to promote self-esteem that encouraged the local people to continue the struggle, even under the harsh conditions that were characterized by limited resources and unstable local experts. Solidarity that is composed of respect and responsibility toward others is important in terms of achieving environmental sustainability (Shumba, 2011). And yet, the solidarity is influenced and dependent upon committed local leaders and local leadership is important in achieving social transformation Nyerere (1967).

According to Bandura (1986), encouragement from valued members of the community can be the main source of motivation. In this study, local leaders and school committees coordinated activities and encouraged the participation of parents in the sessions. Still, the contributions of the local gardeners and extension officers seemed to be highly important. On top of that, the leaders' willingness to share their authority with the teachers educated in participatory learning and action research was the gateway toward a more democratic structure involving the active teaching of environmental topics and active human agency. However, some leaders may not be willing to share their authority for fear of losing their power to the other teachers. In some of the participating schools, the heads of the schools were not willing to share some of their authority, thus sliding back into doxa (Bourdieu, 1986). This kind of relationship reduced the flexibility of the school systems, rendering it difficult to deal with the changes in the school systems' learning methods.

The discussion's nuances demonstrate the earlier-described tensions between a self-efficient local community and the framework of top-down hierarchical power relations

from the government down to local communities and schools. Still, we have shown that within hierarchical power structures it seems possible to create arenas for the development of democratic power relations. The democratic organization of EE in outdoor activities at schools seems to have the potential to influence the rigid top-down teaching regime in the classrooms in a democratic way. In accordance with cooperative action research, the collaboration between different stakeholders and the distribution of power from the experts to the locals and from the leaders to the other citizens seems to motivate both individual and collective actions on a local level. To a certain degree, a lack of material resources and access to decision-making members of the faculty can be counteracted by supplying cultural and social capital, satisfying the conditions for releasing inner motivations: self-determination, competence, and attachment/belonging, as demonstrated in Table 1.

Concluding reflections and recommendations

We have shown that by using action learning and action research as an approach to EE has a potential to foster democratic practices within the frame of hierarchical structures. The results suggest that teacher education might help to promote democratic processes in schools when local leaders are engaged in the process from the planning stage. We have demonstrated how the integration of PAR and action learning can be possible in the context of Tanzanian schools. Thus, we suggest that there is a need for teaching PAR and action learning during the education of teachers as a means to move power relations from hierarchical to democratic structures. We, therefore, recommend integration of PAR and action learning in the teacher education curriculum. We also recommend a holistic and system-oriented EE, addressing the leadership of teaching processes. It seems crucial that leaders at different levels of the educational system own the process and encourage teachers in order to sustain the changes that are made. Pre-service training is not enough to initialize such a holistic change in EE when there are so many teachers who are not educated in holistic ways of EE teaching. There is a continuous need for in-service training to equip teachers with the knowledge and skills to facilitate such processes of change. Besides, EE learning is a dynamic process and it faces continuous challenges because the environmental challenges themselves are changing. We also recommend further studies that emphasize EE: That includes more transformative changes alongside the formation of new and progressive values.

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Integrating Expert and Local Knowledge in Decision Making Over Land Use Management in Butuguri, Butiama District, Tanzania

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Abstract

Local people have developed knowledge of their lands based on soil and land characteristics that remain largely unknown to the scientific community because they cannot be easily quantified. Scientific community use methods for soil and land suitability evaluation that often perform poorly when predicting land productivity at local level because their approach exclude social and cultural aspects. Adaptation of land use systems used by local people with the help from scientific community is a key principle for sustainable land use management. This study documents the role of farmers and extension officers in quantifying land use requirements for sustainable production of cassava, maize and sorghum in Butuguri area, Tanzania. Five criteria important for production three crops were identified through literature and discussion with local farmers and extension officers. Analytic Hierarchy Process (AHP) method was used to analyse and rank the criteria. Results indicated that soil chemical fertility scored the highest value for cassava and sorghum production while rainfall scored the highest for maize production. Topography was ranked the lowest for maize and sorghum production while temperature was ranked the lowest for cassava production. The score weights for production attributes are not uniform for all land use types in an area. This type of information generated by local farmers with assistance of scientific tool provides key inputs when doing area and crop specific land use planning and management, thus increasing land and crop productivity, hence recommended to be used in agriculture.

Key words: Analytic Hierarchy Process (AHP), Butiama District, Butuguri area, Land evaluation

Introduction

Agriculture is one of the ancient land uses discovered by man (Araus and Slafer, 2011). Humans use 51% of the global habitable area for agricultural production (Roser and Ritchie, 2018). However, the amount and quality of land available for agriculture is under pressure from the decisions and demands made by consumers, producers, and governments. Due to pressure of use, the total land area available for agricultural production is finite and the marginal cost of transforming agricultural land is high, creating a potential constraint to population growth (Lans*et al*., 2014). Global food demand is expected to increase 60% by 2050, the rise will be much greater in Sub-Sahara Africa (Van Ittersum*et al*., 2016). Despise the high population (FAO, 2009), and expected 2.5-fold increase by 2050 (Van Ittersum*et al*., 2016), SSA agricultural productivity is stagnant or declining because of land degradation driven by inappropriate land use caused by poverty (Lambina*et al*., 2001). Agriculture (crop and livestock production), is the larger component of land use, contributing to climate change by producing greenhouse gases (Tubiello*et al*., 2015). Many farmers have

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completely eliminated fallow periods and are not compensating for nutrient losses by adopting soil fertility management techniques, such as cover crops, nutrient recycling and manure application (FAO, 2013). Also, SSA is lacking accurate information on the spatial and temporal patterns of agricultural land use and yield, hence no clear insights to guide future planning on sustainable agriculture, policy, and decision-making (Dias *et al*., 2016). To alleviate poverty, tackle land degradation and sustain the growing population in SSA, sustainable management and utilization of steady land for the present and future generations should be considered (Smith, 2018). Land use management can be done by insuring soils are considered when protecting important habitats and ecosystems to reduce the pressure on land from global change drivers (Smith *et al*., 2016).Only scientific knowledge on land use management in SSA is well documented leaving behind indigenous knowledge which becomes susceptible to disappearance due to technology change (Valipour, 2015; Nuwategeka and Nyeko, 2017). For sustainable land use, involvement of current and potential land users in the process of land evaluation need to be adapted (FAO, 1976; Massawe*et al*., 2019).

Interactions with the environment have made local people to accumulate local indigenous knowledge on soil and land suitability evaluation as well as to develop land use systems that are well adapted to the potentials and constraints of their land (Cools *et al*., 2003). Local people have knowledge of their lands based on soil and land characteristics that remain largely unknown to the scientific community (Buthelezi *et al*., 2013). Indigenous knowledge has traditionally been the most important source of information about agricultural practices and production of food and fibre in many rural communities in sub-Saharan Africa although it cannot be quantified (Ingram *et al*., 2010; Nuwategeka and Nyeko, 2017). However, land suitability evaluation by scientific community is done through soil survey and soil survey interpretation which farmers may not fully understand as it excludes social and cultural aspects (Verheye, 2009; Buthelezi *et al*., 2013). The methods used for soil and land suitability evaluation often perform poorly when it comes to predicting land productivity at local level because their approach is largely deductive (Cools *et al*., 2003). Suitability assessment has to be carried out in such a way that local needs and conditions are reflected well in the final decisions in which farmers do qualitative analysis by holistic knowledge of their land whereas scientists use quantitative analysis (Prakash, 2003; Ingram *et al*., 2010). Therefore, for scientific community to fully understand the micro-scale variations within farmer environments and therefore fine tune their recommendations to a specific environment, involvement of local people is needed.

Multi Criteria Decision Making(MCDM) is a decision analysis approach for sustainability (Proops and Safonov, 2004). It aims at improving decision making when a set of alternatives need to be evaluated on the basis of conflicting and incommensurate criteria (Mustafa *et al*., 2011). The MCDM processes use a scoring method to express the decision maker's preference in numerical value (Massawe*et al*., 2019). Analytic Hierarchy Process (AHP) one of Multi Criteria Decision Making method, is a decision making method under situation of uncertainty and with a number of factors compared (Saaty, 2008). It is used to handle quantified assessments of quality intangible attributes

(Alonso and Lamata, 2006; Czekster*et al*., 2019). Analytic Hierarchy Process can also be used by farmers because is very intuitive, easy to use and understandable and thus beats most of the other MCDM methods that have a solid mathematical background but are so complex that they can be used only by scientists and qualified decision analysts. Also it is superior to many other weighting methods because it can deal with inconsistent judgments by providing a measure of inconsistency (Massawe, 2015). This method combines quantitative and qualitative analyses. Qualitative analysis is used to express subjective judgment and experience of people which is commonly done by local people (Huang *et al*., 2007) while quantitative analysis process subjective judgment of people mathematically to give an index on a sliding scale which is mostly done by scientific community (De la Rosa and Van Diepen, 2002). Analytic Hierarchy Process can be used to access suitability of agricultural land for different crop production (Mustafa *et al*., 2011; Akinci*et al*., 2013; Maddahi*et al*., 2014). However, mostly it has been done involving scientific community only.

Land use requirements are explained in terms of land quality to determine the suitability of a particular land unit for particular land utilization type (FAO, 1983). Land use requirement relates to: physiological requirement of crops, management for the land utilization type and conservation requirements in which land utilization type must be operated in sustained basis (FAO, 1993). Different land uses have different requirement hence require different management. However many farmers and extension officers are not aware of this. This study aimed at involving farmers and extension officers in quantifying land use requirements for sustainable production of cassava, maize and sorghum in Butuguri area, Tanzania using AHP, one of Multi Criteria Decision Making method.

Materials and Methods

The study area

The study was conducted in Butuguri area located in Butiama District in Mara Region covering Busegwe and Butuguri Wards (Fig. 1). The area was chosen because of poor crop production experienced by farmers in the area with poor scientific intervention to factors contributing to poor production.The study occupy the area lying between 598 530 and 610 754 m Northings and 980 8624 to 980 9316 m Eastings (zone 36o S of Universal Transverse Mercator).The area receives both short and long rains in which the average annual rainfall ranges between 600 to 1200 mm (Butiama District Profile, 2013). Short rains last from September to January and long rains last from March to May. Its altitude is about 1200 – 1600 metres above sea level (m.a.s.l.). The average annual temperature is 21oC (Mara Region Profile, 2003). The study area is used by smallholders farmers for growing cassava, maize, sorghum and cotton. The area is characterized by grass and scattered woodlands together with bushes and shrubs with invasive plant species such as devil weeds (Chromolaenaodorata) and lantana (Lantana camara). The soils of the area are generally sandy soils.

Figure 1: Study area

Identification of important criteria for growing cassava, maize and sorghum in the area

To get information about criteria important for growing cassava, maize and sorghum in the area, literature review and opinion from local extension officers and farmers of the area were consulted. Two local extension officers assigned in the area were involved, while six farmers were randomly selected from Butuguri and Busegwe Ward. With the help of extension officers, farmers engaging in production of cassava, maize or sorghum were chosen. After discussing the important criteria for growing crops in the area, common agreement was reached that soil physical properties, soil chemical properties, rainfall, temperature and topography are important criteria for crop production. The three staple crops in the area were considered; they included cassava, maize and sorghum.

Ranking of identified criteria for growing crops in Butuguri area

The ranking was done using a theory of measurement of relative intangible criteria known as Analytical Hierarchical Process (AHP) in which a scale of priorities is derived using pair-wise preference matrix by comparing criteria to each other (Saaty, 2014). Farmers and extension officers were the domain experts in this activity. Using a fundamental scale or AHP preference scale 1 to 9 (Table 1), farmers and extension officers translated the verbal judgment to numerical value and formed the paired comparison matrices. Through guidance from researcher, farmers and extension officers categorized five criteria which were soil physical properties, soil chemical fertility, topography, temperature and rainfall into hierarchies. Criteria importance or priority was scaled by the number of levels in the hierarchy in which soil physical properties and soil chemical fertility come first as they were considered as most important criteria estimating probabilities of best-case followed by rainfall as moderate important or intermediate-case one and lastly by temperature and topography as least important criteria. A set of pair-wise comparison matrices was constructed in which each element in an upper level was used to compare the elements in the level immediately below with respect to it (Saaty 2008). The comparison (preference) matrices were used as inputs in BPMSG AHP online priority calculator (Goepel, 2018). The outputs from the calculations were the consistence ratios (CR), the Principal Eigen

values and weights of the criteria. The weights were then used to rank the criteria from most important to least important (Massawe*et al.*, 2019). A consistency ratio (CR) was calculated to determine whether or not the scoring groups had been consistent with their scoring. Revisions of the preference matrices were done for all pair-wise comparisons showing inconsistent judgment when Consistency Ratio (CR) was above 10%. Ranking and weighing was done for all three crops to measure score weights difference for different land use types. Ranking and weighing was firstly done separately by farmers and extension officers then it was jointly done. Independent ranking aimed at making them familiar with the exercise before joint ranking.

Table 1: AHP preferences scale

APH scale of importance for comparison pair	Numeric rating	Reciprocal decimal
Equal importance	1	1 (1.000)
Equal to moderately	2	1/2(0.500)
Moderate importance	3	1/3(0.333)
Moderately to strong	4	1/4 (0.250)
Strong importance	5	1/5(0.200)
Strong to very strong	6	1/6(0.167)
Very strong importance	7	1/7(0.143)
Very strong to extremely	8	1/8(0.125)
Extremely importance	9	1/9(0.111)

Source: Alexander (2012)

Results and discussion

The ranking results are explained below crop-wise. The results are based on joint ranking exercise using AHP method by a group of farmers and extension officers of Butuguri area.

Cassava

The decision matrix suggested jointly by the farmers and local extension officers for cassava is shown on Table 2.

Table 2: Cassava suitability analysis criteria preference matrix

	Soil physical properties	Soil chemical fertility	Rainfall	Temperature	Topography
Soil physical properties	1	1	1	3	2
Soil chemical fertility	1	1	2	7	3
Rainfall	1	0.5	1	4	6
Temperature	0.33	0.14	0.25	1	1
Topography	0.5	0.33	0.17	1	1

The values of Table 2 reflect the domination of soil physical properties, soil chemical fertility and rainfall criteria over temperature and topography in cassava production.

The criteria weights calculated from the decision matrix and their respective rankings

are shown on Table 3.

Table 3: Criteria weights and ranks for cassava suitability analysis

Criteria	Weight	Rank
Soil chemical fertility	34.9%	1
Soil physical properties	27.3%	2
Rainfall	23.2%	3
Topography	8.1%	4
Temperature	6.5%	5

The criteria weights and their respective rankings showed that soil chemical fertility received highest priority by scoring 34.9% as both famers and extension officers agreed that soil chemical fertility is a very important requirement to be considered when growing cassava. Although cassava is believed to produce reasonable yields in areas with poor soil fertility (Boansi, 2017),continuous cultivation of the soilsand partial/no use of soil inputs result into poor cassava production (Ettien*et al*., 2016). Sustainable cassava production depend on good chemical fertility especially micronutrients (Ande, 2011). The result of some trials done in the area by the International Institute of Tropical Agriculture (IITA) showed that plots with fertilizers resulted into better production compared to control plots. Fertilization modified the nutritional status of the cassava stakes resulting into production of high quality planting materials which was sold to other farmers. This was also done in Columbia producing the same results (Molina and El-Sharkawy, 1995). Soil physical properties were ranked second by scoring 27.3% revealing its importance in growing cassava. Soil texture was very important in growing cassava as cassava prefers sandy soils. This texture also allowed easy growth, extension and harvesting of cassava roots (Ande, 2011). However, most sandy soils had lower organic matter content(Ettien*et al*., 2016).

According to priority made, rainfall was ranked third as one of the important criteria for growing cassava by scoring 23.2%. This came due to the fact that although cassava can withstand periods of drought, it is very sensitive to soil water deficit during the first three months after planting (FAO, 2013). Farmers and extension officers together agreed that cassava prefers high amount of rainfall at planting than during other stages of growth. Temperature was given the lowest weight (6.5%) as the temperature of the area did not affect crop growth. Considering topography which scored 8.1%, farmers and extension officers considered this attribute as important for growing cassava due to the fact that the area had highlands which have good texture for cassava production and lowland which do not support cassava production due to poor infiltration resulting from high clay amount resulting from deposited soil emanating from erosion in highlands (Klingebiel*et al*., 1988).

Maize

The decision matrix suggested jointly by farmers and local extension officers is shown on Table 4.

Table 4: Maize suitability analysis criteria preference matrix

	Soil physical properties	Soil chemical fertility	Rainfall	Temperature	Topography
Soil physical properties	1	0.5	0.5	6	2
Soil chemical fertility	2	1	1	9	7
Rainfall	2	1	1	6	7
Temperature	0.17	0.11	0.17	1	2
Topography	0.5	0.14	0.14	0.5	1

The values of Table 5 reflect the domination of soil physical properties, soil chemical fertility and rainfall criteria over temperature and topography in maize production.

The criteria weights calculated from the decision matrix and their respective ranking jointly by farmers and extension are shown on Table 5.

Table 5: Criteria weights and ranks for maize suitability analysis

Criteria	Weight	Rank
Rainfall	41.3%	1
Soil chemical fertility	32.6%	2
Soil physical properties	17.2%	3
Temperature	5%	4
Topography	4%	5

Rainfall received the highest weight in joint group ranking by scoring 41.3% which came as a result of emphasis given to this criterion. The importance of rainfall came on considering the total crop failure or poor yields experienced by both extension officers and farmers when there is no or little amount of rainfall. This was highly contributed by the sandy soil texture of the area as it stores less moisture while water is highly needed by crops during the planting period (IITA, 1982; Jalota*et al.*, 2010).

Soil chemical fertility was ranked as the second most important criterion for growing maize by scoring 32.6%. The criterion was given second priority as the parameter which supports the growth and productivity of maize. The criterion importance came due to it is limiting nature in maize production which came as a result of continuous cultivation of the land without adding inputs for fertilizing the land and sandy soils which have a low potential to retain nutrients (Chikuvire*et al.*, 2007). This was highly contributed by lack or poor access to fertilizer (Droppelmann*et al.*, 2017). Soil physical properties followed in ranking of the attributes by scoring17.2%. The criterion was considered important in growing maize by both farmers and extension officers considered. Soil texture strongly determines water holding capacity of soil (Li *et al.*, 2013). Farmers and extension officers mentioned that soil texture of the area affected maize production as it does not retain water and nutrients. Temperature and topography was considered less

important in ranking by scoring 5.0% and 4.0% respectively. This was due to their less influence in maize production in the area.

Sorghum

The decision matrix suggested jointly by the farmers and local extension officers for sorghum is shown on Table 6.

Table 6: Sorghum suitability analysis criteria preference matrix

	Soil physical properties	Soil chemical fertility	Rainfall	Temperature	Topography
Soil physical properties	1	0.5	0.25	6	4
Soil chemical fertility	2	1	1	6	8
Rainfall	4	1	1	9	7
Temperature	0.17	0.17	0.11	1	2
Topography	0.25	0.13	0.14	0.5	1

The values of Table 7 reflect the domination of soil physical properties, soil chemical fertility and rainfall criteria over temperature and topography in sorghum production.

The criteria weights calculated from the decision matrix and their respective rankings are shown on Table 7.

Table 7: Criteria weights and ranks for sorghum suitability analysis

Criteria	Weight	Rank
Soil chemical fertility	36.9%	1
Rainfall	33.8%	2
Soil physical properties	18.6%	3
Temperature	5.5%	4
Topography	5.2%	5

Soil chemical fertility was considered as the most important attribute for growing sorghum by farmers and extension officers by scoring 36.9%. The ranking was made considering how wide the criterion supported sorghum production. This is because farmers and extension officers experienced high production of sorghum in areas with good fertility. Rainfall was the second criterion to receive high weight by scoring 33.8% showing how it suitably supports sorghum production. This is due to the argument made considering the criterion negatively affects sorghum production in the area. A medium to good and fairly stable rainfall pattern during the growing season is suitable for sorghum production (FAO, 2013). In the area, rainfall is important to moisten the soil which is sandy in nature. Hence sorghum is grown in the early time of the rainy season when there is good moisture in the soil. When there is rainfall delay many farmers do not grow sorghum at all as they cannot get good harvest due to early

drought which stops growth before floral initiation. Considering soil physical properties, farmers and extension officers named it as one of the important criterion for sorghum production by giving weight of 18.6%. Sorghum mainly grown on low potential, shallow soils with high clay content but it grows poorly on sandy soil which is common in the area (DAFF, 2010). Temperature and topography received the lowest weight by scoring 5.5% and 5.2 respectively. The ranking came because the criteria had less effect on sorghum production in the area.

Conclusion

This work involved farmers in a land use management process whereby five attributes identified as important for cassava, maize and sorghum production were scored and ranked using AHP. Farmers and extension officers agreed that soil chemical fertility, soil physical properties and rainfall were the most important attributes for growing all the crops in the area compared topography and temperature. However farmers seemed to have poor management of soil by growing these nutrient mining crops without any replenishment. Filed close follow-up by extension officers and awareness about importance of soil replenishment especially use of fertilizers both organic and inorganic is necessary for sustainable land and crop productivity in this area.

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Nutrition Status of Children 0-23 Months of Age: Comparison of Pastoralist and Crop Farming Communities in Mvomero District, Tanzania

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Abstract

A livelihood system of community is an essential first step that identify the options they have for improving food security, and hence nutrition status of all household members. This study aimed to determine nutritional status of children below two years of age among pastoralist and crop farming communities in Mvomero district. This cross-sectional study involved 348 mothers/caregivers from Mvomero district, Morogoro (206 from crop farming and 142 from pastoralist households). ProPAN standardized research tools and procedures were adopted for data collection and analysis. Socio-demographic information was collected using caregiver survey. Nutritional status of the children was determined using anthropometric indicators. Data were analysed using ProPAN software and t-test and Chi-square test were done in SPSS software to determine t differences between socio-demographic characteristics, stunting, wasting and underweight in the two communities. Mean age of mothers/caregivers was 26 years and of the studied children was 12 months. About 35% of pastoralist and 7.3% of crop farmers caregivers had no formal education. Most of the mothers in crop farming delivered at the health facility (89%) but pastoralists delivered mostly at home (50.7%) or at the traditional birth attendant house (39%).About one third (33.5%) of the children were stunted and there was no significant difference in prevalence of stunting in the two communities. Prevalence of stunting was similar in both communities; Overall prevalence of underweight was 13% and wasting was 3.3%, with relatively higher prevalence among children in pastoralist compared to crop farmers. h, underweight and wasting was relatively higher in pastoralist than in crop farming communities. Encouraging women to attend antenatal and postnatal clinic is necessary. Further studies to explore the factors contributing to high rates of wasting and underweight among pastoralists are warranted.

Key words: Nutritional status, pastoralists, farmers, Tanzania

1 Introduction

Malnutrition is a state of poor nutritional status, which is the result of inadequate or excess intake of nutrients by the body.It is the main cause of morbidity and mortality in infants and children under five years of age, accounting for at least half of all childhood deaths worldwide (UNICEF 2019).It is also recognized as the underlying cause of related deaths of childhood disease such as measles, diarrhoea and acute respiratory infectious diseases (Caulfield *et al*., 2004). Globally, it estimated that 154.8 million of under-five children were stunted and 51.7 million wasted of which 151.9 million and 50.7 million of stunted and wasted children lived in developing countries(UNICEF, WHO and WB 2016).

Stunting is the term used to describe a condition in which children fail to gain sufficient height, given their age. It is caused by long term factors such as chronic malnutrition, especially protein-energy malnutrition, repeated infection, and inadequate psychosocial

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stimulation (WHO, 2017). Some researchers pointed out that the effects of stunting last for lifetime; they include underdeveloped brain leading to diminished mental ability and learning capacity hence poor school performance in childhood. Also reduced earnings and increased risks of nutrition-related chronic diseases, such as diabetes, hypertension, and obesity in later stages of life (Victora *et al*., 2008; Dewey and Begum, 2011). Stunting is almost always irreversible but it can be prevented by improving nutrition for women and children in the first 1,000 days. In Tanzania, there has been progressive decline in prevalence of stunting from about 42% in 2010 to around 34% in 2015 (TDHS-MIS, 2016).

Underweight is the term used to describe a situation where a child weighs less than expected, given his or her age(WHO, 2017). It reflects current, acute as well as chronic malnutrition. Underweight have impact on child survival and development as it increases children's risk of death, limits their cognitive development, and affects health status later in life (Rodríguez *et al*, 2011; Black *et al*., 2008). In Tanzania, the proportion of children below five years with low height for age is about 14% and in Morogoro region it was 11.5% (TDHS-MIS, 2016).

Wasting, or low weight for height, is another form of undernutrition. It is a strong predictor of mortality among children below five years of age (Schaible and Kaufmann, 2007; Victora *et al*., 2008). It is usually the outcome of acute significant food shortage and/or disease which affect food intake or nutrients utilization of an individual. It results from low birth weight, inadequate diet, poor care practices and infections (FAO, 2017). Wasting is prevalent in many of the developing countries mainly due to food insecurity, poverty, natural disasters and political instabilities (Kerac *et al*., 2011). In Tanzania, proportion of children below five years with low height for age is about 4%(TDHS-MIS, 2015-16). Generally, there is great variation in prevalence of undernutrition across regions and sometimes high prevalence observed in the Tanzanian regions with high food production.

Malnutrition, particularly undernutrition, mainly affects the most vulnerable and most disadvantaged populations, especially children, women and rural communities.A study by Mboera *et al*. (2015) in Kilosa, Tanzania indicated that there are variations in terms of risk to diseases and nutritional statuses between communities living in different livelihoods practices where by children from the rice growing households had larger number of the underweight children than the pastoral households. Another study which compared nutritional status of children from Maasai, Rangi, Meru and Sukuma reported that the Maasai are substantially disadvantaged compared to neighboring ethnic groups and signs of vulnerability showed to increase with relying on livestock keeping (Lawson *et al*.,2014).

Generally, most studies done to assess nutritional status rarely considered analysis by livelihood profiles. This study therefore aimed at assessing nutritional status of children among pastoralists and crop farmers of Kilosa district, Morogoro. The results will help to plan and properly target nutrition interventions in the respective communities.

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3.0 Materials and Methods

3.1 Description of the Study Area

The study was conducted at Mvomero district; one among the seven districts of Morogoro region. Mvomero District is located at North East of Morogoro region between 6°00′ and 8°00′ latitudes south of Equator also between longitudes 36°00′ and 38°′ East of Greenwich. The district has a total area of 7325 km squared and a total population of 312 109;of which 154 843 are males. Administratively, Mvomero is made up of four divisions, 17 wards, and 128 registered villages. According to 2012 National census, the average household size was 4.3 people per household (URT, 2013).

The district has two rainfall seasons annually, with a long wet season extending from March to May and a short wet season from October to December. Majority of the district's population derive their livelihood from crop farming growing paddy and maize and only the population in the southern part of the district depends primarily on livestock keeping, raising goats and traditional zebu cattle.

The study was conducted at Sokoine and Kimambira villages in Sokoine and Kisongo wards, respectively. Both villages have a mixture of communities of interest (crop farming and pastoralists communities).

3.2 Study Population, sample size and sampling procedure

This cross sectional study comprised of caregiver-child pair. Purposive sampling was applied to select the villages with a mixture of both the crop farming and pastoralist communities. Simple random sampling was used to select the 348 households with children aged zero to 23 months from the selected villages.For the households with more than one child under 24 months of age, the youngest one was selected. Children with any form of disability, seriously sick and those who were temporary visitors in the study area were excluded from the study.

3.3 Sample size

The sample size was computed using the following formula (Fischer *et al*., 1991);

$n=z^2pq/d^2$

Whereby:

n = desired minimum sample size, Z = the standard normal deviate corresponding to 95% Confidence Interval, p = the proportion of an indicator measured, q = 1- p

d = degree of accuracy or desired precision

Taking the prevalence of stunting in Morogoro 33% or 0.51 (NBS, 2015), Z statistic corresponding to 95% confidence interval for a two-tailed test as 1.96, and degree of accuracy at 0.05, the sample size from this calculation was:

$n = (1.96)^2 \times 0.33 \times 0.67/ (0.05)^2 =339.7$ approximately 340 participants. A total of 357 households were selected which included 5% of non-response.

At the end of data collection, questionnaires from 348 household were complete and analysed that represented 206 households from crop farming) and 142 households from pastoralist. More respondent recruited from crop farming because there is high proportion of households practicing crop farming compared to pastoralist in the

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studied area.

3.4 Data Collection

ProPAN research tools were adopted for data collection. The forms and guides used were: structured caregiver questionnaire applied to all caregivers of children from 0-23 months of age while anthropometry measurements were taken from children of age 6-23 months old (PAHO, 2004).

3.4.1 Interviews

Face to face interviews were conducted to all 348 caregivers. The care giver survey questionnaire comprised question on socio-economic status and demographic characteristics; breastfeeding and complementary feeding practices; utilization of health facilities and other services; and on household hygiene and sanitation.

3.4.2 Anthropometric measurements and determination of nutrition status of the children

Child's weight and length were measured to identify the current prevalence of underweight, stunting and wasting in 269 children between 6-23 months in crop farming (N=156) and pastoralist (N=113) communities. Weight of the child was measured using UNICEF Mother/Child electronic scale manufactured by SECA (Seca gmbh and co. kg, Hammer Steindamm 3-25 22089 Hamburg Germany) and it was recorded to nearest 100g (0.1 kg). Before the child was weighed, the scale was adjusted to zero. Caregiver was allowed to stand on a scale allowing her weight to be recorded within the system of the scale and then set to zero. The child was then handed over to the caregiver while still standing on the scale and the new weight of the child was displayed and recorded.

Length of the child was measured using a measuring board (Shorr Productions, Perspectives Enterprises & Portage, Missouri USA) reading a maximum of 200cm and capable of measuring to the nearest 0.1 cm. The measuring board was placed on a hard flat surface. The child was placed with the face upward, the head towards the fixed end and the body lying parallel to the long axis of the board. The shoulder-blades rested against the surface of the board. The child was measured while barefooted with the toe pointing directly upward and the child's knees kept straight. The movable footboard piece was placed firmly against the child's heels. The measurements were taken to the nearest 0.1 cm and recorded in the anthropometric form. The nutritional indices used for assessing nutritional status of children in this study were weight- for -age z-score (WAZ), height-for -age z-score (HAZ) and weight –for-height z-score (WHZ). Child's degree of malnutrition of either normal, moderate or severe was interpreted using (WHO, 1995) growth references standards.

Before data collection, questionnaires were pre-tested in 10 randomly selected households at Kikuyu ward in Dodoma Municipality. Appropriate corrections were then made to modify questions that were found to be unclear to the respondents before the actual data collection. Enumerators were trained for four days prior to data collection.

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3.5 Data Processing and Analysis

Quantitative data of caregiver survey and anthropometry were entered and analyzed separately using ProPAN softwarewith Epi-info (PAHO, 2004). Thereafter, Z-score generated from anthropometric data and quantitative outputs from caregiver survey were imported into SPSS Version 21 for windows for further analysis. Independent t-test and Chi-square were used to test the significance difference between the two communities.

3.6 Ethical Issues and Permission to Conduct the Study

The permit to conduct research was obtained from Sokoine University of Agriculture. Permission was also sought from the Mvomero District, wardand village authorities. Before administering questionnaires, enumerators explained to the caregivers why they are being sought for interviews and requested their consent to participate in the study. Written consent was used as the study needed some personal information. Enumerators were required to always carry identification and introduction letter describing the research purpose and explaining their presence in the community.

4.0 Results

4.1 Socio-demographic Characteristics of the Caregivers and the Children

A total of 348 children below 24 months from crop farming (n =206) and pastoral (n = 142) households were involved in this study. Mean age for children was about 12 months and mean age of caregivers was about 26 years in both communities but most pastoralist mothers were relatively in a younger age category. The pastoralist households had mean household size of 8.4 while that of crop farming was 5.2. About one third of pastoralist caregivers had no formal education compared to only 7% of the farming communities (Table 1).

Table 1: Characteristics of caregivers and children 0-23 months of age

Variables	Crop farming (n=206)		Pastoralist (n=142)		P-value
	n	%	n	%	
Age of the children (months)					
0 – 5	39	19.0	23	16.2	0.521
6 -11	53	25.7	41	28.9	
12-17	60	29.1	41	28.9	
18 -24	54	26.2	37	26	
Sex of the children					
Male	97	47.1	68	47.9	0.986
Female	109	52.9	74	52.1	
Maternal age (years)					
<18	5	2.4	16	11.3	0.039
18 – 24	62	30.1	55	38.7	
25 -35	110	53.4	45	31.7	
>35	29	14.1	26	18.3	
Marital status					
Married	181	87.8	142	100	0.000
Single	25	12.3	0	0	

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Maternal education level					
Informal education	15	7.3	50	35.2	0.000
Primary education	158	76.7	83	58.5	
Secondary education and post-secondary	33	16	9	6.3	
Maternal occupation					
Laborer	171	83	139	97.9	0.000
Vendor	17	8.2	3	2.1	
Agriculture work	8	4	0	0	
Formal employment	10	4.8	0	0	

4.2 Use of Health Services

Almost all mothers (99.4%) attended antenatal clinic at least once during the course of the last pregnancy. Among these, only 18.4% and 3.5% from crop farming and pastoralist communities respectively reported to attend ANC clinic more than three times. Significantly more mothers (89%) in crop farming households delivered in health facilities compared to only 9% from pastoralist households ($p<0.05$). Likewise, significantly larger proportion of caregivers in crop farmingthan in pastoralist received infant and young child information within the previous three months ($P<0.05$) (Table 2).

Table 2: Use of health services

	Crop farming n =206		Pastoralist n=142		P-value
	n	%	n	%	
Number of ANC visits					
Never	1	0.7	1	0.7	0.859
Once	14	6.8	19	13.4	
Twice	34	16.5	92	64.8	
Thrice	110	53.4	17	12.0	
More than thrice	38	18.4	5	3.5	
Not sure	9	4.4	8	5.6	
Place of delivery					
In health facility	185	89.8	13	9.2	0.000
At home	17	8.2	72	50.7	
At TBA's house	4	2.0	56	39.4	
On the way to hospital	0	0	1	0.7	
Assistance during delivery					
Health professional	184	89.3	13	9.1	0.000
TBA	18	8.7	65	45.8	
Untrained person	4	2.0	64	44.4	
Attend growth monitoring clinic					
Yes	202	98.1	133	93.7	0.049
No	4	1.9	9	6.3	
Caregivers received information on child feeding					
Yes	76	37	19	13.4	0.000
No	130	63	123	86.4	
Children aged 6-59 months who had received vitamin A in the last 6 months					
Yes	161	97.0	107	90	0.034
No	5	3.0	12	10	

4.3 Water Availability and Sanitation

The main source of water for households in both communities were surface water precisely dams; accounting for 59.2% and 90.8% in crop farming and pastoralist communities respectively. Majority of mothers in both livelihoods spent less than an hour to go fetch water and come back. Water was rarely treated to make it safe for drinking, for those who treated it, crop farmers were mostly boiling or adding chlorine while pastoralists just left the water to settle. Almost all households in farming communities had latrines which was a rare facility among pastoralists (Table 3).

Table 3: Water availability and sanitation

Variable	Crop farming (n=206)		Pastoralist (n=142)	
	n	%	n	%
Source of water				
Surface water (dam, river, pond, canal, irrigation channel)	122	59.2	129	90.8
Protected well	24	11.7	7	4.9
Tap	59	28.6	5	3.5
Rainwater collection	1	0.4	1	0.7
Time spent to collect water				
Less than 30 minutes	162	78.6	88	62.0
30 minutes or more	44	21.4	54	38.0
If anything is done to water to make it safer to drink				
Yes	71	34.5	22	15.5
No	135	65.5	120	84.5
Procedure(s) done to make water safer to drink				
Boil	19	26.8	1	4.5
Add bleach/chlorine	25	35.2	1	4.5
Strain it through a cloth	9	12.7	0	0
Use water filter (ceramic, sand, composite, etc.	3	4.2	0	0
Let it stand and settle	15	21.1	20	90.9
Type of toilet facility used by household's members				
Flush toilet	25	12.1	2	1.4
Pit latrine	179	86.9	19	13.4
No facility, bush, field	2	1	121	85.2

4.4 Nutritional Status of the Surveyed Children

Generally, about a third of the children (33.5%) were stunted (low height-for-age), 13% were underweight (low weight-for-age) and 3.3% were wasted (low-weight-for height). There was no significant difference in prevalence of stunting, but underweight and wasting were significantly higher among children from pastoralist households (Table 4).

Table 4: Nutrition status of the surveyed children 6-23 months

Nutrition status	Communities				Overall prevalence n=269		P-value
	Crop farmers n=156		Pastoralist n=113				
	n	%	n	%	n	%	
Weight-for-Age (WAZ)							
Normal	137	87.8	97	85.8	234	87.0	0.023
Moderate	18	11.5	13	11.5	31	11.5	
Severe	1	0.6	3	2.7	4	1.5	
Overall underweight	19	12.2	16	14.2	35	13.0	
Height for age (HAZ)							
Normal	103	66.0	76	67.3	179	66.5	0.440
Moderate	39	25.0	28	24.7	67	25.0	
Severe	14	9.0	9	8.0	23	8.5	
Overall stunting	53	34	37	32.7	90	33.5	
Weight for Height (WHZ)							
Normal	152	97.4	108	95.6	260	96.6	0.001
Moderate	3	2.0	3	2.6	6	2.2	
Severe	1	0.6	2	1.8	3	1.1	
Overall wasting	4	2.6	5	4.4	9	3.3	

When age of children was categorized in two groups: 6-11 and 12-23.9 months; older children group (12-23 months) in crop farming households had a higher proportion of stunted children (44.3%) compared to younger age group (6-11 months) (12%). Pastoralist households showed similar cases of stunting where by older children were more stunted (41.1%) compared to the younger age group (17.5%). Likewise, more children of older category were more underweight compared to younger children in both communities. Furthermore, proportion of wasted children in older age category (2.8%) in crop farming community was slightly higher than that of younger children (2%) but the case was different in pastoralist community whereby younger children were more wasted (5%) compared to older children (4.1%).

Table 5: Nutritional status by age categories Age categories of children in months

Crop farming community	Age categories			
	6-11 (n=50)		12-23 (n=106)	
Communities/ Nutrition status	N	%	n	%
Weight for age				
Normal	46	92.0	91	85.8
Underweight	4	8.0	15	14.2
Total	50	100	106	100
Height-for-age				
Normal	44	88.0	59	55.7
Stunting	6	12.0	47	44.3
Total	50	100	106	100
Height-for-weight				
Normal	49	98.0	103	97.2
Wasting	1	2.0	3	2.8
Total	50	100	106	100
Pastoralist community	**6-11 (n=40)**		**12-23 (n=73)**	

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	N	%	n	%
Weight for age				
Normal	35	87.5	62	84.9
Underweight	5	12.5	11	15.1
Total	40	100	73	100
Height-for-age				
Normal	33	82.5	43	58.9
Stunting	7	17.5	30	41.1
Total	40	100	73	100
Height-for-weight				
Normal	38	95.0	70	95.9
Wasting	2	5.0	3	4.1
Total	40	100	73	100

5.0 Discussion

This study sought to assess nutritional status of children among pastoralists and crop farming communities of Kilosa district. Overall prevalence of stunting was 34% and no significant difference was observed between the two livelihoods. Stunting prevalence in both communities was higher according to WHO (2010) classification of severity of malnutrition in a community.High prevalence of stunting could be due to poor feeding practices which include delay in initiation of breastfeeding, early complementation and inadequate complementation practices. Delaying initiation of breast feeding deprives infant nutritional benefit of colostrum and impedes nutritional status. Inappropriate breastfeeding and delaying on initiation of breastfeeding was reported in Tanzaniaand only 59% of children are exclusively breastfed in Tanzania (Safari *et al*., 2015, TDHS – MIS 2016). Another reason could be due to poverty and ignorance where most complementary foods provided to young children lack essential nutrients for child growth; young children are always given maize porridge mixed with sugar or salt only. Similar findings were reported in the study conducted in rural central Tanzania (Mamiro *et al*., 2005, Kulwa *et al*., 2015,). It was also similar to the country prevalence according to TDHS-MIS (2016). The observed similar prevalence of stunting could be a result of the nature of the foods given to children below two years in the rural communities. In this study, children were commonly given maize porridge and ugali with limited intake of animal source foods (Kibona *et al*., 2019).

About one in ten children was underweight. According to WHO (2010) category, the study subjects were in the medium rates (10-19%) of underweight. The underweight prevalence observed could be contributed by food insecurity and poverty. Underweight can also vary with season; hence the observed rates could be higher in studies done during food shortage. A study by Lawson *et al*. (2014) conducted in Tanzania to compare nutritional status of children from Maasai, Rangi, Meru and Sukuma tribes reported similar findings where the Maasai were substantially disadvantaged compared to neighbouring ethnic groups and signs of vulnerability showed to increase with relying on livestock keeping.Another reason could be the social demographic characteristics of the studied mothers/caregivers. Most of the pastoralist mothers were marriedhence a possibility of less decision on childfeeding in the household. In most African culture, the husband and adult women may have an influence on when and

what the child should be given.Education level could also be a contributing factor. It was observed in this study that most mothers from pastoralists had informal education and they were younger that contributes to their limited power to make decisions. The prevalence of underweight obtained in this study was lower than the national average, which was 16% (TDHS- MIS, 2016).

Overall prevalence of wasting was 3%, with significantly more wasted children among pastoralists. Wasting may happen after short time food shortage or starvation or due to illness. Exposure to unhygienic condition could increase the risk of illness or parasitic infestation and lead to wasting. The common source of water for household use was the surface water from ponds and rivers which was rarely treated. Untreated water could be a source of contamination especially because the pastoralists were seldom using latrines. According to WHO, wasting rates of less than 5% are acceptable (WHO 2017); hence prevalence of wastingobserved in both communities was not of public health significance. The prevalence was lower than the Morogoro regional average (6%) and national average 5% (TDHS-MIS 2016).Other studies conducted in other rural districts in Tanzania showed high prevalence of underweight (Safari *et al*., 2015, Mgongo *et al*., 2017,). It has been reported that nutritional status of children can vary according to seasons, with relative high prevalence of underweight in the lean season compared to harvest season (Roba *et al*., 2016). Longitudinal study to assess seasonal variation in prevalence of wasting could give a better picture, hence may be considered in future studies.

It is important to note that, in this study the prevalence of malnutrition in children from both communities increased with the increase in age of the children. This may be attributed to the fact that at 6 months or earlier, children were introduced to family meals, which may be insufficient to meet their physiological demands of rapid growth and that they were becoming more able to feed by themselves and hence could be more exposed to food-borne pathogens (Dewey, 2013). Similar trend of undernutrition was reported in a study done in Simanjiro (Nyaruhucha *et al*., 2006). A study done by Mgongo *et al*. (2017) found that the odds ratio of being underweight increased with the increase in child's age.

It was common to deliver at home or at the traditional birth attendants (TDAs)house among pastoralists than the crop farmers. Attending to health facilities usually expose the mothers to meeting the health care providers and the peers hence possibility of receiving education or sharing experiences. Health facility is a source of pregnancy and child care information, education on infant and young child feeding, sanitation and hygiene and family planning which all together contribute to improved nutrition status of the children.

6.0 Conclusion and recommendations

Prevalence of underweight and stunting in both communities were above recommended acceptable threshold levels. Prevalence of stunting was similar in both communities; however, underweight and wasting was relatively higher in pastoralist than in crop farming communities. Encouraging women to attend antenatal and

postnatal clinic especially among pastoralist communities is necessary to improve their knowledge on proper child care and feeding practices so as to improve nutritional status. Further studies to explore the factors contributing to high rates of wasting and underweight among pastoralists are warranted.

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Personality Traits of Selected High Performing Lead Farmers in Projects Applying the RIPAT Approach in Tanzania

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Abstract

The Training and Visit (T&V) and Farmers Field School (FFS) approaches of delivering agricultural extension are facing some challenges which have necessitated a look into community based approaches focusing on a broader reach and cost-effectiveness hence, the use of lead farmers (LFs) has become important in recent years. However, the selection of LFs has mainly been based on socio-economic characteristics with limited consideration of personality traits. This paper examines the process of selecting high performing LFs based on the commonly used socio-economic characteristics but with a personality traits lens. Using a cross-sectional research design A sample of 384 farmers was selected randomly from a population of 1,800 farmers. Primarily data was analyses using SPSS whereby variables related with socio-economic characteristics of LFs and Non-Lead Farmers (NLFs) were compared using Chi-square test, and the results show that significant differences existed between LFs and NLFs in relation to households labour and size of the land cultivated. The assessment of personality traits fits for high performing LFs using the Big Five Personality Trait Model and Friedman test has shown that high performing LFs had personalities related with openness (being curious, wide range of interests and independent) and consciousness (hardworking, dependable and organized). It is therefore recommended that personality traits related with openness and consciousness should be considered for selection of high performing LFs.

Key words: Lead farmers, Personality traits, Socio-economic characteristics and RIPAT.

1.0 Introduction

The modalities of conducting agricultural extension through Training and Visit (T&V) and Farmers Field Schools (FFSs) are changing due to the challenges encountered, including inadequate operational funds (Ahmad, 2007; Wambura *et al.*, 2012; Gabagambi, 2013), and few extension agents compared to the number of farmers to be advised (Hella, 2013). Other challenges necessitating the change in modalities of

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extension delivery include the increasing pressure on land and other resources (Ringo *et al*., 2018), and the need to train farmers to raise productivity through the use of new technologies (Bekele *et al*., 2017). Some of the more promising steps to deal with the challenges have been to adopt organic (community-based) approaches focusing on broader reach (Franzel and Simpson, 2013; Bekele *et al*., 2017), cost-effectiveness and sustainability of their efforts beyond the investment cycle (Simpson *et al*., 2015). Among these organic approaches is the Rural Initiatives for Participatory Agricultural Transformation (RIPAT), which extensively makes use of Lead Farmers (LFs). According to Scarborough *et al*. (1997), LFs are defined as individual farmers who have been selected by the community to perform technology-specific activities in Farmer to Farmer Extension (provision of training by farmer to other farmers) whereby they get trained in the use of the technology. Under the RIPAT approach, LFs are those individuals who, during the project implementation period, have been identified as people who have developed social entrepreneurship as agents for change and are among successful farmers from within their group (Vesterager *et al*., 2017). Specific roles of the LFs tend to differ from one project to another, but generally the LFs are trained by external agents, and then in turn they share their knowledge and skills with other farmers in the community.

The study on which this paper is based has adopted personality theory of Big Five Personality Trait Model by Costa and McCrae (1987) to analyse and interpret personalities of LFs. The model has five broad domains which define human personality traits and account for individual differences by determining why people respond differently to the same situation. The measurement of the Big Five Personality traits abbreviated as OCEAN, i.e., Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism-anxiety is as indicated in Figure 1.

Low Score		Personality Trait	High Score
Practical, Conventional, Prefer routine	**O**	**Openness** (imagination, feelings, actions, ideas)	Curious, Wide range of interests, Independent
Impulse, Careless Disorganized	**C**	**Conscientiousness** (competence, self-discipline, thought-fullness, goal driven	Hardworking, dependable, organized
Quiet, reserved. Withdraw	**E**	**Extroversion** (sociability, assertiveness, emotional expression)	Outgoing, warm, seeking adventure
Critical, Uncooperative Suspicious	**A**	**Agreeableness** (cooperative, trustworthy, good-natured)	Helpful, trusting, empathetic

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Calm, even-tempered	**N** **Neuroticism** (tendency towards unstable emotions)	Anxious, unhappy, prone to negative emotions

Fig. 1: The Summarized Big Five Personality Trait Model as adapted from Costa and McCrae (1987).

On the selection of high performing LFs, several studies have emphasized the importance of first-line employees, believing that they are a significant determinant of the quality of business, service and operational success (Edward 1996; Heller and Watson 2002; Tsai *et al*., 2013; Ciroka 2014). According to Campbell (1990), performance is "what the organization hires one to do and do well", while Edward (1996) argues that if a person is in the right job, there is a direct link to performance. Zaim *et al*., (2013) add that, a high performing employee is the one who can demonstrate competency in related areas, motivation and social skills that can be learned through education, job experience or vocational training. High performing LFs under projects applying the RIPAT approach are expected to be skilled, self-motivated, and able to work in difficult conditions under minimum supervision to ensure a good job in the roles they are expected to play (Vesterager *et al*., 2017).

The use of LFs under projects applying the RIPAT approach is mandatory as the projects are designed with inbuilt up-scaling mechanisms whereby the RIPAT 'start' phase is implemented in a few villages which act as a base for selecting LFs who will later be used in facilitating the uptake of technologies to other neighbouring villages during RIPAT 'spreading' phase (Vesterager *et al*., 2017). However, the selection of LFs has mainly been based on socio-economic characteristics with limited consideration of personality traits. Alkahtani *et al*., (2011), Tsai *et al*., (2013) and Ciroka (2014) suggests the use of personality traits to match the right job with the right person. According to Liao and Joshi (2008) personality traits can be used to explain people's attitudes and behaviour, and it is often used to predict outcome variables, such as work attitude and job satisfaction. Hence, there is a need to assess to what extent, in addition to socio-economic characteristics are personality traits considered in the selection of high performing LFs. The objective of this paper, therefore, was to identify personality traits to be considered in the selection of LFs. To achieve this, the paper attempts to answer three specific questions: are there any differences of socio-demographic characteristics between high performing LFs and Non-lead farmers (NLFs)? how is the process of selecting high LFs conducted? What are the personality traits of high performing LFs?

2.0 Methodology

2.1 Study Area

The study on which this paper is based was conducted in Karatu and Singida District Councils in Arusha and Singida Regions, respectively. The selection of the study area was based on the fact that the RIPAT projects have been implemented in the two districts for some time, where the contribution of LFs to the project success was quite significant (Lilleor and Sorensen, 2013).

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Geographically, Karatu and Singida are found in the northern and central parts of Tanzania, respectively. The climatic conditions in Karatu vary whereby in Eyasi Basin the annual rainfall is between 300 and 400 mm, while in Karatu Town it ranges between 900 and 1000 mm per year. Karatu District has three agro-ecological zones: uplands, midlands and lowlands, with altitudes ranging from 1,000 to 1,900m above sea level (KDC, 2004; Meindertsma and Kessler, 1997). The principal crops grown in the highlands include wheat, barley, beans, maize, coffee, flowers, pigeon peas, sorghum, finger millet and sunflower while in the midlands and lowlands of the district the main crops grown are maize, beans, pigeon peas, sorghum, millets and sunflower (URT, n. d.). Onion production is famous under irrigation in the lowlands of Lake Eyasi, especially in Mang'ola Ward.

According to (URT, 2013), the climatic conditions of Singida District are generally semi-arid with an average annual rainfall of about 590 mm ranging from 350 mm to 750 mm per year. The principal crops grown include maize, sunflower, groundnuts, sorghum, millets, onions and sweet potatoes. Both districts are faced with shortage of extension officers. For Singida District, out of the 84 village extension officers required, there are only 19 (23% of the requirement); and out of the 21 Ward Agricultural Resource Centres (WARCs) required, there are only two in the whole district (URT. n. d). In Karatu District, out of 58 village extension officers required there are only 35 (60% of the requirement), and out of 14 WARCs required there is only one WARC (URT, n. d).

2.2 Research Design

The study adopted a cross-sectional research design. This design has been recommended by several scholars, for example Babbie (2010) and Bailey (1998) due to its cost and time effectiveness in data collection. The design entails collection of data on more than one case (usually quite a lot more than one) at a single point in time in order to collect a body of quantitative and /or qualitative data about two or more variables (usually many more than two), which are then examined to detect patterns of association (Bryman, 2004). According to Babbie (2010) the design is also useful for descriptive purposes as well as for determination of relationship between variables at the time of the study. Moreover, the design allows the use of other methods of data collection such as observation and use of official records.

2.3 Study Population, Sample Size and Sampling Techniques

2.3.1 Study population

The study population (N) was all 1,800 households that had benefited from the RIPAT projects in Karatu and Singida Districts.

2.3.2 Sample size

The sample size (n) was 384 households; the number was determined as per Cochran (1977) formula as cited by Bartlett *et al.* (2001) whereby:

$$n = \frac{z^2 p(1 - p)}{e^2}$$

$$n = \frac{z^2(pq)}{e^2}$$

Where:
n = sample size;
z = a value on the abscissa of a standard normal distribution (from an assumption that the sample elements are normally distributed), which is 1.96 or approximately 2.0 and corresponds to 95% confidence interval;
p = estimated variance in a population from which the sample is drawn, which is normally 0.5;
and,
e = acceptable margin of error (or precision).
Using a Z-value of 1.96, a p-value of 0.5, and an e-value of 0.5% (which is equivalent to 0.05), the sample size (n) was determined to be 384 households, as shown below:
$= 1.96^2 (0.50 \times 0.50)/0.05^2 = 384$.

2.2.2 Sampling techniques

The study employed stratified proportionate sampling in order to ensure that no district was over-represented or under-represented, Karatu District had more participants in the RIPAT project compared to Singida District. The strata were districts, wards and types of farmers (LFs and non-LFs). The representatives of households (Table 1) were selected through systematic sampling whereby the first one was selected randomly using random numbers created in MS Excel using the "=RAND( )" command, which generated random numbers. This was done at the ward level where a sampling interval for a relevant sub-population at the ward level was obtained by dividing the sub-population N by the sub-sample size (n) to obtain the sampling interval k, i.e. N/n = k. Then, after the first respondent was selected, every kth person was selected until the sub-population was exhausted.

At least 15% of the respondents were LFs who were assessed based on their seven roles under the projects applying the RIPAT approach, therefore based on an index summated scale, the high performing ones scored 64% and above. The seven roles of LFs under RIPAT include teaching and training, communication, adoption of the technologies, facilitating timely availability of agro-inputs, facilitating adoption of new technologies, project monitoring and report writing. The proportion of 15% aimed at including at least 30 LFs based on the suggestion by Bailey (1998) that a sub-sample for a research in which statistical data analysis is to be done should comprise at least 30 cases (respondents). Males and females were 40% and 60% respectively (Table 1) because women were more than a half of the RIPAT group members (Vesterager *et al.*, 2017).

Table 1: Proportions of RIPAT farmers who were sampled

District	Approx. sub-pop. (20-30% are LFs)	Sampling fraction	Sub-sample	Male farmers (About 40%)		Female farmers (About 60%)	
				Non-LFs	LFs (15%)	Non-LFs	LFs (15%)
Karatu	1,200	384/1,800= 0.2133333	256	82	20	134	20
Singida	600	384/1,800 = 0.2133333	128	33	18	59	18
Total	**1,800**	**-**	**384**	**115**	**38**	**193**	**38**

Besides the LFs and non-LFs, 20 key informants (KIs) were selected purposively. KIs included people who were considered to be knowledgeable about the RIPAT approach, including Extension Officers (EOs), District Project Coordinators (DPC), Village government leaders and Programme leaders/Managers from Research, Community and Organisational Development Associates (RECODA) who are the implementers of the projects using the RIPAT approach. Moreover, focus group discussion (FGD) participants were selected from members of groups of the RIPAT projects in each ward, including men and women. Key informant interviews (KIIs) and FGDs were conducted to allow triangulation of data collection through the questionnaire survey and secondary data from the district agricultural and RECODA offices.

2.3 Data Collection

Both primary and secondary data were collected so as to complement each other. Secondary data were collected from district agricultural reports/data, RECODA publications and RIPAT project reports on agricultural technologies disseminated and their rate of adoption. Primary data were collected through a questionnaire administered to respondents, and through FGDs and KIIs using an FGD guide and a KII checklist. However, before conducting the FGDs, demographic, socio-economic data from all the participants were collected and other data related to their involvement in project applying the RIPAT approach. FGDs were used to get more in-depth understanding of the LFs using the RIPAT approach and the ways by which they were selected. In line with Barbour (2011), FGDs comprising 6-12 members were organized; the groups were composed of older (above 35 years old) and younger (less than 35 years old), male and female farmers. Therefore, in each of the six wards involved in the study, 3 FGDs were organized and two special groups of LFs making a total of 20 FGDs, with a total of 116 FGD participants.

Checklists of behaviour statements with interpretation based on the Big Five Personality Traits Model by Costa and McCrae (1987) were used in the establishment of the personality traits of LFs to be assessed, and an index scale was used in rating the main personality traits (Openness, Consciousness, Extroversion, Agreeableness and Neurotic) ranging from 1 (strongly disagree) to 5 (strongly agree). According to Funder (2001) and Funder and Colvin (1991), the model is the most accurate approximation of the basic personality traits dimensions. The Friedman test which is a non-parametric statistical test was used to detect differences in treatments across multiple test attempts by ranking each row (or block) together, then considering the values of ranks by

columns. The five personality traits were put into the matrix under pair-wise ranking to compare each trait with one another to establish how farmers prioritize the traits.

2.4 Data Analysis

Primarily data collected using the household questionnaire were coded and then analysed using the Statistical Package for Social Sciences (SPSS) computer software version 16 whereby descriptive statistics (i.e. frequencies, percentages, means, minimum and maximum values of variables) were determined. Qualitative data collected through key informant interviews and FGDs were analysed through content analysis whereby codes were developed for various arguments and themes. Information generated from analysis of the qualitative data was used to complement/supplement from household survey.

3.0 Results and Discussion

3.1 Socio- demographic characteristics of the farmers

Socio-demographic characteristics such as age, sex, household size, marital status and education are considered as important variables in this study since performance of LFs can vary with respect to these variables.

Table 2: Socio- demographic characteristics of LFs and NLFs (N=384).

Demographic Attributes	Frequency		Percent			
	LFs	NLFs	LFs	NLFs	Chi-square	Sig. (2-tailed)
Respondents Age (years)						
18-30	0	40	0	10.4		0.025
31-43	39	189	51	49.2		
44-56	24	119	32	31		
57-70	13	35	17	9		
+70	0	1	0.3	0		
Respondents Sex						
Male	38	152	50	40	-	-
Female	38	232	50	60		
Respondents Marital status						
Single	2	19	2.6	6.2	1.475	0.224
Married	74	289	97.4	93.8		

3.1.1 Age

Age is among the factors considered in the selection of participants of the projects applying the RIPAT approach where they are required to be above 18 years old which according to Tanzanian the laws is the minimum age of an adult person. The age of NLFs respondents ranged from 18 to more than 70 years while for LFs it ranged from 31 to 70 years (Table 2). When the ages of LFs and NLFs were compared, it was found that their averages were 43.5 and 41.6 years, respectively. Independent samples t-test showed that there was a statistically significant difference ($p = 0.025$) in average age between the LFs and NLFs. Generally, LFs were older than NLFs. From the FGDs it was noted that age was among the factors considered in the selection of LFs whereby they

wanted mature people, assuming that they would be more respected and reliable; that is why only those above 30 years old were selected as regards the LFs. However, consideration of age in the selection of LFs was also placed on the working age as the majority (83%) when considering the age range of 31 - 56 years, and no one exceeded 70 years. According to literature (Franzel *et al*. 2015; Tsafack *et al*. 2015 and Simpson *et al*. 2015), age is an important factor to consider in the adoption of innovations and consequently is among the important factors for selecting high performing LFs.

3.1.2 Marital status

The numbers and proportions of those who were married and single are given in Table 2 in terms of groups of lead farmers (LFs) and Non-Lead Farmers (NLFs). Chi-square test showed that there was no statistically significant association (p-value=0.224) between being LFs or NLFs and marital status, which means that marital status does not add more value to LFs.

3.2 Socio-economic characteristics

Socio-economic characteristics such as income, education level, credit accessibility, capital and labour are considered as among the important variables which are considered in selection of LFs.

3.2.1 Education level

The study findings show that all (100%) LFs had attended formal education and could read and write while among NLFs, 83.0% had formal education (Table 3).

Table 3: Education level versus type of a farmer (N=384)

Education level	LFs		NLFs	
	Frequency	%	Frequency	%
No formal education	0	0	51	17.0
Formal education (could read and write properly)	76	100	257	83.0
Total	**76**	**100**	**308**	**100**

From the FGDs and RECODA reports, it was revealed that the ability to read and write was among the requirements in the selection of LFs as they are expected to be able to read training materials and write reports. According to Bandiera and Rasul (2005), apart from being able to read and write, education encourages more interaction and instils confidence. A study by Kundhlande *et al*. (2014) cited extension officers from Malawi who pointed out that literacy is important for a person to be a lead farmer as low levels of education make it very difficult to train LFs to become effective in communicating information and disseminating technologies. However, although 100% of the LFs could read and write but the level of their education did not differ much as most of them (96.0%) were primary school leavers, which means that the implementing organization and EOs should prepare teaching materials and conduct training, keeping in mind the education level of the selected LFs.

3.2.2 Land holding size

Many scholars have argued that land is among the important factors in the selection of LFs as it is used for practising the introduced technologies (Simpton *et al*., 2015). The land sizes that the respondents owned are as presented in Table 4.

Table 4: Land holding size

Land size	LFs		NLFs	
	Frequency	%	Frequency	%
<0.41ha	1	1.3	20	6.5
0.41 – 0.83 ha	19	25.0	87	28.3
>0.83 – 1.66 ha	27	35.5	139	45.1
>1.66 - 2.9ha	29	38.2	62	20.1

The study findings show that the mean land holdings of LFs and NLFs were 7.0 acres and 6.7 acres respectively, which were significantly different (p=0.001). Generally LFs had larger land holdings whereby almost three-quarters (73.0%) and about a third (65.3%) of the LFs and NLFs respectively had land sizes ranging from >0.83 to 2.9 ha (>2 to 7 acres). The land holding size of >0.83 to 2.9ha is similar to findings by Anderson *et al*. (2016) for the average land holding size of small-scale farmers in Tanzania. A quarter (25.0%) of the LFs had land ranging from 0.41 to 0.83 ha (1 - 2 acres) which, according to Vesterager *et al*. (2017), can suffice the purpose of practising the project interventions. Under the RIPAT approach, selection of the LFs foresees the farmers who, besides adopting the introduced technologies, become role-models and sources of planting materials for the introduced crops which helps in ensuring project sustainability and continuity of the LFs' roles even after the project lifespan.

3.2.2 Access to loans

The study findings show that 100% of the LFs had been taking loans for various activities (Table 5) while 92.9% of NLFs had been taking loans from various sources including VSLA. It was learnt through focus group discussions that introduction of rural microfinance scheme (village savings and loans association - VSLA) under projects applying the RIPAT approach had increased access to loans which meant increased ability to generate capital. The ability to take a loan can be an indicator of a social entrepreneur which, according to Vesterager *et al*. (2017), is among the factors considered in the selection of LFs.

Table 5: LFs and NLs access to loans

LFs and NLFs access to loans	LFs		NLFs	
	Number	%	Number	%
Yes	76	100	286	92.9
No	0	0	22	7.1
Total	**76**	**100**	**308**	**100**

3.3 Process of selecting LFs under RIPAT

Secondary data from RECODA reports and publications (Vesterager *et al*., 2017) describe selection of LFs as a process which comes at least in the second year of the project and uses the following procedure. Thirty (30) members in a particular RIPAT project are divided into sub-groups of 4 to 6 members, depending on the technologies in

the basket of options. Each sub-group selects two leaders known as a Technical Lead Farmers (TLFs) who, in addition to undergoing practical training, attend in-house training together with an extension officer (EO). The TLFs are then exposed to study visits to learn about the technologies in question. Later, each group, in collaboration with the EO and project manager from the implementing organization, select one or two LFs from amongst all the TLFs in each group who become spreading (overall) LFs. Overall, LFs are further trained on project facilitation procedures, communication skills and adult learning so as to become competent social entrepreneurs to offer notable services in the development of crop/product based value chain in the course of project implementation or after the project lifespan. According to Vesterager *et al*. (2017), the spreading LFs are selected based on seven factors, which are: i) active group member (with good attendance, performing well group activities and abiding by group constitutions); ii) understanding of the concept of RIPAT approach; iii) competence in adopting the introduced technologies; iv) ability to pass on knowledge to others; v) good reputation among the group members and community; vi) ability to read and write; and vii) passing an individual interview.

Through the FGDs and KIIs, it was revealed that when farmers work together in a group they are able to identify individuals possessing the qualities as proposed by Vesterager *et al*. (2017), and some other important personality traits fit for being LFs. During a KII, a LF from Karatu said:

> "*It was my first time to work in a group. Initially, I was a bit doubtful, but I have one thing in myself, that if I say yes to something I put all my efforts; if I say no, I just abandon it completely. I was elected by my fellow group members to be the group leader, and after one year I was selected to be a sub-group lead farmer of Conservation Agriculture (CA). We received more intensive practical and in-house training. Afterward I was selected to be the overall Lead Farmer because from the offered basket of technologies by the project I managed to adopt CA (zero tillage with intercropping of maize and cover crops), livestock (poultry, pigs and dairy goats) and vegetables. Also, I shared project technologies with my neighbours by providing them with planting materials and knowledge.*" (A Lead Farmer from Karatu district, Endamarariek Village - Sept. 2017).

The above testimony on the way the lead farmer was selected shows that selection of high performing LFs is a systematic process. It suggests that the selection of LFs should look beyond project contexts and lifespan by putting into consideration value chain development, market associations and general community development. In this case the factor of social entrepreneurship should be considered in the selection of LFs. Kiptoti and Franzel (2015) describe the selection of LFs similar to the one adopted by the RIPAT approach. According to them, farmer extension facilitators (in the case of the RIPAT approach these are called LFs) were identified and vetted by their communities, then they received broad-based technical training on particular subject matters, leadership and value chain management, and thereafter they were deployed to their own communities. The same study revealed that farmer extension facilitators (FEFs) were comprehensively trained and developed their model farms sufficiently to even cater for

the needs of the more progressive farmers in the communities. According to Simpton *et al*. (2015), allowing the communities and organizations to select LFs helps increase local ownership and accountability. The above is generally critical when it comes to sustainability of the promoted project activities.

A RECODA Programme Leader argued, during a KII, that the LFs should be selected by the community and preferably from the strong groups where they have worked and demonstrated competence and good character. LFs emanating from strong groups tend to be effective as their groups support them during formation of new groups by supplying them with planting materials. Khaila *et al*. (2015) found that the most important factors for selecting LFs in Malawi were being a hard-worker, an active farmer, and being interested in helping others. In Kenya, the factors considered in the selection were based on availability, trainability, acceptability, ability to communicate, literacy, passion and expertise (Franzel *et al*., 2014) while in Cameroon the LFs selection was based on being a hard-worker, having good communication skills, being available, and showing interest and desire to help others (Tsafack *et al*., 2015). Among the important factors observed during the selection of LFs under the RIPAT approach were being an active group member, competence in adopting the introduced technologies, good reputation among the group members and the community and ability to read and write (Vesterager *et al*., 2017). The process and factors mentioned indicate that the selection of LFs is largely based on the socio-economic characteristics.

3.4 Selection of LFs with personality traits lens

In order to analyse personality traits of the high performing LFs, the Five Personality Traits Mode by Costa and McCrae (1987) was used in measuring personality traits parameters which include Openness, Consciousness, Extroversion, Agreeableness and Neurotic. Respondents (both LFs and NLFs) were required according to their perceptions to mention any two high performing LFs and under the guidance of 15 behaviour statements where in each statement they gave score ranging from 1 (strong disagree) and 5 (strongly agree). The statements are: (1) gets upset easily, (2) enjoys being part of a group, (3) likes to solve complex problems, (4) believes that others have good intentions, (5) always prepared, (6) low opinion of myself, (7) natural talent for inluencing people, (8) enjoys the beauty of nature, (9) tries to anticipate the needs of others, (10) can be trusted to keep promises, (11) gets irritated easily, (12) has a lot of fun, (13) likes to visit new places, (14) loves to help others, and (15) guiding personal characteristic statements.

The 15 behaviour statements with interpretations based on the Big Five Personality Traits Model by Costa and McCrae (1987) were used, the descriptive statistics are summarized in Table 6. An index scale was used in rating personality traits ranging from 1 (strongly disagree) to 5 (strongly agree); whereby a higher score indicates the most preferred trait for the high performing LFs.

Table 6: Descriptive statistics for personality traits scores as assessed by LFs and NLs

Personality traits	N	Mean	Std. Deviation
Neurotic	384	2.12	0.629
Extroversion	384	3.80	0.773
Openness/intellect	384	3.98	0.683
Agreeableness	384	3.70	0.713
Consciousness	384	3.67	0.665

The assessment of the personality traits under the Friedman test indicated significant difference (p=0.000); where Openness had the highest score, followed by Extroversion, Agreeableness, Consciousness and finally Neurotic (Table 6). In order to understand which traits differed significantly, first neurotic scores were compared against the remaining four traits, and the results show that the scores differed significantly (p=0.000) while comparison among the remaining four traits showed that the traits differed significantly except Agreeableness and Consciousness (p= 0.355). The results suggest that in the selection of high performing LFs, personality traits related with openness (curious, wide range of interests and independent) should be given higher consideration followed by extroversion (outgoing, warm, seeking adventure) while factors related to Neurotic trait (anxious, unhappy, prone to negative emotions) should be given less weight.

Further analysis of the personality traits of the LFs was conducted under FGDs, whereby the Five Personality Traits Model (see figure 1) were used in guiding the discussions. Figure 1 helped in the interpretation of the personalities of high performing LFs through provision of the meaning of each personality traits based on the personal behaviours being high or low. Through the FGDs, three scenarios were used in identifying high performing LFs based on their personality traits. The participants of the FGDs (LFs and NLFs) were enlightened on how to respond to the 15 guiding personal characteristic statements (Table 7), whereby the first scenario was to assess the high performing LFs whom each one thought was the best to him/her. Secondly, they selected the high performing Lead Farmer who was well known to all group members, and thirdly, self-assessment of the LFs was done. Before discussion, each member responded individually to the 15 statements. The results were discussed and are summarized in Table 7 and then interpreted accordingly.

Table 7: Responses on the different behaviours of the high performing LFs under RIPAT projects

No.	Researchable statements in determining the Personal characteristics	Individual selection of LF	Best known LF	Self - assessment of LFs	Average range of 1 to 5.
	Neurotic;				

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1	Gets upset easily	2.1	2	1	1.7
2	Low opinion of myself	1.7	3.2	1.2	2
3	Gets irritated easily	2.1	1.8	2	1.9
	Average				**1.86**
	Extroversion				
4	Enjoys being part of a group	4.7	3.7	4.8	4.4
5	Natural talent for influencing people	4.7	3.6	4.5	4.2
6	Has a lot of fun	3.8	3.6	3.8	3.7
	Average				**4.1**
	Openness/Intellect;				
7	Likes to solve complex problems	4	4.5	4.2	4.2
8	Enjoys the beauty of nature	4	3.7	4.5	4
9	Likes to visit new places	4.6	4	4.7	4.4
	Average				**4.2**
	Agreableness				
10	Believes that others have good intentions	4.2	3.5	4.2	3.9
11	Tries to anticipate the needs of others	4.2	4.3	4.5	4.3
12	Loves to help others	4.7	3.7	5	4.4
	Average				4.2
	Consciousness.				
13	Always prepared	4.4	4.1	4.6	4.4
14	Can be trusted to keep promises	4.6	4.7	4.9	4.7
15	Sets high standards for myself and others	3.8	4.3	4.2	4.1
	Average				**4.4**

The sudy findings in Table 7 with clustered interpretation summary show the personality traits of high performing LFs based on attested personal characteristics and corresponeding scores that ranged from 1 (strongly disagree) to 5 (strongly agree). The study findings show that the most important personality trait considered in the selection of LFs is consciousness (4.4), followed by openness (4.2) and agreableness (4.2), while neurotic was undesirable (1.86).

From the individual asssessments, the statement of love to help others scored 5 (100%) which can be inferred as altruism (spirit of voluteerism); it can be among the important elements to be considered in the selection of LFs. Each of the big five personality factors represents a range between two extremes (low and high score) whereas in reality most people tend to lie somewhere midway along the continuum of each factor, rather than at polar ends (Livesley, 2008).

Members of the FGDs comprehended the concepts of the five main personality traits based on the application of the 15 behaviour statements above in assessing the personality traits fits in the selection of LFs. The explanations from Fig. 1 were further used in carryout pair-wise ranking. The five personality traits were put into a matrix; after discussing the comparisons of each trait to another consensus was reached on the preferred personality traits in the selection of LFs was agreed upon (Table 8).

Table 8: Pairwise ranking based on the preffered personality traits in the selection of LFs

Personality traits	Openness	Consciousness	Extroversion	Agreeableness	Neurotic	Scores	Ranking
Openness		Consciousness	Openness	Openness	Openness	3	2
Consciousness			Consciousness	Consciousness	Consciousness	4	1
Extroversion				Openness	Extroversion	1	4
Agreeableness					Agreeableness	2	3
Neurotic						0	5

The results from the pairwise ranking further showed that Consciousness is the most preferred personality trait in the selection of LFs (scored 4), followed closely by Openness. Neurotic was ranked last. From the discussions, it was learnt that Consciousness was most preferred because of the personal characteristics/behaviours of being hardworking, dependable and being organized, while Openness was characterised by curiosity, wide range of interests and independent. Generally, the group participants were of the opinion that high performing LFs are those who walk their talk. One of the group participants said: "We need a person who is eager to learn and who is proactive in practising new things so as to lead by example".

By using the same guiding researchable statements and Figure 1, a KI (District Project Coordinator - DPC) from Singida indicated Consciousness and Openness as important personality traits to be considered in the selection of high performing LFs, but suggested Extroversion personality traits (outgoing, warm, seeking adventure) to be among the factors to be considered when working in a closed society which may need LFs with outgoing behaviour. He had this to say:

Charismatic LFs are required in localized areas where communities are very traditional with taboos which sometimes work against development ethics such as working together in group and even when they come together they are very reluctant to share out their ideas. In this case, the LFs are required to be like salesmen in the introduction of the project ideas" (Singida DPC, Sept 2017).

A RIPAT project manager expressed the way he admired LFs who were hardworking, dependable, organized and open to new technologies, which implies he was also of the opinion that selection of LFs should consider Consciousness and Openness personality traits. He further added that as LFs do not get a salary, their selection should take into consideration personality behaviour of volunteerism (altruism) which, according to Franzel *et al*. (2014), is more about unselfish behaviour which makes someone feel rewarded when helping.

3.4 Motivation to become a Lead Farmer

The study explored the motivation to become a lead farmer in order to consider it in the selection criteria. From the FGDs with LFs about what motivated them to become LFs, it was expressed that the spirit of helping others, desire to get new knowledge,

recognition, income generation and project benefits were among the key factors. One Lead Farmer said:

> *"I decided to be a Lead Farmer because I feel good when I help others to solve their problems. When dairy goats were introduced in our area many were reluctant to keep male goats, but I took one and today (after three years) more than 20 of my neighbours have improved goats (crossbreed) because they have brought their local goats to my place for breeding"* (Lead Farmer, Meria village in Singda; Sept. 2017).

In a KII with Singida District Agricultural, Irrigation and Cooperative Officer (DAICO), it was observed that they had a shortage of extension officers, and they appreciated the roles of LFs in reducing that gap but they suggested that the selection should consider those with a spirit of volunteerism (altruism - Agreeableness) since there is no fund allocated specifically for them. The study by Kundhlande *et al*. (2014) revealed that the main motivation to become a Lead Farmer was the increased social status and early access to technology, followed by altruism, job benefits, social networking and income generating activities. Based on this, generally, project implementing organizations and extension officers need to bear in mind the kind of LFs they want to select because they have different motivations and will thus respond to different incentives. In addition, it was observed that the driving force to become LFs was the experiences and positive results brought by the project with a stipulated guide on how they are going to implement successfully their roles so as to achieve similar results. The RIPAT Manual explains how LFs are trained to become competent and passionate to undertake their roles successfully in collaboration with government extension staff (Vesterager *et al*., 2017).

4.0 Conclusions and recommendations

Personality traits are among the important factors to be considered in the selection of high performing LFs where the use of the Five Factor Personality Traits Model is very important. From this study, among the socio-economic characteristics which LFs possess over NLFs include age (in the sense of maturity and experience), literacy (ability to read and write) which goes together with trainability and confidence, ability to take a loan to invest in agriculture and ownership of land. Sex and marital are not considered as an important factor to be a Lead Farmer unless there is a need of gender balancing. The study concludes that high performing LFs are individuals with personality traits related to openness (curious, wide range of interests and independent) and consciousness (hardworking, dependable and organized) followed with agreeableness (voluntarism spirit).

Based on the findings and on the above conclusions, the following recommendations are made:

i. Age, literacy, ability to take a loan to invest in agriculture, and land ownership to allow practising the introduced interventions and being a source of planting materials should be given priority as socio-economic characteristics for selection of LFs. Sex

and marital status should not be the main factors for such selection, but where necessary they can be used for gender balancing.

ii. Moreover, personality traits of openness (being curious, wide range of interests and independent) and consciousness (hardworking, dependable and organized) should be given higher considerations in the selection of high performing LFs.

iii. The use of LFs is not well formalized by government systems, so there is a need for policy analysis, in particular the agricultural and livestock policies and advocacy, aiming at formalizing the use of LFs in the government extension services and factoring in personality traits in the selection criteria of LFs.

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Propagation Potentials of Pesticidal Plants: A Case of *Commiphora Swynnertonii* (Burtt) and *Synadenium glaucescens* (Pax)

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Abstract

Plants provide pest control resources for many people worldwide. Nevertheless, harvesting is often destructive. The development of suitable propagation techniques will provide a strong base for the conservation of pesticidal plants. Screen house experiment was conducted to evaluate propagation potential of Commiphora swynnertonii and Synadenium glaucescens. Two separate experiments were conducted. The first experiment evaluated the effect of pre-sowing treatments on seed germination. The second experiment evaluated the effect of cutting types and growth regulator treatments on rooting and growth of stem cuttings. Pre-sowing seed treatments involved soaking seeds in water at room temperature (25 oC), hot water (60 oC), Gibberellin (GA3) solution and Potassium nitrate (KNO3) at different concentrations. The experiment was set in a randomized complete block design (RCBD) with four replications. On evaluation of the effect of type of cuttings and growth regulators, there were nine treatment combinations comprising of three types of cuttings (softwood, semi-hardwood and hardwood), two rooting hormones (Indole-3-Acetic Acid (IAA) and Naphthalene Acetic Acid (NAA)) and control. The experiment was set in a 3x3 factorial in a randomized complete block design with four replications. The study revealed that seed germination of both plants was poor but it was significantly affected by pre-sowing treatments. In C. swynnertonii, early germination (9.75 days), high germination percentage (22.50%) and better survival percentage (20.00%) were recorded in seeds treated with KNO3 at 10 ppm. While in S. glaucescens, seeds soaked in water (25 0C) for 24 hours had the minimum number of days to germination (9.25 days), high germination percentage (25.00%) and better survival percentage (17.50%) compared to the other treatments and control. It was also observed that semi-hardwood cuttings of C. swynnertonii and softwood cuttings of S. glaucescens dipped in 2000 ppm NAA solution for 30 minutes led to higher rooting of 52.50% and 97.50%, respectively. The findings suggest that semi-hardwood cuttings and softwood cuttings dipped in 2000 ppm NAA solution could be used for mass propagation of C. swynnertonii and S. glaucescens, respectively.

Key words*: Pesticidal plants, propagation, C. swynnertonii* and *S. glaucescens.*

1.0 Introduction

Over-exploitation, pressures from urbanization, mining, overgrazing and intensive agriculture have pushed more plant species towards extinction. There is a need to develop suitable conservation techniques that will provide a strong base for sustainable use of pesticidal plants. Among important pesticidal plants that are threatened with extinction is Commiphora swynnertonii and Synadenium glaucescens. The highly exploited Commiphora swynnertonii is a small tree or shrub grows up to 4 m high (Paraskeva *et al.,* 2008). The plant belongs to Burseraceae family. It grows wild in

northern regions of Tanzania particularly the Manyara region (Bakari *et al*., 2012). Equally important; Synadenium glaucescens is a succulent shrub or tree of several meters high belonging to the family Euphorbiaceae. It is endemic to eastern Africa regions and found in several regions of Tanzania such as Morogoro, Tanga, Njombe and Iringa (Mabiki *et al*., 2013). Several investigations have focused on the validation of pesticidal activities of these plants. Matendo (2017) assessed the insecticidal effectiveness of these plants on management of tomato leaf miner (Tuta absoluta). The results show that the ethanolic extract of *C. swynnertonii* resin caused significant mortality to larvae and adults T. absoluta. The resin extract of C. swynertonii has claimed to be potential in the management of ticks, fleas and tsetse flies (Kalala *et al*., 2014). Latex of *S. glaucescens* is used as a seed dressing against vegetable plant parasitic nematodes; Tylenchorhynchus brassicae and Rotylenchus reniformis (Matendo, 2017).

The availability of *C. swynnertonii* and *S. glaucescens* in natural forests is decreasing very fast. A survey conducted by Mabiki (2013) in Mufindi and Njombe region revealed the disappearance of the *S. glaucescens* in the wild. A total of 220 people were interviewed and 96% of the total respondents agreed that the plant is available, of them 80% agreed that the abundance of the plant is less compared to a few years ago. The survey conducted by Bakari (2014) in Manyara region revealed that there is over-exploitation of C. swynertonii in Simanjiro district due to mining, overgrazing, urbanization and other agricultural activities.

The current demand of *C. swynnertonii* and *S. glaucescens* is mostly met from the wild collection. Severe measures are needed for the conservation of these pesticidal plants before they are completely lost. One of the techniques to meet the increasing demand and reduce the pressure of harvest from the wild is their mass propagation. However, propagation of some important pesticidal plants is beset with the problems of poor seedling establishment and rooting of stem cuttings (Diwakar *et al*., 2011; Lal *et al*., 2014). Several factors such as type of cutting, environmental conditions during rooting, rooting hormones and rooting medium influence the regeneration of plants from cuttings. A number of chemical substances such as gibberellin, various nitrate solutions and water have been reported to be used for breaking dormancy in seeds, enhancing their permeability, inducing and hastening the germination and thereby acting as regulator for seed germination (Dewir *et al*., 2011; Pandey, 2012; Lal *et al*., 2014; Olajide *et al*., 2014; Stejskalová *et al*., 2015; Eremrena and Mensah 2016). This study tested stem cuttings and seeds as important potential propagation materials of *C. swynnertonii* and *S. glaucescens*.

2.0 Materials and Methods

2.1 Description of the Study Area

The study was conducted in the screen house of Horticulture Section at the Sokoine University of Agriculture (SUA) Morogoro, Tanzania from November 2018 to April 2019. The study area is located at 6o05'S, 35o37'E, at an elevation of 568 m above the sea level. The annual rainfall ranges between 800 and 950 mm (Kisetu *et al*., 2013). Stem cuttings and seeds of *C. swynnertonii* were collected from Mererani ward in Simanjiro

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District of Manyara Region (4o0‘0 S, 36o 30‘0 E). A specialized botanist was involved for correct identification of the plants. The stem cuttings and seeds of *S. glaucescens* were obtained from the department of Food Science and Technology of Sokoine University of Agriculture, Morogoro, Tanzania (6o85’S, 37o65’E) and Kola ward at Morogoro Municipal Council (6o81’S, 37o69’E), respectively. Growth regulators (NAA, IAA and GA3), Potassium nitrate (KNO3) and Sodium hypochlorite (NaOCl) were purchased from Jakovic General Supplies Ltd.

2.2 Examination of Propagation Potential through Seeds

Mature *C. swynnertonii* and *S. glaucescens* seeds were extracted from the fruits and dried at room temperature (25 oC) for 3 days. The seeds were disinfected with 2% sodium hypochlorite solution for 2 minutes and subjected to the following pretreatments; T0: Control (no pretreatment given), T1: Soaking seeds in water (25 oC) for 24 hours, T2: Soaking seeds in hot water (60 oC) for 10 minutes, T3: Seeds treated with Gibberellin (GA3) solution at different concentrations (T3a: GA3 250 ppm, T3b: GA3 500 ppm and T3c: GA3 1000 ppm) for 72 hours and T4: Seeds treated with Potassium nitrate (KNO3) at different concentrations (T4a: 10 ppm and T4b: 20 ppm) for 24 hours. A total of 320 seeds were sown in 32 plastic pots (4 liters), each containing 10 seeds. Pots were filled with steam sterilized forest soil, farmyard manure and rice husks at a ratio of 4:2:1. Seeds were sown at a depth of 0.5 to 1.0 cm. The pots were placed in the screen house and watered on every alternate day depending upon the moisture content. The experiment was arranged in Randomized Complete Block Design (RCBD) with four replications. Data on germination were recorded according to the method described by Sharma (2009) with some modification.

2.3 Examination of Propagation Potential through Stem Cuttings

Evaluation of propagation potential using stem cuttings were conducted according to the method described by Pandey, (2012) with some modification. Softwood, semi-hardwood and hardwood cuttings of 25 - 30 cm length were harvested. Lower end 1.5 – 2.0 cm portion of the cuttings were separately dipped for 30 minutes in two rooting hormones namely, Naphthalene Acetic Acid (NAA) 2000 ppm and Indole-3-Acetic Acid (IAA) 2000 ppm. A total of 360 cuttings for each species were planted in 36 plastic pots (10 liters) each containing 10 cuttings. Pots were filled with steam sterilized forest soil, farmyard manure and rice husks at a ratio of 4:2:1. The cuttings were planted at a depth of 15 cm. The pots with untreated cuttings were considered as control. The experiment was laid out in a 3x3 factorial in a RCBD with four replications. The pots were placed in the screen house and watered on every alternate day depending upon the moisture content. Data on shoot and root parameters were recorded after four months of planting according to the method described by Diwakar (2011) with some modification.

Data analysis: Data collected were subjected to analysis of variance using GenStat software 15th Edition (VSN International Ltd. UK). Treatment means were separated by Duncan´s Multiple Range Test (DMRT) at $p \leq 0.05$.

3.0 Results

3.1 Effect of pre-sowing treatments on seed germination of *C. swynnertonii*

It was found that there were significant difference among treatments in number of days taken to germination (p <.001), germination percentage (p <.001) and seedling survival percentage (p = 0.009). Seeds treated with KNO3 at 10 ppm had the minimum number of days taken to germination, the maximum germination percentage and seedling survival percentage compared with the other treatments and control. No germination observed in seeds treated with GA3 solution at 250, 500 and 1000 ppm (Table 1).

Table 1: Effect of pre-sowing treatments on number of days taken to start germination, germination percentage and seedling survival percentage of *C. swynnertonii*

Treatments	Number of days taken to start germination	Germination percentage	Seedling survival percentage
T_0	13.25b	12.50b	12.50bc
T_1	12.25b	17.50bc	10.00abc
T_2	12.75b	15.00bc	7.50ab
T_{3a}	-	0.00a	0.00a
T_{3b}	-	0.00a	0.00a
T_{3c}	-	0.00a	0.00a
T_{4a}	9.75b	22.50c	20.00c
T_{4b}	13.75b	12.50b	7.50ab
CV%	40.8	58.8	102.5
P-values	<.001	<.001	0.009

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to DMRT.
- = no germination.

T0 = Control (no pretreatment), T1 = Soaking seeds in water (25 0C), T2 = Soaking seeds in hot water (60 0C), T3a = Seeds treated with GA3 solution at 250 ppm, T3b = Seeds treated with GA3 solution at 500 ppm, T3c = Seeds treated with GA3 solution at 1000 ppm, T4a = Seeds treated with KNO3 at 10 ppm and T4b = Seeds treated with KNO3 at 20 ppm.

3.2 Effect of Pre-sowing treatments on Seed germination of *S. glaucescens*.

It was found that there were significant difference among treatments in number of days taken to germination (p <.001), germination percentage (p <.001) and seedling survival percentage (p = 0.024). Seeds soaked in water (25 0C) for 24 hours had the minimum number of days taken to germination, the maximum germination percentage and seedling survival percentage compared with the other treatments and control. No germination observed in seeds soaked in hot water (60 0C) for 10 minutes and those treated with GA3 solution at 500 and 1000 ppm (Table 2).

Table 2: Effect of pre-sowing treatments on number of days taken to start germination, germination percentage and seedling survival percentage of *S. glaucescens*

Treatments	Number of days taken to start germination	Germination percentage	Seedling survival percentage

T_0	20.50d	12.50b	7.50ab
T_1	9.25b	25.00c	17.50b
T_2	-	0.00a	0.00a
T_{3a}	11.25bc	10.00b	5.00ab
T_{3b}	-	0.00a	0.00a
T_{3c}	-	0.00a	0.00a
T_{4a}	12.00bc	10.00b	10.00ab
T_{4b}	15.00c	20.00c	15.00b
CV%	36.1	51.1	116.1
P-values	<.001	<.001	0.024

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to DMRT.
- = no germination.

T0 = Control (no pretreatment), T1 = Soaking seeds in water (25 0C), T2 = Soaking seeds in hot water (60 0C), T3a = Seeds treated with GA3 solution at 250 ppm, T3b = Seeds treated with GA3 solution at 500 ppm, T3c = Seeds treated with GA3 solution at 1000 ppm, T4a = Seeds treated with KNO3 at 10 ppm and T4b = Seeds treated with KNO3 at 20 ppm.

3.3 Effect of cuttings type on shoot and root parameters of *C. swynnertonii*

Type of cuttings had significant effect on number of days taken to sprout (p = 0.005), number of sprouts per cutting (p <.001) and length of the longest sprout per cutting (p <.001) (Table 3). Softwood cuttings sprouted earlier compared to semi-hardwood and hardwood cuttings. Hard wood cuttings had the maximum number of sprouts per cutting and length of the longest sprout per cutting. The type of cuttings did not have significant (p ≤ 0.05) effect on the number of leaves of the longest sprout per cutting (Table 3). However, the semi-hardwood cuttings had the maximum number of leaves of the longest sprout per cutting followed by hardwood and softwood cuttings.

Table 3: Effect of cutting types and growth regulators on number of days taken to sprout, number of sprouts per cutting, length of the longest sprout per cutting and number of leaves of the longest sprout per cutting of *C. swynnertonii*

Treatments	Number of days taken to sprout	Number of sprouts per cutting	Length of the longest sprout per cutting	Number of leaves of the longest sprout per cutting
Soft wood	12.08a	3.904a	47.92a	53.25a
Semi-hard wood	13.75a	4.458a	87.50b	68.17a
Hard wood	17.42b	5.333b	87.54b	67.00a
C.V%	25.1	16.1	25.2	64.3
P-values	0.005	<.001	<.001	0.609
IAA	12.25a	4.675a	63.50b	52.33a
NAA	14.33ab	4.554a	111.75c	91.58b
Control	16.67b	4.467a	47.71a	44.50a
C.V%	25.1	16.1	25.2	64.3
P-values	0.022	0.786	<.001	0.019

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to DMRT.

There were significant difference among type of cuttings on number of roots per cutting ($p = 0.004$), length of the longest root per cutting ($p = 0.037$), rooting percent ($p < .001$) and cutting survival percentage ($p < .001$) (Table 5). Hardwood cuttings had the maximum number of roots per cutting followed by semi-hardwood and softwood cuttings. Semi-hardwood cuttings had the maximum, length of the longest root per cutting, rooting percent and cutting survival percentage compared with the other cuttings.

3.4 Effect of growth regulators on shoot and root parameters of *C. swynnertonii*

Growth regulators had significant effect on number of days taken to sprout ($p = 0.022$), length of the longest sprout per cutting ($p < .001$) and number of leaves of the longest sprout per cutting ($p = 0.019$) (Table 4). The stem cuttings treated with IAA sprouted earlier compared to NAA and control. The stem cuttings treated with NAA had the maximum length of the longest sprout per cutting and number of leaves of the longest sprout per cutting. The growth regulators did not differ significantly ($p \leq 0.05$) on number of sprouts per cutting (Table 4). However, the maximum and minimum number of sprouts per cutting was observed in stem cuttings treated with IAA and control, respectively.

Table 4: Interaction effect of cutting types and growth regulators on number of days taken to sprout, number of sprouts per cutting, length of the longest sprout per cutting and number of leaves of the longest sprout per cutting of *C. swynnertonii*

Treatments	Number of days taken to sprout	Number of sprouts per cutting	Length of the longest sprout per cutting (cm)	Number of leaves of the longest sprout per cutting
S + IAA	11.00a	3.875a	22.00a	51.50ab
S + NAA	12.00a	3.812a	105.25cde	73.50ab
S + Control	13.25a	4.025a	16.50a	34.75a
SH + IAA	11.50a	4.000a	77.50bc	49.00ab
SH + NAA	14.50a	5.550b	122.75e	109.50b
SH + Control	15.25a	3.825a	62.38b	46.00ab
H + IAA	14.25a	6.150b	91.00bcd	56.50ab
H + NAA	16.50ab	4.300a	107.25de	91.75ab
H + Control	21.50b	5.550b	64.25b	52.75ab
C.V%	25.1	16.1	25.2	64.3
P-values	0.626	0.001	0.025	0.899

Means followed by the same letter in the same column are not significantly different at $P \leq 0.05$ according to DMRT.
S = Soft wood cuttings, SH = Semi-hard wood cuttings, H = Hard wood cuttings.

There were significant differences among the growth regulators and control on number of roots per cutting ($p = 0.018$), rooting percent ($p = 0.014$) and cutting survival percentage ($p < .001$) (Table 5). The stem cuttings treated with NAA had the maximum number of roots per cutting, rooting percent and cutting survival percentage compared

with IAA and control. The growth regulators did not differ significantly ($p \leq 0.05$) on length of the longest root per cutting (Table 5). However, the maximum and minimum length of the longest root per cutting was observed in stem cuttings treated with NAA and control, respectively.

Table 5: Effect of cutting types and growth regulators on number of roots per cutting, length of the longest root per cutting, rooting percent and cutting survival percentage of *C. swynnertonii*

Treatments	Number of roots per cutting	Length of the longest root per cutting (cm)	Rooting percent (%)	Cutting survival percentage (%)
Soft wood	0.587a	14.42a	7.50a	6.67a
Semi-hard wood	2.558b	44.42b	31.67c	29.17c
Hard wood	2.833b	34.17ab	22.00b	19.50b
C.V%	79.6	87.7	55.9	49.3
P-values	0.004	0.037	<.001	<.001
IAA	2.554b	33.67a	18.33a	18.33b
NAA	2.592b	41.58a	28.67b	27.00c
Control	0.833a	17.75a	14.17a	10.00a
C.V%	79.6	87.7	55.9	49.3
P-values	0.018	0.113	0.014	<.001

Means followed by the same letter in the same column are not significantly different at $P \leq 0.05$ according to DMRT.

3.5 Interaction effect of cuttings type and growth regulators on shoot and root parameters of *C. swynnertonii*

Interactions between type of cuttings and growth regulators were significant differences on number of sprouts per cutting ($p = 0.001$) and length of the longest sprout per cutting ($p = 0.025$) (Table 4). Hardwood cuttings treated with IAA had the maximum number of sprouts per cutting compared to the other treatments and controls. Semi-hardwood cuttings treated with NAA had the maximum length of the longest sprout per cutting followed by hardwood cuttings treated with NAA and softwood cuttings treated with NAA. The interactions between type of cuttings and growth regulators did not differ significantly ($p \leq 0.05$) on number of days taken to sprout and number of leaves of the longest sprout per cutting (Table 4). However, the minimum and maximum number of days taken to sprout was observed in softwood cuttings treated with IAA and untreated hardwood cuttings (control) respectively. Semi-hardwood cuttings treated with NAA and untreated softwood cuttings (control) had the maximum and minimum number of leaves of the longest sprout per cutting, respectively.

There were significant differences among the interactions between type of cuttings and growth regulators on rooting percent ($p = 0.024$) and cutting survival percentage ($p = 0.003$) (Table 6). Semi-hardwood cuttings treated with NAA had the maximum rooting percent and cutting survival percentage compared to the other treatments and control. The interactions between type of cuttings and growth regulators did not differ significantly ($p \leq 0.05$) on number of roots per cutting and length of the longest root per

cutting (Table 6). However, the semi-hardwood cuttings treated with NAA had the maximum number of roots per cutting and length of the longest root per cutting compared to other treatments and controls.

Table 6: Interaction effect of cutting types and growth regulators on number of roots per cutting, length of the longest root per cutting, rooting percent and cutting survival percentage of *C. swynnertonii*

Treatments	Number of roots per cutting	Length of the longest root per cutting (cm)	Rooting percent (%)	Cutting survival percentage (%)
S + IAA	0.612ab	14.75ab	10.00abc	10.00a
S + NAA	0.750abc	18.00ab	7.50ab	5.00a
S + Control	0.400a	10.50a	5.00a	5.00a
SH + IAA	3.175cd	51.88ab	27.50c	27.50b
SH + NAA	3.950d	56.75b	52.50d	50.00c
SH + Control	0.550ab	24.62ab	15.00abc	10.00a
H + IAA	3.875d	34.38ab	17.50abc	17.50ab
H + NAA	3.075bcd	50.00ab	26.00bc	26.00b
H + Control	1.550abcd	18.12ab	22.50abc	15.00ab
C.V%	79.6	87.7	55.9	49.3
P-values	0.317	0.848	0.024	0.003

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to DMRT.
S = Soft wood cuttings, SH = Semi-hard wood cuttings, H = Hard wood cuttings.

3.6 Effect of cuttings type on shoot and root parameters of *S. glaucescens*.

It was found that there were significant differences among the type of cuttings on number of sprouts per cutting (p <.001), length of the longest sprout per cutting (p = 0.026) and number of leaves of the longest sprout per cutting (p = 0.002) (Table 7). Hardwood cuttings had the maximum number of sprouts per cutting followed by semi-hardwood and softwood cuttings. Softwood cuttings had the maximum length of the longest sprout per cutting and number of leaves of the longest sprout per cutting compared with the other cuttings. The type of cuttings did not differ significantly (p ≤ 0.05) on number of days taken to sprout (Table 7). However, the minimum and maximum number of days taken to sprout was observed in softwood cuttings and hardwood cuttings, respectively.

Table 7: Effect of cutting types and growth regulators on number of days taken to sprout, number of sprouts per cutting, length of the longest sprout per cutting and number of leaves of the longest sprout per cutting of *S. glaucescens*

Treatments	Number of days taken to sprout	Number of sprouts per cutting	Length of the longest sprout per cutting	Number of leaves of the longest sprout per cutting
Soft wood	10.42a	2.487a	36.92b	27.83b
Semi-hard wood	10.58ab	3.537b	32.83ab	24.83ab
Hard wood	12.08b	5.337c	27.00a	22.08a
C.V%	16.4	24.4	26.0	13.7

P-values	0.064	<.001	0.026	0.002
IAA	10.83a	3.650a	31.17a	24.08a
NAA	10.33a	3.687a	36.33a	28.42b
Control	11.92a	4.025a	29.25a	22.25a
C.V%	16.4	24.4	26.0	13.7
P-values	0.112	0.556	0.123	<.001

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to DMRT.

There were significant differences among type of cuttings on number of roots per cutting (p <.001), length of the longest root per cutting (p = 0.002), rooting percent (p <.001) and cutting survival percentage (p <.001) (Table 9). Hardwood cuttings had the maximum number of roots per cutting followed by semi-hardwood and softwood cuttings. Softwood cuttings had the maximum length of the longest root per cutting, rooting percent and cutting survival percentage as compared with the other cuttings.

3.7 Effect of growth regulators on shoot and root parameters of *S. glaucescens*

It was found that there were significant differences among growth regulators and control on number of leaves of the longest sprout per cutting (p <.001) (Table 7). The maximum number of leaves of the longest sprout per cutting was observed in stem cuttings treated with NAA followed by IAA and control. The growth regulators did not differ significantly (p ≤ 0.05) on number of days taken to sprout, number of sprouts per cutting and length of the longest sprout per cutting (Table 7). However, stem cuttings treated with NAA had minimum number of days taken to sprout and maximum length of the longest sprout per cutting compared to IAA and control. Control had the maximum number of sprouts per cutting followed by NAA and IAA.

Table 8: Interaction effect of cutting types and growth regulators on number of days taken to sprout, number of sprouts per cutting, length of the longest sprout per cutting and number of leaves of the longest sprout per cutting of *S. glaucescens*

Treatments	Number of days taken to sprout	Number of sprouts per cutting	Length of the longest sprout per cutting (cm)	Number of leaves of the longest sprout per cutting
S + IAA	10.00a	2.850ab	34.00ab	26.00bc
S + NAA	10.00ab	2.438ab	43.25b	32.00d
S + Control	11.25abc	2.175a	33.50ab	25.50abc
SH + IAA	10.25abc	3.750bc	33.00ab	25.25abc
SH + NAA	10.00a	3.262abc	34.50ab	28.00cd
SH + Control	11.50abc	3.600abc	31.00ab	21.25ab
H + IAA	12.25abc	4.350cd	26.50a	21.00ab
H + NAA	11.00abc	5.362de	31.25ab	25.25abc
H + Control	13.00ac	6.300e	23.25a	20.00a
C.V%	16.4	24.4	26.0	13.7
P-values	0.967	0.083	0.901	0.812

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to DMRT.
S = Soft wood cuttings, SH = Semi-hard wood cuttings, H = Hard wood cuttings.

There were significant differences among growth regulators and control on number of roots per cutting (p = 0.002), rooting percent (p = 0.030) and cutting survival percentage (p = 0.030) (Table 9). The stem cuttings treated with NAA had the maximum number of roots per cutting, rooting percent and cutting survival percentage compared with IAA and control. The growth regulators and control did not differ significantly (p ≤ 0.05) on length of the longest root per cutting (Table 9). However, the maximum and minimum length of the longest root per cutting was observed in stem cuttings treated with NAA and control, respectively.

Table 9: Effect of cutting types and growth regulators on number of roots per cutting, length of the longest root per cutting, rooting percent and cutting survival percentage of *S. glaucescens*

Treatments	Number of roots per cutting	Length of the longest root per cutting (cm)	Rooting percent (%)	Cutting survival percentage (%)
Soft wood	26.16a	29.67b	90.83c	90.83c
Semi-hard wood	26.50a	21.58a	70.83b	65.83b
Hard wood	45.63b	19.33a	35.83a	31.67a
C.V%	25.6	27.5	20.7	22.9
P-values	<.001	0.002	<.001	<.001
IAA	26.16a	22.54ab	70.00b	65.83b
NAA	39.93b	27.12b	70.83b	69.17b
Control	32.20a	20.92a	56.67a	53.33a
C.V%	25.6	27.5	20.7	22.9
P-values	0.002	0.071	0.030	0.030

Means followed by the same letter in the same column are not significantly different at P ≤ 0.05 according to DMRT.

3.8 Interaction effect of cutting types and growth regulators on shoot and root parameters of *S. glaucescens*

Interactions between type of cuttings and growth regulators did not differ significantly (p ≤ 0.05) among treatments on number of days taken to sprout, number of sprouts per cutting, length of the longest sprout per cutting and number of leaves of the longest sprout per cutting. However, softwood cuttings treated with NAA had minimum number of days taken to sprout which is similar to softwood cuttings IAA and semi-hardwood cuttings treated with NAA (Table 8). The maximum number of days taken to sprout was observed in untreated hardwood cuttings (control). The maximum and minimum number of sprouts per cuttings was observed in untreated hardwood cuttings (control) and untreated softwood cuttings (control), respectively. Softwood cuttings treated with NAA had the maximum length of the longest sprout per cutting and number of leaves of the longest sprout per cutting compared to the other treatments and controls.

There were significant differences between interaction of cutting types and growth regulators on number of roots per cutting (p = 0.015) (Table 10). The maximum and the minimum number of roots per cutting was observed in hardwood cuttings treated with

NAA and softwood cuttings treated with IAA, respectively. Interactions between cutting types and growth regulators did not differ significantly ($p \leq 0.05$) on length of the longest root per cutting, rooting percent and cutting survival percentage (Table 10). However, softwood cuttings treated with NAA had the maximum length of the longest root per cutting, rooting percent and cutting survival percentage compared to the other treatments and controls.

Table 10: Interaction effect of cutting types and growth regulators on number of roots per cutting, length of the longest root per cutting, rooting percent and cutting survival percentage of *S. glaucescens*

Treatments	Number of roots per cutting	Length of the longest root per cutting (cm)	Rooting percent (%)	Cutting survival percentage (%)
S + IAA	20.07a	29.12bc	90.00de	90.00de
S + NAA	28.92a	33.38c	97.50e	97.50e
S + Control	29.47a	26.50abc	85.00de	85.00de
SH + IAA	27.22a	19.00ab	80.00cde	72.50cd
SH + NAA	28.70a	28.25bc	72.50cd	70.00cd
SH + Control	23.57a	17.50a	60.00bc	55.00bc
H + IAA	31.18a	19.50ab	40.00ab	35.00ab
H + NAA	62.16c	19.75ab	42.50ab	40.00ab
H + Control	43.56b	18.75ab	25.00a	20.00a
C.V%	25.6	27.5	20.7	22.9
P-values	0.015	0.586	0.773	0.891

Note: Means of each category followed by a common letter are not significantly different at 0.05 level of significance.
S = Soft wood cuttings, SH = Semi-hard wood cuttings, H = Hard wood cuttings.

4.0 Discussion

Seed germination of both *C. swynnertonii* and *S. glaucescens* was generally poor but it was significantly affected by pre-sowing treatments. In *C. swynnertonii*, early germination, high germination percentage and better survival percentage were recorded in seeds treated with KNO3 at 10 ppm. This could be due to the role of KNO3 in balancing hormonal portion within seed which in turn results in germination inhibitors ratio like abscisic acid (Farajollahi *et al*., 2014). These results are in agreement with the findings of Lal and Kasera (2014) who reported that KNO3 at 5 mg/L resulted to higher germination and seedling development of Commiphora wightii. Lower concentrations of nitrate solutions promoted germination and seedling development, while higher ones retarded them. Suppression of germination by higher concentrations of KNO3 has also reported in Lepidium latifolium (Karimmojeni *et al*., 2011), Sorbus pohuashanensis (Bian *et al*., 2013) and Capsicum frutescens (Eremrena and Mensah, 2016). Similar results were observed in this study, as lower concentrations of KNO3 (10 ppm) increased germination percentages, but higher concentrations (20 ppm) retarded germination. KNO3 play a critical role in increasing the physiological efficiency and

influence germination may be due to change in water relationship (Lal and Kasera, 2014).

In *S. glaucescens*, seeds soaked in water (25 0C) for 24 hours had the minimum number of days taken to start germination, high germination percentage and better survival percentage as compared to the other treatments and control. The results are in accordance with the findings of Pandey (2012) who reported the highest germination of Gymnema sylvestre seeds when soaked in water for 24 hours. The author suggested that the treatment of water for 24 hours helps in breaking seed dormancy and improves germination. Soaking the seeds in water at room temperature helps in softening the seed coats, removal of inhibitors and reduces the time required for germination and increases germination percentage (Olajide *et al*., 2014). This observation concurs with other studies (Sabongari and Aliero, 2004; Offiong *et al*., 2010).

Vegetative propagation of *C. swynnertonii* and *S. glaucescens* by stem cutting is achievable. The results of this experiment demonstrated that stem cuttings have influenced the shoot and root development of *C. swynnertonii* and *S. glaucescens*. In *C. swynnertonii*, hardwood cutting has shown the best shoot performance particularly in the number of sprouts per cutting and length of the longest sprout per cutting. This is because hardwood cuttings contain sufficient stored food such as hydrocarbons, nucleic acids, proteins and natural hormones such as IAA that can be used for shoot growth and development (Roland *et al*., 2006). Similar finding was reported by Ayan *et al*. (2006) who observed that basal cutting of Alnus glutinosa gave the highest sapling length growth compared with tip cutting. Semi-hardwood cuttings have shown the best root performance particularly in length of the longest root per cutting, rooting percent and cutting survival percentage. The reason may be due to the early differentiation of root cells and enhanced cell elongation by the effect of the hormone. The findings of the present study also agree with Yeshiwas *et al*., (2015) who found that semi-hardwood stem cuttings of rose gave higher root length compare to hard and softwood cutting. In *S. glaucescens*, softwood cuttings have shown the best shoot and root performance particularly in the number of days taken to sprout, length of the longest sprout per cutting, number of leaves of the longest sprout per cutting, length of the longest root per cutting, rooting percent and cutting survival percentage. This is most probably due to the higher concentration of shoot and root promoting substances forming in the apical shoots, which are translocated to the base of shoot and more available carbohydrates, which aid in rooting. It is however contrary to findings by Ayan *et al*. (2006).

On the other hand, the results revealed a significant influence of growth regulators on the shoot and root parameters of *C. swynnertonii* and *S. glaucescens*. The cuttings treated with NAA at 2000 ppm was found superior in both plants. This may be due to the action of auxin (NAA) which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances at the base of cuttings and resulted in accelerated cell elongation and cell division in a suitable environment (Hartmann *et al*., 2007). The superiority of NAA was also observed in Lawsonia inermis by Quainoo *et al*., (2014) who reported that NAA effected the number of leaves, roots and root length per

cutting. The results of the analysis of variance showed that there were significant interaction effects of growth regulators and cutting types on the shoot and root parameters of *C. swynnertonii* and *S. glaucescens*. In *C. swynnertonii*, semi-hardwood cuttings treated with NAA has shown the best performance while in *S. glaucescens*, softwood cuttings treated with NAA has shown to be superior. The results were similar to Ullah *et al.*, (2005) who found early sprouting and maximum root length of Guava in semi-hardwood and softwood cuttings treated with 1000 ppm NAA.

5.0 Conclusion

It is evident from the present study that, *C. swynnertonii* and *S. glaucescens* can be propagated through stem cuttings. The growth regulators had remarkable influence in enhancing the rooting and survival percentage. Among the different growth regulators, NAA 2000 ppm was found to be the best for multiplication of *C. swynnertonii* by semi-hardwood cuttings and *S. glaucescens* by softwood cuttings. Pre-sowing treatments have only marginally improved the seed germination of both plants. Further study on in vitro propagation of these plants is recommended. Seeds and clonal gene banks should be established to conserve the genetic diversity of these plants.

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Irrigation by Smallholder Farmers in the Usangu Plains, Tanzania

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Abstract

Groundwater (GW) use for irrigation by smallholder farmers has been proposed as a solution to increasing water scarcity in the Usangu Plains, Tanzania. This study evaluated the financial viability of utilising GW for irrigation by smallholder farmers in the plains. Specifically, the study analysed the costs and benefits of using GW for small scale irrigation and examined the socio-economic factors influencing the use of GW for irigation. Primary data were collected using a semi-structured questionnaire which was administered to a random sample of 97 households in three villages, while data from key informants were gathered using a checklist. Secondary data from various sources were used to supplement the primary data. Discounted cash flow, descriptive statistics, and logistic regression were used to analyse data. Key findings show that, investment in GW for irrigation is economically viable at a discounting rate of 12% and had a Net Present Value of TZS 38 636 794, Cost Benefit Ratio of 6.55, and Internal Rate of Return was 81%. Socio-economic factors namely household size was statistical significance (P<0.05) while gender, income and membership in socio networks although were not significant had a positive association with GWI. High initial investment cost relative to farmer's income level was revealed. Conclusively, investment in GWI by smallholder farmer is financially viable and household income level was found to be a constraint to GWI development. The study suggest that, government and development agencies should participate in GWI investment such as through subsidisation and tax exemption of GWI devices. Further, market for agricultural goods should be improvedand enhancesupport to increase productivity of smallholder farmers that will lead to increased incomes enabling affordability of GWIs.

Keywords: Cost Benefit Analysis, Groundwater, Internal rate of return, Net present value, Smallholder farmer, UsanguPlains

1.0 Introduction

Africa has a population of more than 650 million people who depend on rain-fed agriculture in an environment which is already affected by water scarcity and land degradation (FAO, 2010). In particular,agricultural sector in Africa mainlySub Saharan Africa (SSA) is said to employ more than 80% of its rural community who are predominantly smallholderfarmers. Thus, development inagriculture sectorisseen as an important measure of securing smallholder farmers from extremepoverty, food insecurity and at the same time safeguarding the environment (Allaire, 2009). Given the semi-arid condition of SSA with unpredictable nature of the rainfall, irrigation agricultureis among the strategies available for increasing agricultural production.Conversely, surface water resources in SSA are under increasing pressure as a result ofincreasingdemandand alsorapid environmental change (Calow*et al.*, 2010). Thus consideration of groundwater (GW) use for irrigation has been advocated as one of the strategy to drought mitigation, adaptation to climate change impacts, livelihood

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enhancement, and food security to smallholder farmers in SSA (Villholth*et al*., 2013 andTuinhof*et al*., 2011).

Groundwater use for irrigation by smallholder farmers is reported to benefit thousands of households in many part of the world through income generation, employment creation and also food security assurance. Namara*et al*. (2011); ECA, (2011) and Villholth*et al*.(2013)advocateGW use for irrigation by smallholder farmers as a strategy to reduce risks associated with environmental degradation,rainfall variability and also increased yields of food crops.Also, African Climate Policy Centre (ACPC), (2013) emphasizeson GW as an important renewable resource that can contribute significantly towards offsetting the impact of climate change, food insecurity and extreme poverty in the SSA.Akudugu *et al*. (2012); Dittoh*et al*.(2013); Shah*et al*. (2013) and Villholth (2013) reported GW as a solution to smallholder farmers since it responds to their demand for its reliable and flexible irrigation water supply due to itsmode of access, ownership and also investment.Tanzania is an agriculture based developing country whereby about 80% of its population are smallholder farmers engaged in a wide range of agricultural activities for their food and livelihoods enhancement. Like other SSA countries, agriculture development in the country is highly constrained by inadequate and unreliable water for irrigation.Usangu Plains found in Southern part of Tanzania is one of the areas facedwithachallenge of water scarcityas it was first detected in early 1990 as a result of significance change of river flows in dry season (Kajembe*et al*.,2009; Walsh, 2012).This challengemarked to have a multiple negative impacts inagricultural activities,livelihood option of the smallholder farmers, important biodiversity of the Ruaha National Park, Usangu Wetlandand andMtera, and Kidatu dams thatapproximately generate 50% of the nation hydroelectric power (i.e. 284MW out of the total capacity of hydropower generation in the countryof 567.7 MW) (TANESCO, 2019).As part of a strategy to address this problem to safeguard theenvironment, sustainable development of GW use for irrigation by smallholder farmers was proposed to supplement surface water(WWF, 2010; URT, 2008 and WB, 2006).However, implementation of existing plan is stillquestionable sincethe existing literature does not offer enough information on the financial viability ofinvesting in GW use for irrigation by smallholder farmers. Villholth *et al*. (2013) observed that,there is a potential profit gains for the farmers, by being able to grow a second crop in the dry season through irrigation with GW.According to the authors,economics of the farmers is a major constrainst to GW irrigation development in the Usangu Plains. Nevertheless,not much attention has been paid on the estimated costs and benefits that areassociated with investing on GW irrigation and also on determinant factors of the smallholder farmers to use GW for irrigation.It is important to know whether an investment is worthy or otherwise remains equally important as a guide for investment decisions.This paper presentsthecosts and benefits associated with the useofGW for irrigation as well as the socio-economic factors enhancing or constraining GW irrigation by smallholder farmers in the Usangu Plains, Mbarali District in Tanzania.

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2.0 Materials and Methods

2.1 Description of the study area

Usangu plains is located in the upper part of the Great Ruaha River Basin catchment (Figure 1)in the south-western highlands of Tanzania, between latitudes 7o 41' and 9o 25' south, and longitudes 33o 40' and 35o 40' east. It falls in two administrative regions and eight districts with the larger part in Mbeya Region primarily in Mbarali District.The Usangu Plains represents almost (15,560 km2) of the land of Mbarali District (URT, 2010). It encompasses an extensive wetland, comprising seasonally flooded grassland and a much smaller area of a permanent swamp commonly known as Ihefu which collects water from all the rivers in the Uporoto and Kipengere mountain ranges. This makes the area critical to Tanzania for livelihood options of the smallholder farmers and agro-pastoralists.The area is also home to majority of smallholder farmers producing irrigated paddy, maize, pulse, fruits, vegetables and also livestock keeping.Furthermore,Usangu plains provide the lifeblood of the Ruaha National Park and the Usangu wetlands that makes critical habitat for much of Tanzanian biodiversity including the population of endangered game animals like elephants and wild dogs. The flowing water through the Usangu plains and the park feed into the Mtera, and Kidatu hydropower reservoirs (Mwakalila, 2011), which produce about 50% of the country hydroelectric power, before joining the Rufiji River and emptying into the Indian Ocean (Kashaigili, 2006).The climate of the Usangu is mostlysemi-arid with seasonal temperature and rainfall variations. Temperatures range between 20 and 25oC, whereas annual rainfall varies between 500–700 mm/year. It receives the unimodal type of rainfall from November to May, normally scattered and varies across the Usangu plains. Rainfall is generally unreliable, and localized droughts are common (URT, 2010).

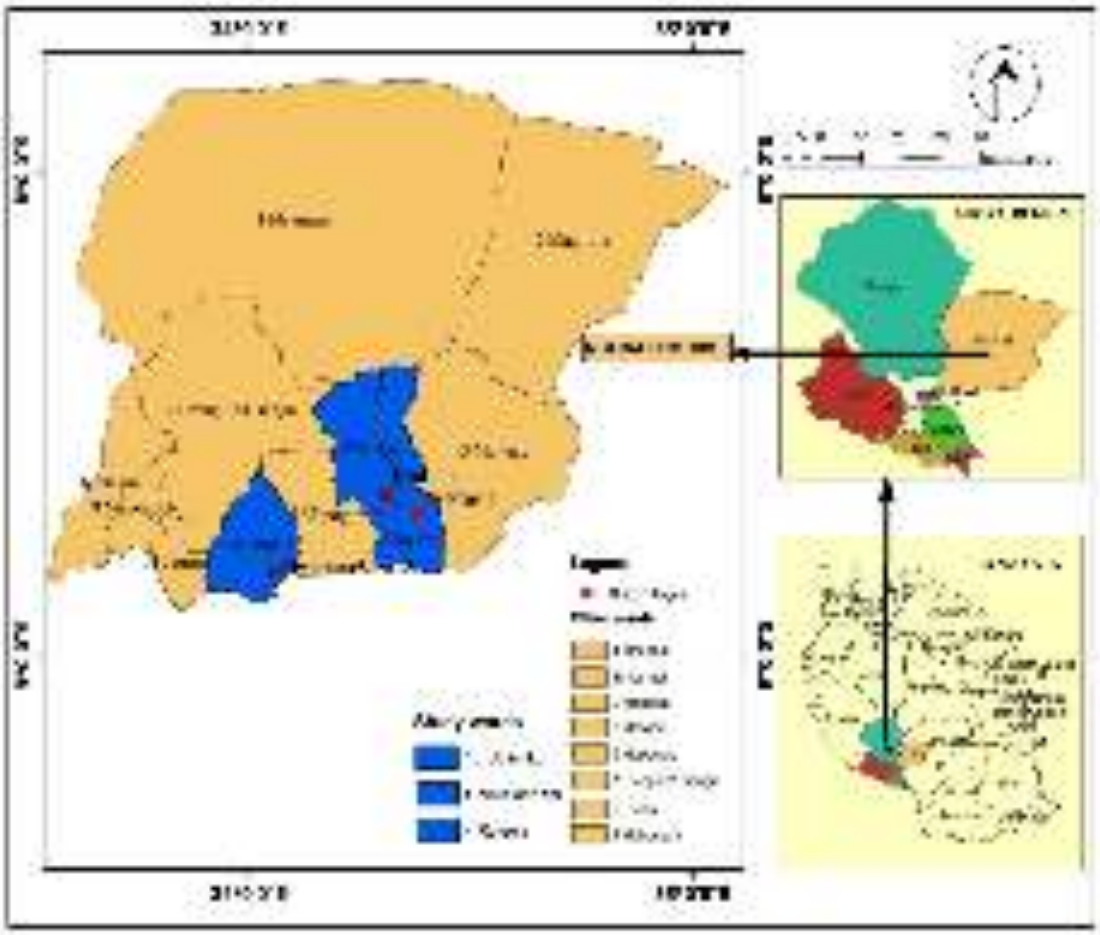

Figure 1: Map of the study area showing the studied villages.

Land use and land cover in the area include settlements, scattered croplands, grassland with scattered croplands, open bushland, seasonally inundated grassland and perennial swamp (Kashaigili, 2006; Mwita, 2016).Communities around in the Usangu Plains are smallholder farmers who depend mainly on small scale agriculture. About 90% of the population rely on agriculture, while livestock keeping, petty businesses are also important economic activities. Irrigated paddy is the dominant crop produced in the plains during wet season and it is produced mainly for subsistence to smallholder farmers and in a little extent for commercial purpose.

The human population in the Usangu plains was estimated to be more than 300,517 people as per 2012 national census data with an annual growth rate of 2.7 (URT, 2013). The population is multi-ethnic and multi-cultural in which Sangu are the indigenous ethnic group and other ethnic groups include, Bena, Hehe, Maasai, Sukuma and Nyakyusa. There has been a huge change in ethnic composition with increasing competition in land-use systems (Ngailo, 2011).

3.2 Research design, Sampling and Data collection techniques

The study employed two designs, a case study and exploratory cross-sectional research designs. Case study design was crucial for the present study because, currently the use of GW in the Usangu Plains is mainly for domestic purposes and to a very small extent for irrigation. Among the studied villages, only one village Nyeregete was found using GW for irrigation from dug wells at a very small extent. Apart from the studied villages, Mont Fort Secondary School is one of the places in the Mbarali District where GW investment and its use for irrigation is highly practised to supplement surface water irrigation. Thus, Mont Fort Secondary School was used as a case study, where detailed information which is associated with functioning of GWI and investment was studied. Also, the study employed a exploratory cross-sectional research design. Under this design, data from households were collected once examined and the relationship between variables was determined. The study design was advantageous as it was compatible with the available time and resources (Bryman and Bell, 2015).

The sampling procedures involved purposive selection of three out of 99 villages in the district. The villages were Nyeregete, Ubaruku and Mwaluma. These were selected based on the evidence that there were groundwater uses. The households were randomly selected using a random number table technique from the population of smallholder farmers in the study villages.According to Bailey (1994), a sample size of at least 30 households is statistically adequate. Accordingly, a total sample of 97 households was interviewed (Nyeregete village, 33 households; Ubaruku village, 34 households; and Mwaluma village, 30).

Both qualitative and quantitative data were collected. Quantitative data were collected using a semi-structured questionnaire containing both open-ended and closed questions. The questionnaire was administered to households. The information collected includes households' socioeconomic and demographic information, economic activities, groundwater information, information on previous crop production season and the existing price for inputs and outputs. Qualitative data were collected through Focus Group Discussion, Key informant interviews using probing questions and checklist. Furthermore, direct observation, transect walk and informal discussion were also carried out to counter check some of the responses from farmers and to get an insight on the actual field conditions. In addition, an in-depth interview was carried out with wells drillers, Rufiji Basin Water Board and the MbaraliDistric Water Engineer to gather more information associated with cost and benefit of GW use for irrigation in the case study.

2.3 Data analysis

Descriptive statisticsand financialanalysis were used for data analysis. Gross margin and Net Present Value (NPV), Internal Rate of Return (IRR) and Cost Benefit Ration (CBR) decision criteria were employed to analyse data oncosts and benefits associated with the use of GW for irrigation and its investment. NPV, IRR and CBR were applied to evaluate the long-term financial viability of using groundwater for small scale irrigation, while gross margin was used to evaluate the profitability of using GW

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irrigation against SW for irrigation as an alternative scenario in a short run period of time. Theinformation on surface water irrigation was included in this analysis in order to compare the profitability with and without groundwater irrigation, while other factors such as climate change notwithstanding. Sensitivity analysis was carried out to study the effect of a change in fluctuating factors such as prices of inputs and outputs scale of production and discount rate on NPV and CBR.

NPV, IRR and CBR was obtained using the following formula (Lin *et al.*, 2000):

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} \quad \text{.....} \quad (1)$$

$$CBR = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}} \quad \text{.....} \quad (2)$$

IRR was obtained by using the following formula

$$IRR = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} = 0 \quad \text{.....} \quad (3)$$

Where for all equation 1, 2 and 3

Σ = is the sum of the discounted cost and benefits

B = benefits at year at year 2016 (market value of yield at year 2016)

C = Cost at year 2016 (market value of inputs, fees and other production costs)

t = the time in years i.e. 30 years (t=30)

r = discount rate 12%, 18% and 20%

$(1 + r)^t$ = discount factor

The cost component included the initial capital cost of the borehole, operation and maintenance cost, water fee, market prices of inputs, the cost of ploughing, planting weeding, and harvesting.

In line with the CBA framework, the analysis was carried out on the basis of the following assumptions:

Discounting reflects the time value of money. Benefits and costs are worth more if they are experienced sooner such that all future benefits and costs should be discounted to its present value for the investments with long life span. The higher the discount rate, the lower the present value of future benefits and costs. For projects with the costs concentrated in early periods and benefits following later, raising the discount rate tends to reduce the net present value. The discounting rate of 12% was used in this analysis as per the Bank of Tanzania (BOT), and as indicated in the Monthly Economic Review of February, 2017. Apart from constant discounting rate from the Central Bank in Tanzania (BOT), the study also considered 16% and 20% of interest rates that are used by different microfinance banks of Tanzania as they are the main credit sources for smallholder farmers. However, there is considerable uncertainty over the correct discount rate and also high uncertainties are expected in agricultural production and which include an increase in the production costs and a decrease in returns that can

affect investment financial viability. Different scenarios were assumed to check the investment sensitivity.

Scenario one anticipates the increase of production cost and reduced income while scenario two assumed an increase in production cost and increased income. Therefore, scenario one assumed a 25% increase in the production costs and 10% decrease in income while scenario two assumed 100% increase in the production costs and 25% increase in income. However, Gebrehewaria*et al*. (2016) also revealed that the size of land for production affects the investment financial viability. This is due to the economies of scale, whereby, the cost per unit of an output generally decreases with an increase in the scale of production. The sensitivity of the investment was measured at a 0.4 ha of land. Based on these scenarios, sensitivity of investing in GW for small scale irrigation was tested at 12%, 16% and 20% discounting rates.

It is widely acknowledged that estimating the life of a project or program is difficult, subjective and widely debated. It depends on the assessments of the program's physical life, technological changes, shifts in demand or fashion, competing products that emerge and the general state of the world many years in advance. However, since GWI involves fixed cost which is capital intensive, lifespan is one of the important variables of determining the viability of an investment. This takes into account the entire income stream for the whole lifespan of the investment. For example, the available evidence shows that boreholes are drilled and function for a lifespan of 20 to 50 years (Carter *et al*., 2014). This study opted for 30 years investment lifespan. However, the life span of wells can last less or more than the opted lifespan. Such lifespan was selected so as to avoid underestimation or overestimation of the financial viability of such investment.

Cost-benefit analysis (CBA) was applied to estimate the direct costs and benefits accrued from investing in GW irrigation by smallholder farmers. In-line with the CBA framework, the analysis was carried out on the basis of the following considerations:

i. All costs and benefits are estimated in incremental terms as opposed to surface water irrigation as a business as usual alternative.
ii. The analysis starts at (year 0) when the initial investment costs of the GWI facilities occurred while the maintenance and operation cost were assumed to start from the second year after the investment.
iii. All production costs and benefits from using groundwater for irrigation were regarded with the crude assumption that, since it was difficult to forecast the cash flows for the entire lifespan of the investment, constant value was used in measuring project viability throughout the lifespan of the project. Costs and benefits have been quantified and valued in TZS using the Nov – Dec 2016 market prices.
iv. Two production seasons in a year for groundwater irrigation were assumed where paddy could be produced during the wet season and during the dry season the same field would be used to cultivate any other crop. This is due to the argument that through GW, the farmer has an added advantage of irrigating his/her farm during the dry season. Empirical evidence was observed during data collection, whereby some households that owned wells (mostly dug wells) had irrigated

backyard gardens during the dry season. Vegetables and tree fruits were grown in these gardens for their own consumption and for sale in the local market. At Mont Fort Secondary School paddy seedlings, vegetables, onions and orchard crops were found grown on school gardens using GWI in the dry season.

v. This analysis used onion as the second crop during the dry season. This was due to the argument that paddy was reported as both a cash and food crop grown during wet season, while onions, water melon and vegetables were reported as cash crops grown in the dry season. Thus, paddy and onion were selected in estimating the viability of investing in GW irrigation by smallholder farmers. By considering such scenarios, a relative profitability of using GW for small scale irrigation was established.

vi. Operation and maintenance were estimated to take 10% of the investment cost per year. This was estimated from the communal deep well supplying water to the villages of Ubaruku and Mpakani, where hydroelectric power is used as a source of energy.

Gross Margin Analysis

Gross margin was used to analyse profitability of using groundwater for small scale irrigation. As performance from agriculture varies from season to season and crop to crop, gross margin analysis is useful for production cycles of less than a year as this enables costs and returns to be directly linked to a particular activity. It also allows establishing profitability of the enterprise (Makombe*et al.,* 2007). The Model for gross margin analysis is presented as follows:

$GMI=\sum TR-\sum TVC$ ……..……..……..... (4)

$TR= P_y.Y_i$ ……..... (5)

$TVC = P_x.Xi$ ……..……..... (6)

Where GMI = Gross Margin Income
TR = Total Revenue
TVC = Total Variable Cost
Py = Unit Price of Output Produced
Y = Quantity of Output (Kg)
Pxi = Unit Price of Variable input used
Xi = Quantity of Input.

3.0 Results

3.1 Short term economic analysis of GW use for irrigation

Table 1 presents the estimated profitability of surface water and GW use for irrigation. The production cost for the first and second seasons was TZS 1,586,250 for surface water and 4,860,000 for groundwater use. Average net profit of first and second seasonswas TZS630,415 and 4,820,415 respectively (Table 1). The relative profitability of using

surface water for irrigation was also evaluated and the findingsshowed that GW use for irrigation by smallholder farmers is more worthwhile. Themainreason of that difference could be an opportunity that a farmer can get by having more than one production season in a year through GW irrigation. Also to ensure financial viability of using GW water use for irrigation need to be combined with high valued crops that have high demand both in local and international markets.

Table 1: Profitability of using GW for irrigation

Operation	Parameter	Surface water (TZS/ ha)	Groundwater (TZS/ ha)
Production Cost [a]	(Wet season) **Paddy**		
	Nursery management	40 000	40 000
	Ploughing	162 500	162 500
	Furrowing	162 500	162 500
	Inputs (fertiliser, seeds, and pesticides per acre	296 250	296 500
	Planting	210 000	210 000
	Weeding	165 000	165 000
	Bird scaring	50 000	50 000
	Harvesting	500 000	500 000
	Total cost of production (paddy)	**1 586 250**	**1 586 250**
	Dry season (Onion)		
	Nursery management	NA	60 000
	Ploughing and basin preparation	NA	212 500
	Inputs (fertiliser seeds and pesticides)	NA	1 775 000
	Planting	NA	150 000
	Harvesting	NA	212 500
	Total cost of production (onion)		2 410 000
	Water use fee per year	50 000	150 000
Other cost	O and M [b]	0	2 300 000
	Others total cost	50 000	2 450 000
	Total Production cost	1 636 250	6 446 250
Benefits			
Crop yield (ton/ha/year)	Paddy	4.25	4.25
	Onion	NA	20
Output price (TZS/ton)		533 333	533 333
		NA	450 000
Total revenue (TZS/ton/year)	Paddy 4.25 Onion 20	2 266 665	11 266 665
Gross Margin [c]		630 415	4 820 415

Data represent farm statistics from the harvest of the cropping season 2016
Production cost [a:] Production cost per hectare per season

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O and M cost [b]: Operation and Maintenance Cost per year

3.2 Financial viability of GWI

The depth of the wells used in CBA was adopted from the dug wells and also from motorised wells found in the study area; as per report from the Mbarali District council and from the Rufiji Basin Water Board and also well labels. About 25 dug wells and 5 functioning machinery drilled wells were observed during the survey. Their depth ranged from 9 to 23 for dug wells with an average of 15 meters and 14 to100 meters for machine drilled wells. This study focused on three different types of well depths namely, 40, 50, and 100 meters. This is due to the reason that, the GWI demands for initial capital increases as the well depths increases. Also shallow wells (both dug and machinery drilled wells) were reported to have low recharge capacity and sometimes they dry up completely during the off rain season. As a result a 40 meters well depth was chosen as a yardstick in the analysis of well depth to support small scale GW irrigation due to the empirical evidence observed during case study survey at Mont Fort secondary School where by their 40 meters well depth supports water to the compound for domestics, livestock, fish pond and also small-scale irrigation.

Table 2 shows a summary of NPV, IRR and CBR calculations for 1 hectare of paddy and one hectare of onion. As shown in Table 2, the highest NPV was observed while investing in 40 meters depth with the value of TZS 38 636 794, 23 032 915, and 19 807 103 at the discounting rate of 12% 18% and 20% respectively. Likewise, investing in 50 and 100 meter depth had positive NPVs at the same discounting rate although less than that observed when investing in 40 meters deep well. The possible reason for this was due to the increasing cost of drilling as the well depth increases. The business as usual scenario gives the NPV of TZS 4 534 025, 2 947 353 and 2 615 663 which was lower than when investing in GW use for irrigation.

Investing in GWI had positive NPVs at a discounting rate of 12% 18% and 20% per hectare in all adopted well depth; this implies that the present value of benefits stream was greater than the present value of the cost stream. Therefore according to the NPV criterion, investing in GWI by smallholder farmer is financially viable since the NPVs are above zero. Thus, upon decision making process, smallholder farmers' investment in GWI is economically viable. This implies financial viability of GWI by smallholder farmers tend to decrease with the increasing cost of investment.

The BCR was also greater than one and according to decision criteria, projects with BCR which is positive and greater than one are financially viable because the discounted benefits are higher than the discounted costs. The IRR was greater than all the discount rate which was used to compute NPV and BCR, and as a general rule the project with an IRR higher than the discount rate is deemed to be acceptable. The maximum interest rates (IRR) for the investment projects were to recover its investment and operating expenses in its lifetime and to break even.

Table 2: Summary of the results of Cost Benefit Analysis

Parameter	40 meters deep (TZS/ha)			100 metres deep (TZS/ha)	Surface water
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		50 meters deep (TZS/ha		irrigation (TZS/ha)
Investment	7 800 000	9 437 500	23 000 000	_
Production cost				
Maintenance cost and Operation	780 000	943 750	2 300 000	_
Inputs cost	3 996 250	3 996 250	3 996 250	1 586 250
Water use fee	150 000	150 000	150 000	50 000
Total Production cost	4 926 250	5 090 000	6 446 250	1 636 250
Crop Value	11 266 665	11 266 665	11 266 665	2 266 665
Net Benefit	6 340 415	6 176 665	4 820 415	630 415
NPV at 12%	38 636 794	35 997 029	14 133 330	4 534 025
NPV at 18%	23 032 915	20 879 629	3 045 165	2 947 353
NPV at 20%	19 807 103	17 763 101	833 783	2 615 663
CBR at 12%	6.55	5.27	1.69	-
CBR at 18%	4.48	3.61	1.16	-
CBR at 20%	4.05	3.26	1.04	-
1RR	81%	66%	21%	

3.3 Sensitivity analysis

Sensitivity analysis was carried out to test the changes in NPV, CBR and IRR as a result of changes in market prices of variable inputs, price of outputs, and the scale of production. Sensitivity analysis was made for the increase in the production cost, decrease income and reduction in land size. The NPVs at all the discount rates in all developed scenarios were positive when 40 meters deep well was used. Investing in 50 meters well depth, gives a negative NPV at the discounting rate of 20% and in one acre piece of land which was used in production contrary to the NPVs of 100 meters well depth, which were consistently negative at all the discounted rate (Table 3). The CBRs were also greater than one when investment was to made in 40 -50 well depth for scenario one and two with the exception of 50 meters whereby at a discounting rate of 20% meters and reduced area of cultivation to one acre the CBR is less than one. This reflects that the financial viability of GWI by smallholder farmer tend to decrease with an increase capital cost and reduced area of cultivation. The findings imply further that a decrease in the scale of production leads to a decrease in the financial viability of GWI, at such investment in GWI by smallholder farmer should be made at not less than one acre. The maximum IRR was also observed in all the scenarios when the investment was to be made through 40 and CBR was greater than one.

Table 3: Sensitivity analysis GWI

Parameter estimated	40 meters well depth	50 meters well depth	100 meters depth
Scenario 1 :25% Increase in production costs			

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10% decrease in income			
NPV at 12%	21 676 107.88	18 652 014. 89	-5 560 364.92
NPV at 18%	12 007 582.56	9 604 463. 82	-9 756 766
NP Vat 20%	10 022 542.35	7 756 823. 39	-10 527 440.28
CBR at 12%	4.11	3.21	0.73
CBR at 18%	2.28	2.2	0.50
CBR at 20%	2.54	1.99	0.45
IRR	51%	40%	8%
Scenario 2: 100% increase in production costs and 25 increase in income			
NPV at 12%	23 464 396.48	19 646 920. 81	-11 971 102.86
NPV at 18	13 170 063.57	10 251 204.30	-13 924 080.57
NPV at 20%	11 054 199.76	8 330 781.7	-14,225,772.5
CBR at 12%	4.37	3.33	0.42
CBR at 18%	2.99	2.28	0.29
CBR at 20%	2.7	2.06	0.26
IRR	54%	41%	3%
Scenario 3: Land size for production is one acre **(0.4 ha)**			
NPV at 12%	6 615 647 59	3 975 882.97	-17 887 816.37
NPV at 18%	2 217 496 59	64 211.02	-17 770 253.45
NPV at 20%	1 334 215 77	-709 784.93	-17 639 103.67
CBR at 12%	1.95	1.47	0.12
CBR at 18%	1.34	1.01	0.09
CBR at 20%	1.21	0.91	0.08
IRR	24%	18%	-4%

3.4Socio-economic Factors Determining the use of GWI by Smallholder Farmers

The analysis of socio-economic factors that influence the use of GWI by smallholder farmers was undertaken using the logit model. The model was statistically significant ($P < 0.001$) as suggested by Omnibus Tests of Model Coefficients (likelihood ratio test), which gives an overall indication of how well the model performs. The results of the logit model are presented in Table 4. This study found that all selected factors affect the decision of the household on the use of GW for irrigation. It further highlight the importance of household size in explaining the use of GWI by smallholder farmer. Households size was statistically significant ($P < 0.05$) and positively related to the use of GWI by smallholder farmers. This implies that, when, the household size increases by one unit, there is an increase in the probability that the households will use GW for irrigation by 38.3% the coefficient estimates (Table 4). The plausable explanation for this situation is availability of adequate labour to be deployed in groundwater small scale irrigation. Furthermore, this finding indicates that an increase in the number of the households leads to an increase in the ability and desire to diversify the available resource for food security and livelihoods support.

Table 4: Logistic regression analysis result

Variable	B	S.E	Sig
Gender	1.181	0.979	0.228
Households size	0.383	0.190	0.043*
Age	0.020	0.30	0.501
Education level	16.224		0.777

Access to financial institution	19.235	10073.519	0.998
Social network membership	1.275	1.163	0.273
Households income level	0.000	0.000	0.777
Constant	-42.232	30063.844	0.999

The findings indicate that the model with descriptors performs better than the null hypothesis.

The results show further that the model performance is statistically significant (χ^2 (44.045) = 8, $p < 0.001$). The inferential test for goodness-of-fit, the HosmerandLeme show (H-L) statistic, indicates that the model fits the data well at $p > 0.05$. The descriptive measures of goodness-of-fit also supports that the model fits the data well (Cox and Snell R2=0.189; andNagelkerke R2=0.388). The descriptor which is statistically significant as the determinant of GW use is: households size ($P < 0.05$).

4.0 Discussions

4.1 Groundwater and small scale irrigation

Groundwater is the critical underlying resource for human survival and economic development in extensive drought-prone areas across Sub-Saharan Africa (SSA) (Foster *et al*., 2012). Tuinhof *et al*. (2011) observed that many parts of SSA are prone to severe drought that is directly related to persistent poverty, hence there is a high demand for investment to focus on drought impacts. In SSA, dependence on groundwater in rural and urban water supply is undisputable, as evidenced by high presence of wells (boreholes and dug wells) for both domestic and livestock consumption. Currently, there is growing interest in the prospect

of accelerating groundwater use for agriculture irrigation both at small scale and commercial scale with high-value crop production, drought mitigation and climate change adaptation (Foster *et al*., 2012). Ngigi (2009) observed that smallholder farmers GWI in SSA are important development pathways to fight against poverty, food security, land and labour productivity, as well as rural employment and adaptation to the increasing impact of climate variability and climate change. Furthermore, Abric *et al*. (2011) ascertain such a pathway reflects the recognition of small scale irrigation benefits that is practised most by poor farmers while Villholth (2013) reports that groundwater responds the demand of smallholder farmers for a reliable and flexible irrigation water supply. As compared to surface water irrigation (SWI) scheme which is often seen limited according to geographical location and highly capital intensive, ground water irrigation is observed to be more attractive to smallholder farmers due to its mode of access and ownership.

4.2 Investment in groundwaterirrigation

The decision that farmers make about investing in a particular technology are based on the cost and benefits that are associated with such a technology. This is highly

influenced by the ability of the farmer to access such technology. Adegbola and Gardebroek (2007) revealed that farmer investment in a certain agricultural technology is influenced by the economic gain that is anticipated.Capital investment has been observed as the largest constraint facing poor farmers in SSA. Villholth (2013) observed that access to and demand for GWI in well construction and other facilities for an operationare seen as a limiting factor that hinders GWI development in SSA. The cost of well drilling including both manual drilling less than about 20 m and motorized drilling has been observed to increase from the simple to the more advanced technologies. Abric *et al*. (2011) show that the prices for low-cost shallow manual drilling in West Africa is approximately one-tenth of prices given for deep wells. Hence, manual drilling wells have been promoted and adopted widely in West Africa as a suitable approach for smallholder irrigation. In terms of operation and maintenance in most of the regions in SSA, farmers have been observed using manual lifting devices including bucket with rope and treadle pumps due to the high cost of motorized pumps operated by fossil fuel and electricity. It is further noted that while the capital investment is financed by the government and transferred to smallholders, operational and maintenance costs are high, while beneficiaries' willingness and ability to pay these costs was very low, posing large risks for the financial feasibility and sustainability of such projects, such that manual drilling shallow wells are seen favourable to smallholder farmers due to its investment cost that can be affordable to smallholder farmers. However, economic viability of the groundwater use for irrigation could be the determinant factor whether to promote it or not.

5.0 Conclusion

From the findings, the use of GWI by smallholder farmers was found economically viable when investing in shallow wells. The CBA carried out between GW use for irrigation by smallholder farmers using both shallow wells and deep wells shows positive NPVs when investing in shallow wells. Such that according to NPV criterion investing in GW irrigationby smallholder is suggested to be worth through investing in shallow wells. The findings further revealed that financial viability of investing in GW irrigation by smallholder farmer decrease with increasing investment cost.

Because GWI requires high initial investment, it is recommended that different strategies such as co-investment or cost sharing mechanism to be used. Further community awareness in producing crops with high value and reliable markets for agriculture crops is recommended to ensure sustainable economic viability of GW irrigation by smallholder farmers.

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Genetic Analysis of the Giant Tiger Prawns Reveals Priority Areas for the Establishment of Marine Protected Areas in Tanzania

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Abstract

Rapid growth of the human population along the Tanzanian coast has led to overfishing and habitat degradation, which might disrupt connectivity patterns and influence genetic diversity and population structure. Since knowledge about this is essential for sustainable management, this study analysed fragments of the mitochondrial control region (534 base pairs) from 123 giant tiger prawns (Penaeus monodon) collected at the Tanzanian coast.The sequences showed high haplotype ($h = 1 \pm 0.024$) and low nucleotide diversity ($\theta\pi = 1.82 - 2.35$ %). Results of neutrality and mismatch analysis showed that the studied population experienced a bottleneck followed by periods of population growth in its recent history. Analysis of molecular variances did not detect significant genetic differentiation among sites($FST = -0.0003$, $p > 0.05$; $\Phi ST = -0.00251$, $p > 0.05$), suggesting that although the decline in prawn abundance is reported in some areas, the fishery is panmictic and it is capable to replenish overexploited areas. The estimates of the number of migrants showed that the estuarine mangroves at Pangani, Saadani, and Rufiji are the net exporters of migrants, implying that if these ecosystems are well protected, they have a potential to replenish depleted areas and improve the resilience of the fishery. Since the country is targeting to increase marine protected areas from 6.5 % to 10 % by 2020, priority should be given to the above mentioned estuaries.

Key words: Giant tiger shrimp, D-loop, Western Indian Ocean, East Africa

1 Introduction

Since time immemorial, the fishery of the giant tiger prawns (Penaeus monodon) has proved to have immense support to fishing communities along the Tanzanian coast and contribution to the National income. The fishery is predominantly artisanal and the main fishing grounds along the coast are associated with estuaries of large rivers(Kyomo, 1999). Adult giant tiger prawns inhabit estuarine mangroves, but because their larvae cannot withstand low salinity, matted females migrate to deep waters to spawn. After hatching, the larvae undergo a series of developmental stages before returning to estuarine mangroves, where they grow until they attain maturity (Garcia, 1988).Because the prawns have to migrate to offshore and estuarine ecosystems to complete their life cycle, degradation of any of these two ecosystems by anthropogenic or natural factors will automatically generate effect to the resources and may lead to the collapse of the resources in case there are no measures in place (Mosha

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and Gallardo, 2013).

Allestuarine mangroves in the country are nationally gazetted but due to poor surveillance, enforcement, and public awareness, the mangroves are threatened with overexploitation; anthropogenic pollution;the reduction of river flow; and mangrove clearing for agriculture, salt production, and urban development(Taylor *et al*., 2003; Mangora, 2011; Rumisha *et al*., 2016).Although the intensity of these activities varies among districts, the country lost about 1280 ha of mangroves between 2000 and 2005 (FAO, 2007). The loss threatens the sustainability of the giant tiger prawns which use mangroves as nurseries and feeding grounds. This is due to the fact that the loss of habitat can reduce the population size of the prawns and disrupt dispersal capabilities, which leads to reduced fitness of the population and genetic erosion (Dixon *et al*., 2007). Significant evidence of genetic erosion and reduced dispersal capabilities due to mangrove deforestation are reported in the fiddler crab Austruca occidentalisand the Littorinid gastropod Littoraria subvittatafrom the Tanzanian coast(Nehemia and Kochzius, 2017; Nehemia *et al*., 2017).

Also, the decline in prawn catches due to overfishing and destructive fishing practices is reported in several areas along the coast (Jiddawi and Ohman, 2002). It is estimated that during 2004 to 2007, the catch of prawns declined sharply from 661 to about 202 tonnes, respectively(Silas, 2011). The decline can have a devastating impact on marine ecosystems as it can destabilise the food chain and transform an originally stable, mature, and efficient ecosystem into one that is immature and stressed (Garcia *et al*., 2003).Such transformation could have serious effects on the genetic population structure and the sustainability of the fishery, especially if the number of spawning adults is significantly reduced.In response to the decline, several measures were taken to enable the fishery to recover. The measures include a moratorium on prawn trawling, closed seasons, zoning, and rotation of prawn fishing vessels in fishing grounds (FAO, 2001). Furthermore, measures are taken to increase fish sanctuaries along the coast. According to the National Biodiversity Strategy and Action Plan 2015 – 2020, the country is targeting to expand marine protected areas (MPAs) from 6.5 % to 10 % by 2020 (URT, 2015). The MPAs are expected to improve the resilience of the fishery and protect the species from local extinctions by replenishing depleted areas. Despite the perceived benefits, there is limited information regarding the patterns of genetic connectivity among prawn fishing grounds, which is crucial for determining the priority areas for the establishment of MPAs. Furthermore, it is not known whether the giant tiger prawn fishery should be managed as a single panmictic stock or there are demographically isolated stocks which should be treated as separate management units. Since this information is essential for sustainable management,this study used fragments of the mitochondrial control region to establish whether there are genetically distinct subpopulations along the coast and to propose appropriate management measures.

2 Materials and methods

2.1 Study area

The study was conducted along the coastline of the Western Indian Ocean, Tanzania, which extends to over 800 km. Oceanic circulations in the region are driven by trade winds and the East African Coastal Current (EACC) which flows from south to north (Schott and McCreary, 2001). The current transports nutrients and larvae along the coast. Seven sampling sites were selected based on the availability of giant tiger prawns (Fig. 1). The sites included sites 2 (Pangani), 3 (Saadani), and 5 (Rufiji), which are the main prawn fishing areas. The study sites in these areas were located in estuarine mangroves at the mouth of river Pangani, Wami, and Rufijirespectively. Generally, the mangrove forests in these areas are relatively intact. The study site at Saadani (site 3) was located within the Saadani National Park, which is a protected area. The mangrovesites 1, 4, and 7 are located in Tanga, Dar es Salaam, and Mtwara respectively and are the most populated areas on the coastline. From 2002 to 2012, the population at sites 1, 4, and 7 increased by 12.6, 75.5, and 17.5% respectively (URT, 2013). Due to rapid growth in human population, increased fishing pressure and increased use of destructive fishing gears is reported in these areas (Jiddawi and Ohman, 2002; Mosha and Gallardo, 2013).

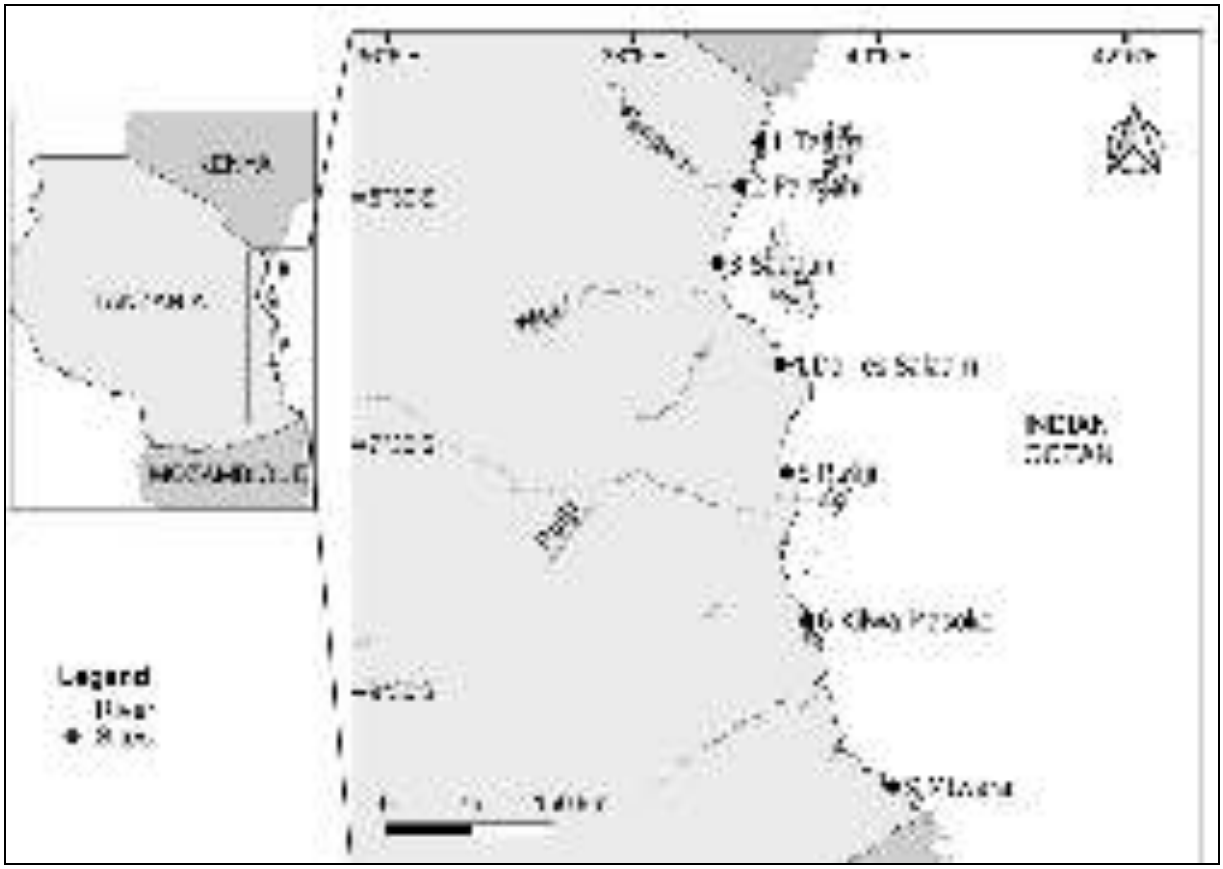

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Figure 1:Map of the Tanzanian coast showing sample sites (adapted from Rumisha *et al*. (2017a))

2.2 Sampling

Sampling of giant tiger prawns (P. monodon) was conducted between 2014 and 2016. A total of 123 individual giant tiger prawns were collected (Table 1). A section of the pleiopod tissue (about 50 mg) was collected from each individual and *preserved in 95 % ethanol for molecular* analysis. *T*he geographical coordinates of each site were recorded with a GPS receiver and it is reported in Table 1.

Table 1:Number of samples analysed and the geographical coordinates of the sample sites

Sites		Coordinates		Number of samples	Sample identification number
		Latitudes (º S)	Longtudes (º E)		
1	Tanga	5.052	39.124	17	CR1 -17
2	Pangani	5.407	38.967	17	CR18 -34
3	Saadani	6.038	38.779	18	CR35 -52
4	Dar es Salaam	6.857	39.290	15	CR53 - 67
5	Rufiji	7.729	39.334	19	CR68 -86
6	Kilwa Masoko	8.926	39.508	19	CR87 - 105
7	Mtwara	10.272	40.214	18	CR106 -123
Total				**123**	

2.3 DNA extraction

Total DNA was extracted from the pleiopod tissue of *P. monodon* using the E.Z.N.A. Tissue DNA Kit (Omega Bio-Tek Inc., Norcross, USA). Tissue lysis, DNA extraction, and purification were performed according to the manufacturer's protocol. Agarose gel electrophoresis was performed to check the quality of the DNA extracts.

2.4 Polymerase chain reaction

Polymerase chain reaction (PCR) was performed using an MJ research PTC 200 Peltier thermocycler. A partial fragment (534 bp) of the mitochondrial control region was amplified using the primers 12S 5´-AAGAACCAGCTAGGATAAAACTTT-3´ and PCR-1R 5´-GATCAAAGAACATTCTTTAACTAC-3´ (Chu *et al.*, 2003). The PCR was done in a total volume of 25 µL containing 10 ng of the DNA template, 0.45 U of the *Thermus aquaticus* (Taq)DNA polymerase, 0.2 µM of each primer, 0.2 mM DNTP, 3 mM $MgCl_2$, 1x Taq buffer, and 0.5 mg bovine serum albumin. The PCR conditions were: 5 min at 94 °C, followed by 35 cycles of 1 min at 94 °C, 1 min at 48.8 °C, and 1.5 min at 68 °C. A final extension step of 20 min at 68 °C was added to ensure complete amplification. Agarose gel electrophoresis was performed to determine the yield and quality of the PCR reactions. Sequencing of both strands was performed by Macrogen Europe. Pairwise alignment of the forward and reverse sequences was performed using the ClustalW algorithm as implemented in MEGA ver. 6.0 (Tamura *et al.*, 2013) to generate consensus

sequences of 534 base pairs.

2.5 Data analyses

A total of 123 mitochondrial control region sequences were obtained from the analysed tissues. A multiple sequence alignment was performed with the software MEGA ver. 6.1 (Tamura *et al.*, 2013). The program FaBox DNA collapser ver. 1.41 (Villesen, 2007) was used to collapse the aligned sequences into haplotypes. The same program was used to generate input files for population genetics software used in subsequent analysis. The number of haplotypes, haplotype diversity, and nucleotide diversity were determined with the program Arlequin ver. 3.5.1.2 (Excoffier and Lischer, 2010). The same programme was used to perform the analysis of molecular variance (AMOVA) and to compute a matrix of pairwise F_{ST}-values. The significance of pairwise F_{ST}-values was calculated by 10000 random permutations of haplotypes between populations. A minimum spanning haplotype network was constructed with the software PopART ver. 1.7 (Leigh and Bryant, 2015), to examine the relationship between haplotypes. Fu's Fs (Fu, 2007) and Tajima's D (Tajima, 1989) tests of neutrality were performed to evaluate the demographic history of the studied populations. Mismatch distribution analysis was performed to estimate the parameters of the sudden expansion model (Harpending, 1994). The program MIGRATE-N ver. 3.6.11 (Beerli and Palczewski, 2010) was used to estimate the mutation-scaled effective population size Θ ($2Ne\mu$) and the mutation-scaled migration rates ($M = m/\mu$) (where Ne = effective population size, m = immigration rate per generation, μ = mutation rate per generation) based on the full model. The program was run according to Rumisha *et al.* (2018). The number of immigrants per generation was obtained by multiplying Θ and M (Beerli and Palczewski, 2010). The net number of immigrants was determined for each site in order to identify potential sources of migrants (net number of immigrants = number of immigrants – number of emigrants).

3 Results

3.1 Genetic diversity and demographic history

A total of 123 mitochondrial control region sequences (534 base pairs) were obtained. Accession numbers were assigned to each sequence and the sequences were published in the GenBank repository(accession numbers: MK879924 - MK880046). The sequences showed 121 haplotypes and a total of 127 polymorphic sites (Table 2). All sites showed high haplotype diversity which is accompanied by low nucleotide diversity (Table 2). The lowest nucleotide diversity was observed at sites 1, 4, and 5.

Table 2: Average molecular diversity indices (± SE) for the giant tiger prawn Penaeus monodon from the Tanzanian coast. N = sample size, nh = number of haplotypes, h = haplotype diversity, θπ = nucleotide diversity, nt = number of transitions, ntv = number of transversions, nps = number of polymorphic sites. For sample sites, see Fig. 1.

	N	GenBank accession number	n_h	h	θ_π (%)	n_t	n_{tv}	n_{ps}
1	17	MK879924 - 40	17	1 ± 0.020	1.88 ± 1.01	50	8	56
2	17	MK879941 - 58	17	1 ± 0.020	2.23 ± 1.19	54	13	59

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3	18	MK879959 - 75	18	1 ± 0.019	2.15 ± 1.14	55	16	64
4	15	MK879976 - 90	15	1 ± 0.024	1.99 ± 1.07	47	10	53
5	19	MK879991 - MK880009	19	1 ± 0.017	1.82 ± 0.98	47	13	52
6	19	MK880010 - 28	19	1 ± 0.017	2.16 ± 1.15	53	17	59
7	18	MK880029 - 46	18	1 ± 0.019	2.35 ± 1.24	58	15	64

The Fu's Fs and Tajima's D test of the pooled mitochondrial DNA sequences showed significant deviation from the neutral evolution hypothesis (Tajima's D = -1.72, $p < 0.05$: Fu's Fs = -24.29, $p < 0.02$). Mismatch distribution of the pooled samples showed a unimodal distribution, which suggests recent population expansion (Fig. 2). The raggedness index and sum of squared deviations (SSD) (raggedness index = 0.00414, $p > 0.05$: SSD = 0.0001; $p > 0.05$) showed that the hypothesis of recent population expansion cannot be rejected. Selective neutrality tests and mismatch analysis were also performed for each population. Each sample site showed significant deviation from the hypothesis of neutral evolution (Table 3). In addition, the estimated raggedness indices for each site were not significant.

Table 3: Demographic parameters estimated under the selective neutrality tests and mismatch analysis of the mitochondrial control region sequences of Penaeus monodon at the Tanzanian coast. Bolded values are significant, τ =time in number of generations since expansion. For sample sites, see Fig. 1

Statistics	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Tajima's D	**-1.66**	-1.33	**-1.59**	-1.51	-1.41	-1.29	-1.36
Tajima's D p-value	0.032	0.073	0.044	0.052	0.067	0.086	0.078
FS	**-9.31**	**-8.19**	**-9.32**	**-7.14**	**-11.56**	**-10.23**	**-8.74**
FS p-value	0.001	0.001	0.001	0.001	0.000	0.001	0.001
T	10.18	10.58	11.24	10.50	9.78	9.11	13.56
SSD	0.011	0.006	0.009	0.006	0.008	0.004	0.003
Model (SSD) p-value	0.26	0.56	0.30	0.60	0.32	0.74	0.81
Raggedness index	0.027	0.018	0.019	0.022	0.019	0.009	0.011
Raggedness p-value	0.21	0.41	0.35	0.44	0.35	0.81	0.79

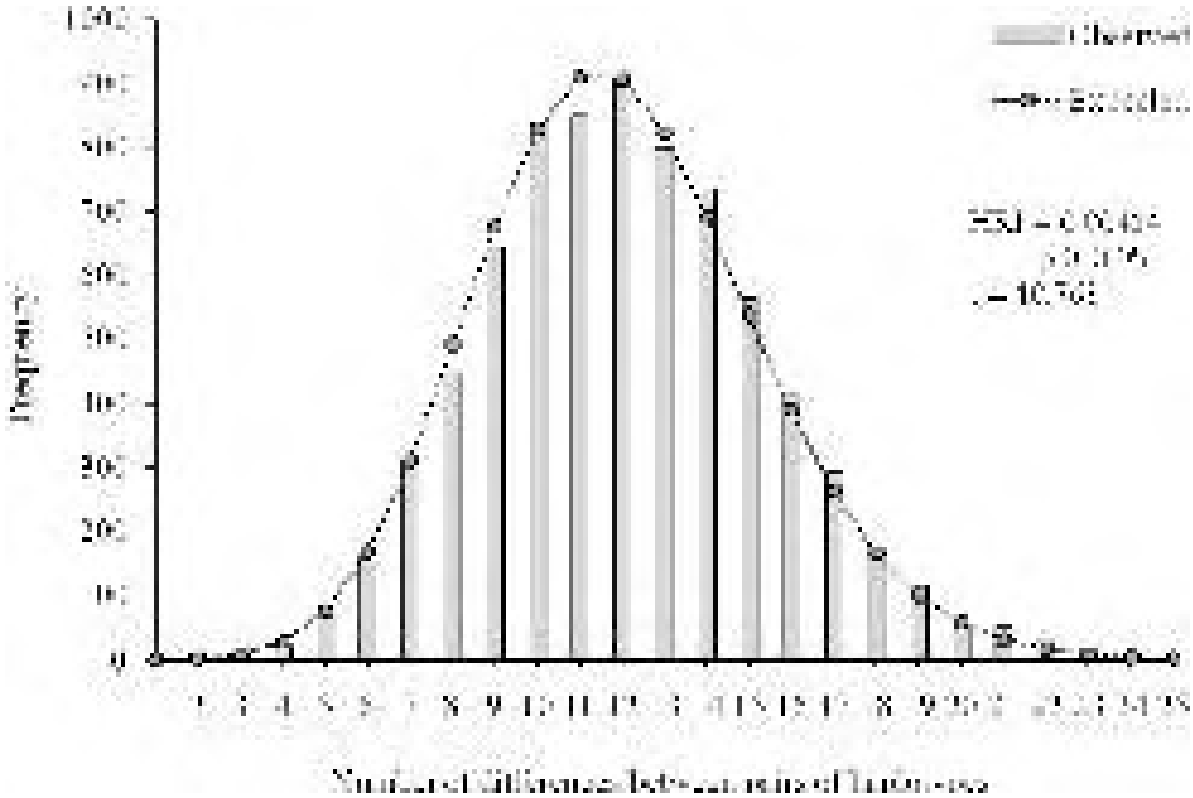

Figure2: Pairwise mismatch distribution showing a unimodal distribution of the mitochondrial control region haplotypes in *Penaeus monodon* from the Tanzanian coast. HRI = raggedness index, τ =time in number of generations since expansion.

3.2 Genetic connectivity among sites

The analysis of molecular variance (AMOVA) did not show significant genetic differentiation between sites (FST = -0.0003, p > 0.05; ΦST = -0.00251, p > 0.05). The observed lack of genetic structure was also revealed by the haplotype network (Fig. 3). The network did not produce a meaningful phylogeographic structure.The estimates of the number of migrants showed that each site receives migrants from adjacent ecosystems (Table 4). Furthermore, the analysis showed that the estuarine mangroves at sites 2 (Pangani), 3 (Saadani), and 5 (Rufiji) are the net exporters of migrants for recruitment at other sites. The effective population size (Θ) ranged between 0.1044 and 0.4342, with sites 3 and 5 showing the highest Θ (Table 4).

Table 4: Mutation-scaled effective population size (Θ) and gene flow (2Nem) in the giant tiger prawns from the Tanzanian coast

Site	Theta	Total immigrants	Total emigrants	Net number of immigrants
1	0.3531	493	186	307
2	0.1044	35	150	-114
3	0.4302	293	502	-209
4	0.3643	348	328	20

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5	0.4342	308	374	-66
6	0.4009	359	300	59
7	0.3460	407	403	4

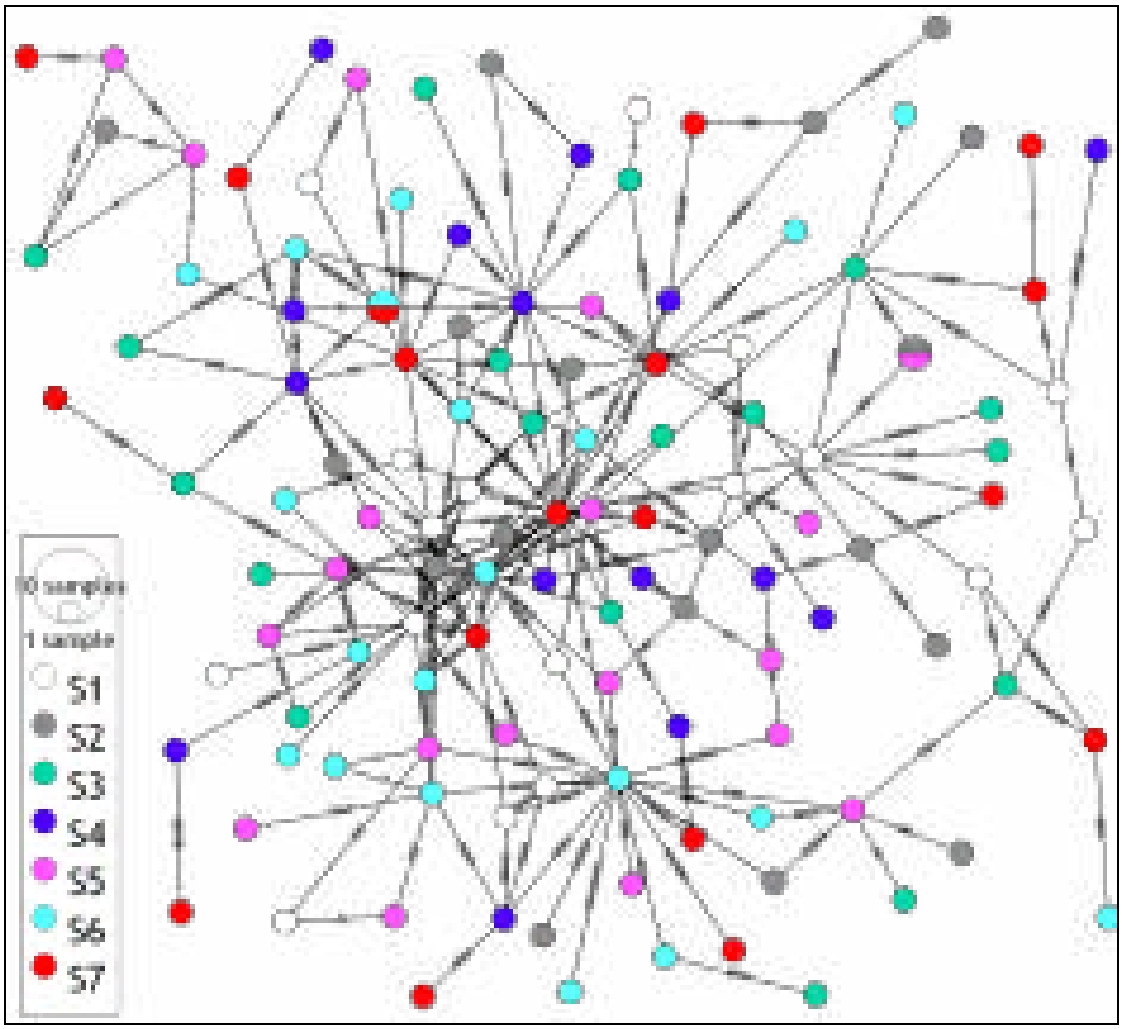

Figure 3: Minimum spanning network showing relationships among mitochondrial control region haplotypes in Tanzanian giant tiger prawns (*Penaeus monodon*). Each circle represents a haplotype. Size of each circle is proportional to the number of individuals carrying each haplotype. Hatch = mutations, S = site. For sample sites, see Fig. 1 and table 1.

4 Discussion

4.1 Genetic diversity and demographic history

The measured estimates of haplotype and nucleotide diversity are comparable to the findings of other researcher in the region (You *et al.*, 2008; Mkare *et al.*, 2014). The prawns showed high haplotype diversity (h = 1 ± 0.024) which is accompanied by low nucleotide diversity ($\theta\pi$ = 1.82 – 2.35 %; Table 2). The observed high haplotype diversity

results from the excessive number of unique haplotypes and it is indicative of a large sustained population size. The idea that the population size of the giant tiger prawn is probably large, is supported by the fact that the measured indices of the effective population size (Table 4) are higher than those of other mangrove macroinvertebrates from the Tanzanian coast (Nehemia *et al*., 2017; Rumisha *et al*., 2017b, 2018). The fact that all sites showed high haplotype diversity coupled with low nucleotide diversity indicates that the population experienced periods of population growth in its recent history. This is supported by the results of neutrality and mismatch analysis which showed that the studied population experienced a bottleneck followed by a sudden population expansion. Furthermore, the hypothesis of recent population expansion was supported by the constructed hyplotype network (Fig. 3). The network revealed that the population contains121 unique haplotypes with close similarities in nucleotide sequences, which suggest that the haplotypes originated recently (Ferreri *et al*., 2011). Recent population expansion is reported in several other mangrove fauna in the western Indian ocean (WIO) and it is attributed to the last glacial period (Silva *et al*., 2013; Otwoma and Kochzius, 2016; Nehemia and Kochzius, 2017; Rumisha *et al*., 2017b). Periodic rise and fall of the sea level during the period could account for the bottlenecks and subsequence expansion of populations in the WIO (Hewitt, 2000).

4.2 Genetic connectivity and its implications for fisheries management

The sequences did not show significant genetic differentiation among the sample sites(F_{ST} = -0.0003, $p > 0.05$; Φ_{ST} = -0.00251, $p > 0.05$).The analysis of molecular variance showed that variations among sites accounted for less than 1 % of the total variations. The lack of mitochondrial genetic differentiation is supported by the structure of the haplotype network (Fig. 3) which showed that the haplotypes are closely related, with no clear phylogeographic structure. The same pattern of mitochondrial genetic differentiation is reported in other mangrove macroinvertebrates in the WIO (Mkare *et al*., 2014; Rumisha *et al*., 2018) and it suggests that there are no barriers to gene flow among estuarine ecosystems at the Tanzanian coast. The lack of genetic differentiation between sites which are more than 700 km apart (sites 1 and 7),indicate thatthe giant tiger prawns can disperse fairly easily throughout the entire coast. This imply that, although the decline in prawn abundance is reported in some areas (Silas, 2011; Mosha and Gallardo, 2013), the fishery is panmictic and it is capable to replenish overexploited areas. Furthermore, it suggests that the spatial management strategies which are currently implemented or which might be developed in the future, should rather consider other ecological and socio-economic factors than the genetic delineation of the stock.

The estimates of the number of migrants showed that each site receives migrants from adjacent ecosystems (Table 4). Since the breeding season of prawns is associated with the rainy season(Kyomo, 1999), if the closure of fishing from December to February is properly enforced, it will protect the juveniles and enable them to disperse widely to replenish depleted areas. Also, a minimum mesh size should be imposed to protect the juveniles from unsustainable fishing practices. Currently, the minimum mesh size of 50 mm is imposed on commercial trawlers but it is rarely enforced on the artisanal fishers

(Silas, 2011). The fishers use nets of smaller mesh size,which maximize the catch but also increase the proportion of juvenile prawns in the catch (FAO, 2001). Furthermore, the estimates of the number of migrates showed that the estuarine mangroves at Pangani, Saadani, and Rufiji are the net exporters of migrants (Table 4), implying that if these ecosystems are well protected, they have a potential to replenish depleted areas and improve the resilience of the fishery.According to the National Biodiversity Strategy and Action Plan 2015 – 2020, the country is targeting to expand marine protected areas from 6.5 % to 10 % by 2020(URT, 2015). Based on the observed patterns of migration, it is advisable that priority should be given to the above mentioned estuaries.

5 Conclusion

Knowledge of the genetic population structure is crucial for identifying biological units for fisheries management and for MPA spatial planning. This study revealed extensive gene flow among the giant tiger prawns at the Tanzanian coast implying that the fishery should be managed asa single randomly mated stock unless there are other ecological and socio-economic factors for spatial delineation of the stock. Furthermore, the study revealed that the estuary at Pangani, Saadani, and Rufiji are the net exporters of migrants for recruitment at other sites. This implies that although decline in abundance is reported in other prawn fishing grounds along the Tanzanian coast, the above mentioned estuaries are capable to replenish depleted areas. Since the country is planning to increase MPAs from 6.5 % to 10 % by 2020 (URT, 2015), it is advisable that priority should be given to the above mentioned estuaries.

Acknowledgement

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Salt Farming as an Economic Activity and its Effect on Mangrove Ecosystems along the Coastal Area of Tanzania

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Abstract

Salt farming is an important economic activity done in mangrove forests that contributes to income generation to the inhabitants along the coastal area of Tanzania. This study was conducted to assess the impact of salt farming on mangrove ecosystem by comparing morphometric and abundance of macro invertebrates residing in relatively pristine mangroves and mangroves around salt ponds. Samples of Littoraria subvittata and Austruca occidentalis (bio indicators) were randomly collected during low tides along the coast of Tanzania mainland and Zanzibar to assess the impact of salt farming on the abundance and body size of macroinvertebrates. Sediments were collected to assess the impact of salt farming on the sediment particle size distribution and organic matter content. Results indicate differences in Scaled body Mass Index (SMI) between samples from salt farming and relatively pristine areas in most sites. Although for L. subvittata the difference was not significant, the relative abundances for both species were found to be higher in relatively pristine mangroves compared to salt farming mangrove sites for both species. On the other hand, sediment organic matter content analysis revealed significantly ($P<0.05$ higher) percentage of organic matter content (3.94±1.14%) in relatively pristine mangroves compared to mangroves around the salt farming sites (2.70±0.48%). It is concluded that salt farming has negative influence on mangrove ecosystem. Therefore, there is a need for conservation and restoration of this ecosystem through planting of mangroves in areas where trees are cleared and selectively logged for salt ponds and where ponds have been abandoned.

Keywords: Arboreal snails, crabs, scale body mass index and population distribution

1.0 Introduction

Solar salt production has contributed to loss of an extensive area of mangroves in Tanzania (Nehemia and Kochzius 2017; Nehemia *et al*., 2017; Walters *et al*. 2008). The mangrove areas mostly affected include Tanga, Bagamoyo, Kilwa, and Mtwara (Semesi, 1992). Clearing and selective logging of mangrove trees for construction of solar salt ponds has been suggested to have significant influence on the distribution and abundance of gastropods with possible indirect effects on the functioning of the ecosystem (Maia and Coutinho, 2013; Talapatra *et al*., 2014). Solar salt farming has been reported to affect fish assemblages in Tanzanian mangrove creek systems by reducing the abundances that is contributed by the change in the hydrodynamics and sediment characteristics (Mwandya *et al*., 2009).

The link between mangroves and macroinvertebrates can be disrupted by salt works activities if no strong measures are taken to enhance sustainable solar salt production in mangroves. Littoraria subvittata and Austruca occidentalis are the most abundant species of littonids and fiddler crabs respectively, in mangroves along the East African coast (Litulo, 2004; Torres *et al*., 2008). The species have been used as bio indicators to detect the impact of human activities in mangroves (Cannicci *et al*., 2009; Peer *et al*.,

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2015). Changes in the community structure of bio indicators due to anthropogenic disturbances can indicate the health status of the mangrove ecosystem (Skilleter, 1996; Bartolini *et al*. 2011; Pawar, 2015).

Comparison of abundance of bio indicators between areas affected and relatively unaffected by human activities can help to detect the impact of disturbances caused in mangrove ecosystem. Body condition has suggested to have an influence on an animal's health and fitness (Peig and Green, 2009). The length-weight relationship and condition factors have been used to assess the habitat quality for macroinvertebrates (Albuquerque *et al*., 2009). Scale mass index has also been used to assess the wellbeing (most typically, variation in the size of energy reserves) of fish in their habitats (Maceda-Veiga *et al*., 2014; Peig and Green, 2010, 2009) and has recently been suggested to be useful in a broad range of studies in animal ecology, conservation biology and wildlife management compared to other existing body condition indices (Peig and Green, 2009)

In this study, we intended to assess the effect of salt farming on the health of mangrove ecosystems. Specifically, we intended to identify the effect of solar salt farming on abundance and body dimension distributions of L. subvittata and A. occidentalis. Also, we wanted to assess the impact of solar salt farming on mangroves, the habitats of L. subvittata and A. occidentalis in terms of soil organic matter content (SOMC) and sediment particle size (SPS).

2 Material and methods

2.1 Study sites

Samples of macroinvertebrates (L. subvittata and A. occidentalis) were collected in mangroves along the coast of Tanzania mainland (Tanga, Bagamoyo, Mtwara and Kilwa) and Zanzibar (Pemba and Unguja) (Fig. 1). in July 2014 during low tide. In each sampling site, two stations (salt pond and relatively pristine sites) were established at least 4km apart.

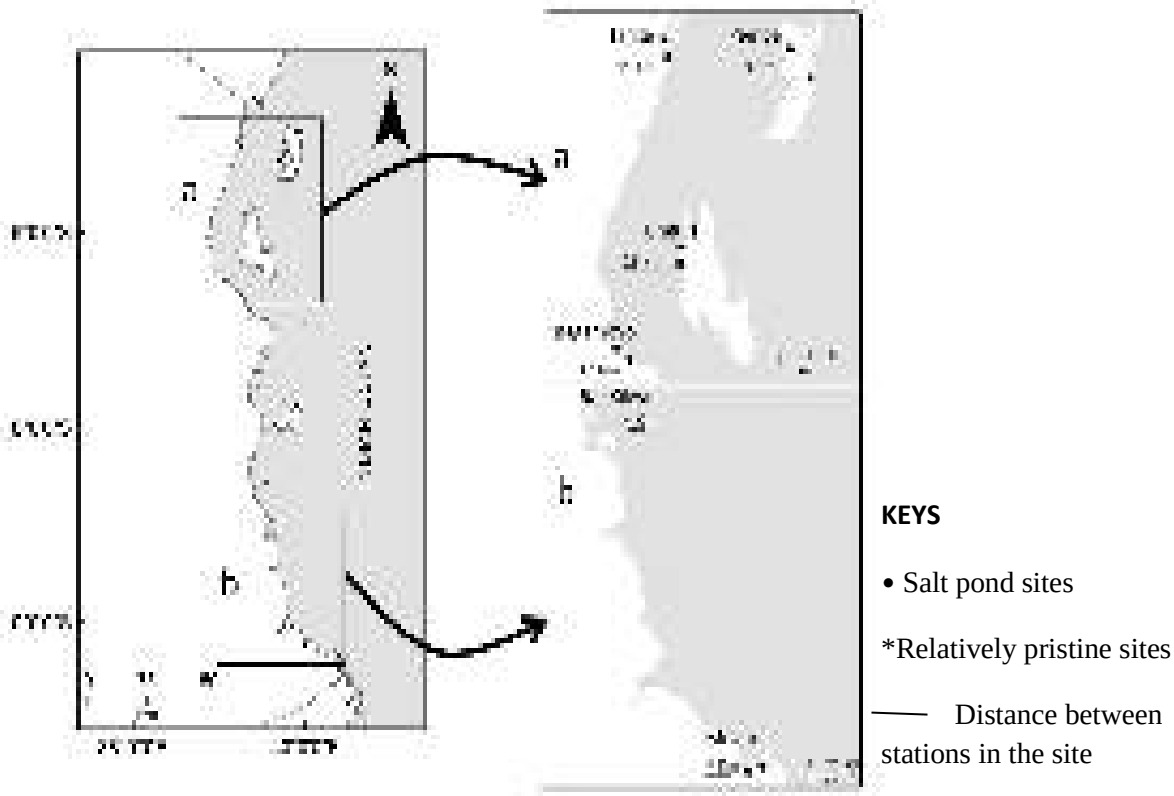

Figure 8: Sampling sites along the coastal of Tanzania mainland and Zanzibar.

2.2 Sampling and sample preparation

For determination of abundance, three independent time based samplings were conducted in three quadrates each covering 100m2. Five mangrove trees were randomly selected in each quadrate and all Littoraria spp. found on the trees were collected for 15 minutes and then identified through their morphology (Reid, 1984). The samples of Littoraria subvittata were preserved in a 75% ethanol for further analysis. Likewise, samples of Austruca spp. were collected randomly in 100m2 area in the three quadrates but the time for sampling were extended to 30 minutes and all the sample collected were identified through morphology (Naderloo *et al*., 2016). All the samples of Austruca occidentalis identified were preserved in a 75% ethanol for further analysis.

The samples collected for determination of abundance were also used for analysis of shell width-Shell length relationship for L. subvittata, major claw length-chelar propodus relationship for A. occidentalis and scaled body mass index for both species (Peig and Green, 2010). Additionally, the samples of L. subvittata and A. occidentalis with almost the same class size were sorted together for analysis of population class size distributions.

Samples of sediments were also collected in three quadrates of each station and mixed

to form homogeneous mixture of sediment per station. The samples were used for analysis of organic matter content and a particle size distribution.

2.3 Determination of body dimensions and weights

Body dimensions (carapace length (CL), carapace width (CW), shell length (SL) of L. subvittata) and major craw length and chelar propodus of A. occidentalis) were measured using digital vernier caliper with a precision of 0.05mm while body wet weight (WT) for both species was measured using an analytical balance (model: 40085) with a precision of 0.01g.

3.4 Determination of organic matter content and sediment particle size distribution

Organic matter content (OG) in sediment samples was analyzed using ashes technique (Heiri *et al*., 2001). Prior to the analysis, about 5-7g of the sediment samples were dried in oven (model: 1246) at 105°C for 24hrs in order to remove all water. The samples were next cooled in desiccator for 1hr and then their weights were measured an analytical balance (model: 40085). The samples were then placed in a furnace (muffle furnace model: 55224) and burned to ash at 550°C for 36hrs to decompose all organic carbon. The ash samples were cooled in a desiccator for 1hr and the weights were remeasured. The amount of percentage OG content was calculated using the following formula (Heiri *et al*., 2001):

$$\%\ OG = \frac{100\,(\text{Weight of sample dried at } 105°C - \text{Weight of sample dried at } 550°C)}{\text{Weight of sample dried at } 105°C}$$

Sediment particle size distribution was determined by using a series of metal sieves (4, 2, 1, 0.5, 0.25, 0.125, 0.063mm). Sediment were categorized as gravel (>2mm), very coarser sand (>1mm), coaser sand (>0.5mm), medium coarse sand (>0.25mm), fine sand (>0.125mm), very fine sand (>0.063mm) and mud (silt and clay; <0.063mm). Thereafter, sediment median particle size (D50) in Phi scale was determined. The smaller the D50, the coarse the sediments and vice versa.

3.5 Data Analysis

The data sets were tested for homogeneity of variances using Levene's test and normality through Shapiro-Wilk test as implemented in the software R (version 3.1.2). The assumptions for parametric test were not met even after data were log (-x) and arcsine [square root (X/100)] transformed to improve homogeneity of variance.

The scaled body mass indices for L. subvittata and A. occidentalis were calculated as an index of body condition (Maceda-Veiga *et al*., 2014). Therefore, the differences in relative abundances, body dimensions and weight, scale body Mass Index, OG content and sediment particle size distribution among the samples were determined using paired Wilcoxon Signed-Rank Sum Test as implemented in R (version 3.1.2).

4 Results

4.1 Abundance distribution of species

The relative abundance was found to be high in relatively pristine mangroves for both L. subvittata and A. occidentalis species (Fig 2a, b). The differences in relative abundance observed in A. occidentalis between mangroves around the salt ponds and relatively pristine mangroves were significant (P<0.05).

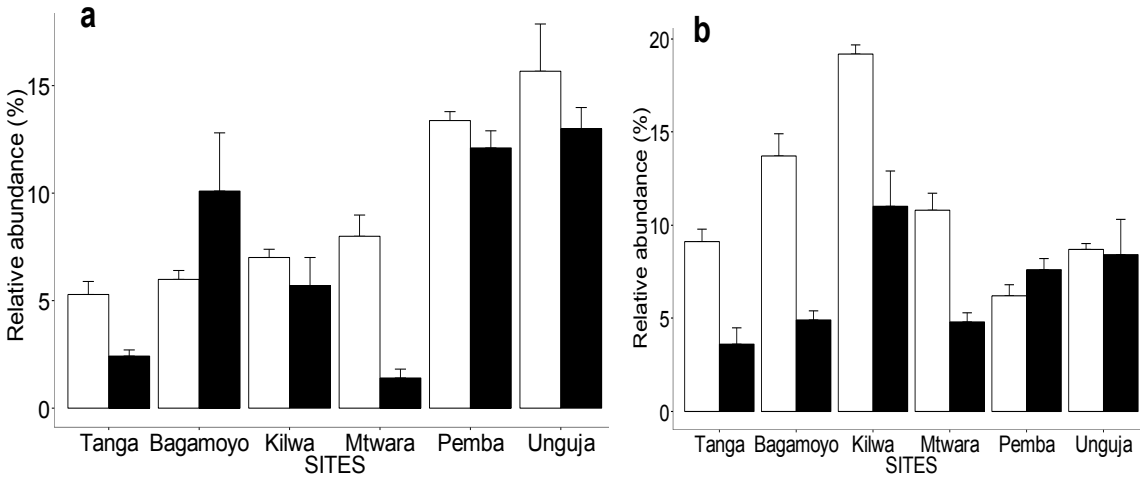

Figure 2: Abundance of a) *L. subvittata* and b) *A. occidentalis* in relatively pristine and salt farming mangrove sites. Black bars indicate samples from mangroves around salt farming and white bars indicate samples from relatively pristine mangrove sites.

4.2 Body dimension and class size distribution

Out of the 3,217 samples of macroinvertebrates collected, 1,727 were L. subvittata and 1,490 were A. occidentalis. The mean shell diameter for L. subvittata ranged between 6± 0.45 and 7±1.11mm and the Total length for A. occidentalis ranged between 6±2.51 and 11±1.52 (Table 1).

Table 12. Mean individuals wet weinght and mean shell diameter of L. subvittata and A. occidentalis in each site

Sites (Codes)	Mean wet weight (mg)(±	Mean shell diameter/Total

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			length (mm)(± SD)	
	A.	*L. subvittata*	*L. subvittata*	*A. occidentalis*
Tanga - Lumbachia (TN)	14±5.20	25±5.29		7±0.00
Tanga – Mpirani (TS)	31±10.21	16±11.34	6±2.51	7±0.67
Bagamoyo – Kaole (BN)	34± 7.02	34±9.17	12±3.01	7± 0.98
Bagamoyo – Nunge(BS)	58±46.23	14±2.00	8±0.54	6±0.55
Kilwa - Timaki (KN)	40±7.51	28 ±3.61	8±0.74	6± 0.98
Kilwa- Makubuli (KS)	33±23.16	16±4.58	9±0.91	6±0.55
Mtwara - Ng'wale (MN)	46±18.08	27±7.21	9±0.97	7±0.72
Mtwara – Kilimahewa (MS)	8±7.00	12±4.93	8±1.34	7±1.11
Pemba – Chakechake (PN)	77±6.56	15±4.16	8±0.84	6±0.89
Pemba – Kangagani Wete (PS)	70±13.43	13±1.53	9±1.19	6± 0.62
Unguja – Fujoni (UN)	90±38.19	12±8.96	11±1.52	6±0.47
Unguja – Bumbwini (US)	76±16.50	22±2.65	9±3.38	6± 0.45
			10±1.71	

Results for class size distribution indicate that the lower class sizes (8-11.99mm) of L. subvitta dominated the mangroves around the salt farming sites, whereas, the higher class sizes (12-19.99mm) dominated the relatively pristine mangroves (Fig 3a). For A. occidentalis, the oposite was revealed whereby the lower class sizes (5-11.99mm) dominated the relatively pristine mangrove areas while the higher class sizes (12-17.99mm) dominated the mangroves around the salt farming sites (Fig 3b) .

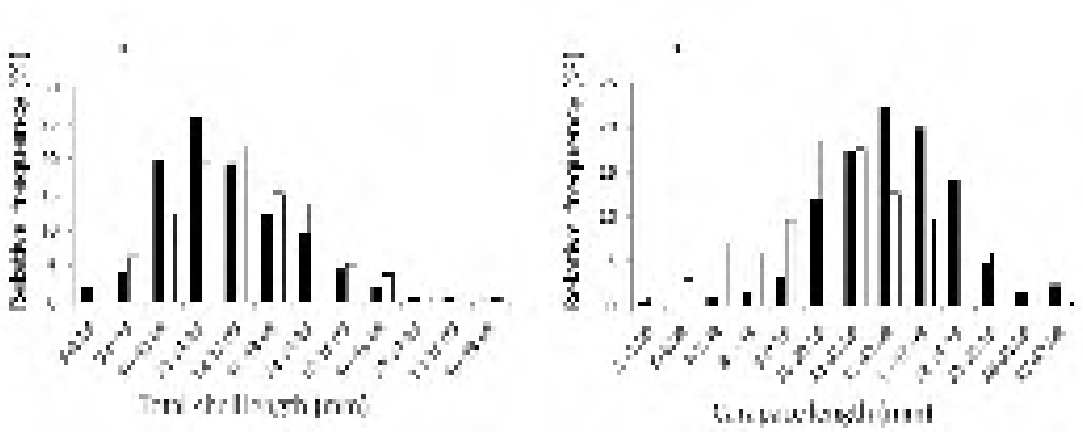

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Figure 3: Class size distribution of a) *L. subvittata* and b) *A. occidentalis* along the Tanzanian coast. A black bar indicates samples from mangroves around the salt farming and white bar indicates samples from relative pristine mangrove sites.

Morphometric relationships (Shell length and Shell widith) for L. subvittata were linearly correlated in relatively pristine mangroves and mangroves around salt farming sites (Fig 4a,b). Likewise, Major claw length-chelar propodus length relationship for A. occidenatlis were linearly correlated in both habitats (Fig 4c,d).

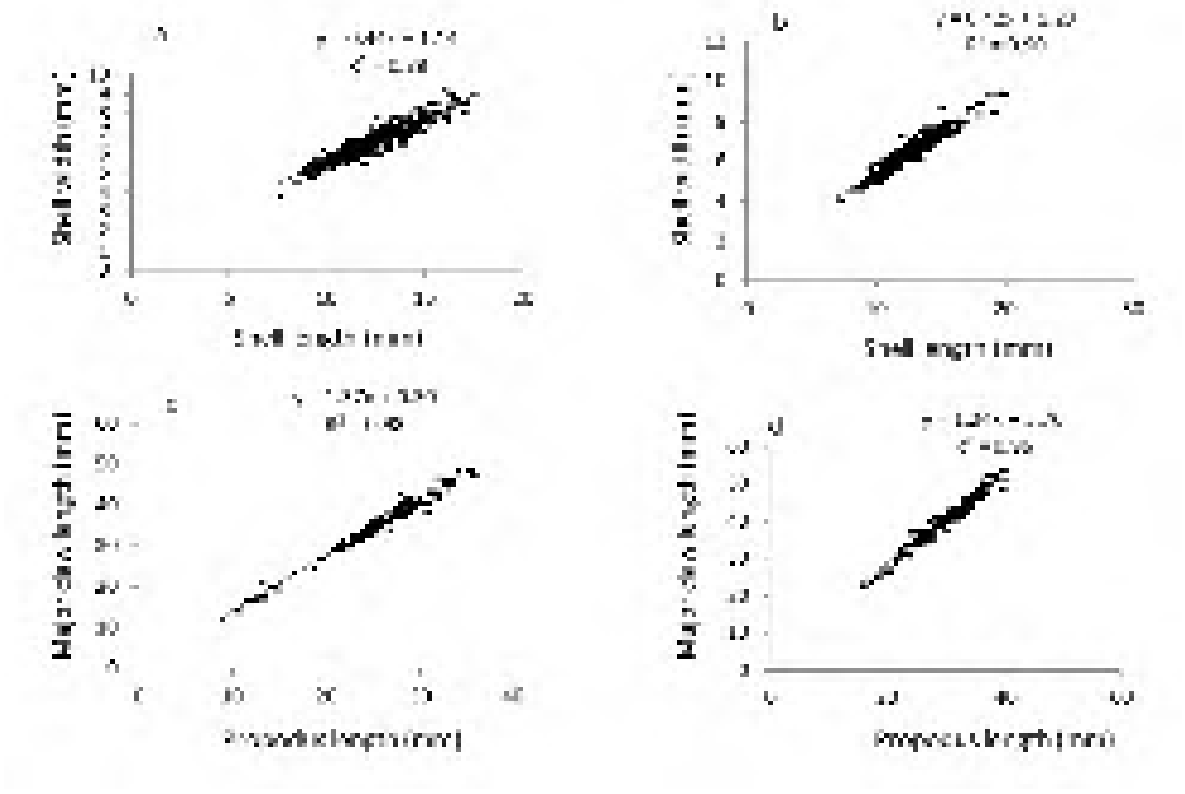

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Figure 4: relationship between Shell length – shell width relationship in a) relatively pristine mangrove and b) mangroves around the salt ponds for *L. subvittata* and Major claw length-chelar propodus length relationship in c) relatively pristine mangrove and d) mangroves around the salt ponds for *A. occidentalis* along the Tanzanian coast.

4.3 Scaled body mass index

Results showed that L. subvittata samples from the relatively pristine mangroves had higher SMI compared to those from mangroves around the salt ponds (Fig 5a). The opposite trend was observed for A. occidentalis whereby samples from most sites of mangroves around the salt ponds had higher Scale body mass index compared to those from relatively pristine mangroves (Fig. 5b). The differences between samples from mangrove around the salt ponds and natural mangrove for each site was significat ($P < 0.01$) except Unguja site where the difference was not significat for L. subvitta samples.

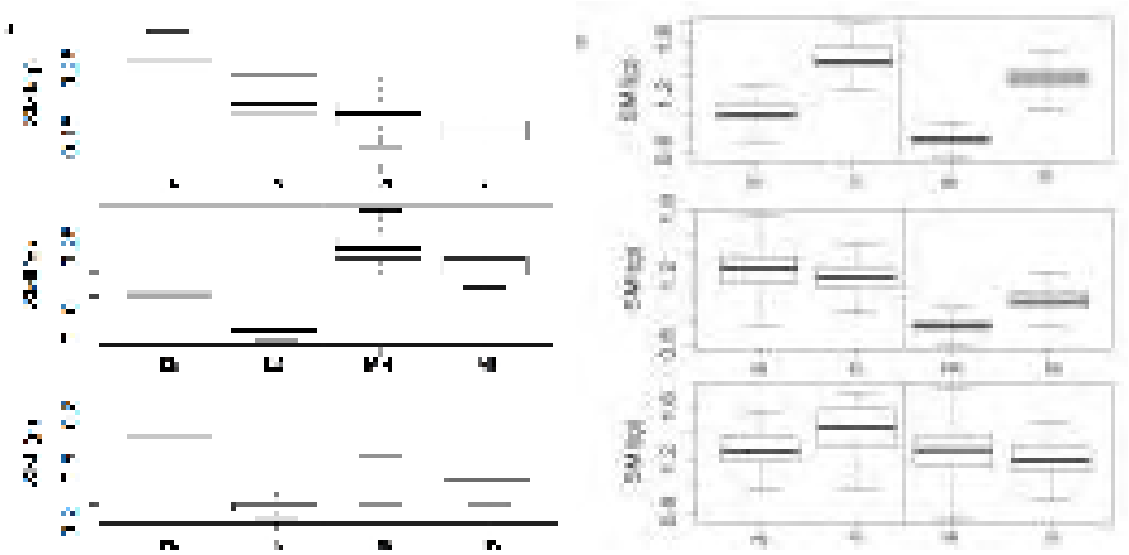

Figure 5: Scaled Mass Index for a. *L. subvittata* and b. *Austruca occidentalis* along the Tanzanian coast.

4.4 Organic Matter Contents and sediment particle size distribution

The %OG was consistently higher in relatively pristine sites compared to salt farming sites for all stations (Fig. 6a).The differences observed in %OG between relatively pristine mangroves and salt farming areas was significant ($P<0.05$).

However, the overall trend of the sediment particle size distribution revealed that, large particle sizes dominated the salt farming areas compared to relatively pristine mangrove areas except for Tanga and Mtwara where the opposite was observed (Fig. 6b).

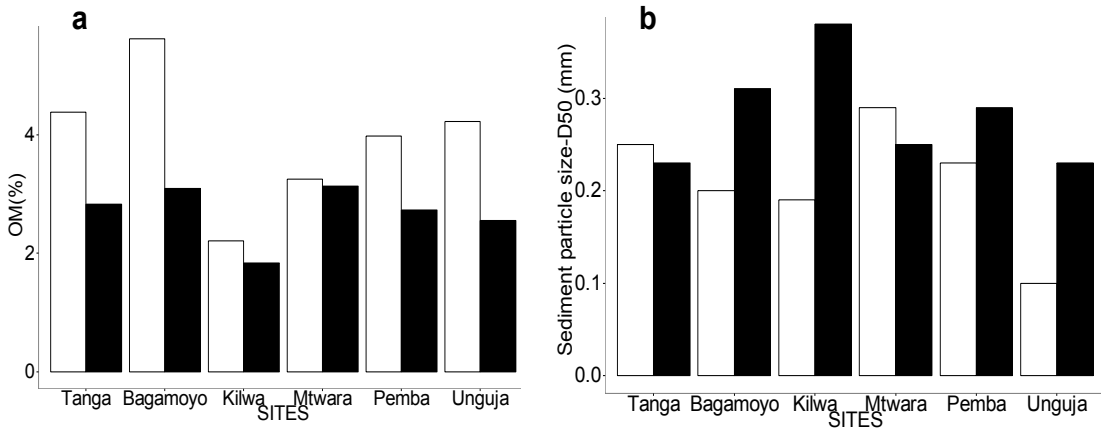

Figure 6: a) Amount of organic matter content and b) Sediment particles distribution in relative pristine mangroves and mangroves around the salt ponds along the Tanzanian western Indian coast. A black bar indicates samples from

mangroves around the salt farming and white bar indicates samples from relative pristine mangrove sites.

5.0 Discussion

The relative abundance of L. subvittata and A. occidentalis in relatively pristine sites was observed to be higher compared to salt farming sites. Similar results has been reported on other gastropod (Neritina virginea) population in a black mangrove stand (Avicennia germinans) of the Southern Caribbean (Amortegui-Torres *et al*., 2013). Habitat modification involving selective logging has been reported to contribute to the reduced abundance of snails (Blanco *et al*., 2012). Mangrove removal results into microclimate alteration, the change in sediments characteristics, increased insolation, induced canopy gaps and the promotion of predation (V Amortegui-Torres *et al*., 2013). All these factors can contribute to the lower abundance observed in salt farming compared to relatively pristine mangroves.

The lower class size of L. subvittata was observed to dominate mangrove areas around salt farming whereas, the lower class size of A. occidentalis was found to dominate the relatively pristine areas of mangroves. The lower domination of small class size of some Austruca spp. have been reported in areas impacted by human activities compared to relatively pristine area (Carlson, 2011). However, domination of higher class size of some gastropods in areas impacted by human activities has also been reported (Amortegui-Torres *et al*., 2013). This may be suggesting that when A. occidentalis is small in size is at high risk of being spotted by predators such as birds but when they attain high class size the risk is reduced. On the contrary, for some arboreal gastropods such as L. subvittata when small class can hide themselves under the leaves of mangroves but as they increase in size, they become prominent and exposed to predators and the intensity of such risk is high is mangroves around the salt ponds. Indeed, predators such as birds and fishes have influence on the population distribution of macroinvertebrates such as fiddler crabs (Mokhtari *et al*., 2015).

The Scaled body mass index of macroinvertebrates is strongly influenced by environmental factors, food quality and quantity in the habitats of an organism, and these factors have influence on the condition factor which have direct association with SMI of that organism (Dubey *et al*., 2014). The results indicates that L. subvittata had higher SMI in relatively pristine sites compared to salt farming sites. However, we recorded lower SMI of A. occidentalis in relatively pristine mangroves compared to salt farming sites. It has been reported that A. occidentalis prefer in sandy and sandy-muddy loamy where nutrient-rich filamentous, detritus and bacteria are deposited by receding tide each day which give this species ample availability of fresh food (Chatterjee, 2014). The crab, A. occidentalis are deposit feeders with spoon-tipped setae in their mouth parts that allow them to sort food particles well in sandy sediments (Lim, 2005). In general, larger sediment particle sizes were recorded in mangroves around the salt ponds. This can help to explain the higher SMI observed in A. occidentalis in salt farming compared to relatively pristine sites for this species. It has been reported also that change in environmental factors such as temperature and humidity may affect the wellbeing of snails (Albuquerque *et al*., 2009). Salt farming

areas are characterized by short and less abundant trees with poor canopy cover due to clear-cutting and selective logging and the snails in their habitats are subjected with stresses such as high temperature caused by canopy openness and increased solar radiation (Nehemia *et al.*, 2019). These factors can help to explain the lower SMI of L. subvittata observed in mangrove around the salt ponds compared to relatively pristine mangroves. The environmental stress in mangroves around the salt ponds may be affecting the well-being of L. subvittata.

Larger sediment particle size and lower organic matter content (OG) was found in salt farming compared to relatively pristine mangroves area and the trend for OG is consistent in all sites. The difference of OG in salt farming and relatively pristine is significant ($P<0.05$). The same trend for organic C and N content determined using an Elemental Analyser (Thermo Flash1112) connected on-line via a Conflo III interface to an Isotope Ratio Mass Spectrometer (Thermo Delta + XL) (Nehemia *et al.*, 2019) has been reported in the same area. Lower organic matter in deforested areas has been reported also by other studies in Zanzibar and Kenya (Bosire *et al.*, 2003; Sjöling *et al.*, 2005). The lower OG may be suggesting a smaller contribution of mangrove material such as leaf litters to the organic content in sediments in salt farming areas. The large sediment particles is associated with lower organic matter content (Burone *et al.*, 2003) and this can help to explain the lower OG observed in mangrove around the salt ponds. The large sediment particles obtained in mangrove around the salt ponds can be explained by erosion of fine soil particles (Nehemia *et al.*, 2019). The clearance and selective logging of mangrove trees may expose the top soil to tidal currents which erode the fine sediment particles.

6.0 Conclusion

The results suggest that solar salt farming contributes to change in abundance, the class size population structure and organic matter content. Therefore it will sound better if strong measures are taken to rescure the mangroves in salt farmed areas through conservation and restoration of this ecosystem by planting mangroves in the area where trees were cleared and selectively logged for salt ponds and where ponds have abandoned. Futhermore the results suggests that the salt farming activities affect the well being of the species studied differently where by for L. subvittata the Scaled body mass Index is lower for samples from salt pond sites and for A. occidentalis is lower for samples from relative pristine mangrove sites. This may be suggest that the well being of an organism is not reflected by having higher SMI but other factors may be playing role. Therefore establishing the standard SMI for the well being of different species will help to resolve such observation as any deviation from the standard will mean poor health. Future studies that focus in establishing database for standard Scaled body mass Index to act as reference for L. subvittata, A.occidentalis and other macroinvertebrate species will be important.

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Health Literacy and its Associates in the Context of One Health Approach: A Research Agenda Towards an Industrial Economy in Tanzania

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Abstract

Transformation of agriculture and natural resources for sustainable development towards industrial economy in Tanzania, inter alia, relies on the quality of population. Health has always remained a very essential determinant of quality of a population. Evidently, attaining optimal health calls for collaboration between humans, animals and environmental health professionals plus understanding consequences of humans, animals and environment interactions on health. Attaining good health faces numerous challenges, health literacy (HL) inclusive. Despite, HL being a predictor of health outcomes, health care costs and utilization, yet, it is not empirically known to which extent most countries, Tanzania inclusive, have made efforts in terms of research and interventions in this important variable. A cross sectional study was conducted in Morogoro urban and Mvomero districts in Morogoro, Tanzania to specifically (i) assess HL, (ii) determine factors associated with HL, (iii) identify research efforts and interventions on HL in Tanzania. . Data were collected through a structured questionnaire from 1440 respondents obtained using multistage sampling procedure. HL was measured using One Health Literacy Assessment tool. Quantitative data were analysed using IBM-SPSS (v20) and Gretl software. The results revealed that 36.3% of the respondents had inadequate HL, 30.8% with Marginal HL and Adequate HL standing at 32.9%. Pearson coefficient correlation revealed HL correlating to group of attitudes ($r = 0.135$, $p = 0.01$), levels of engagement in health-related discussion ($r = 0.609$, $p < 0.05$), health behaviour categories ($r = -0.648$, $p = 0.05$) and category of information seeking ($r = 0.753$, $p = 0.05$). Scanty empirical evidence exists on having HL researched and documented adequately in Tanzania. Having observed low HL and scanty research efforts and interventions on HL, efforts should be strengthened to promote HL under One Health Approach, given its importance towards realization of optimal health for humans, animals and the environment.

Keywords: Health literacy, Correlates, One Health Approach, One Health Literacy Assessment, Tanzania

1 Introduction

Unquestionably, good health is a cornerstone of development in all societies (URT, 2003a; URT, 2003b; IMF, 2004; URT, 2007a; WHO, 2012a; 2012b; Levin-Zamir *et al.*, 2017). Undeniably, health status of a society has profound effects on the rest of the sectors in a particular society (i.e. politics, social and the economic aspects) (Sayah and Williams, 2012; Edwards *et al.*, 2012; Sørensen *et al.*, 2015). On the contrary, other sectors in the society (the society, politics and the economy) have also considerable impacts on health status in a given society (Edwards *et al.*, 2012; Sayah and Williams, 2012). It is well known that good health determines quality of a population. Obviously, quality population is a crucial parameter for economic development (URT, 2003b; URT, 2007a; Lutz, 2014). In the presence of healthy population (high quality population) in the

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society there are chances for the economy to perform very well. It is evident that good health boosts labour productivity, educational achievement and income, hence lessens poverty (Udoh and Ajala, 2001; Bloom, *et al*., 2004). Ill-health and diseases have always been barriers to economic growth and subsequently to national development worldwide (Bloom *et al*., 2001; Strittmatter and Sunde; 2011; WHO *et al*., 2013). It is therefore apparent, that attaining development goal calls for improving health status of a nation's population. Nevertheless, numerous challenges exist towards attainment of good health (Byrne, 2004; Mamdani and Bangser, 2004; Kaseje, 2006; Sanders and Chopra, 2006).

In this context, it is obvious that transformation of agriculture and natural resources for sustainable development towards attainment of an industrial economy in Tanzania, inter alia, relies on the quality of population, which is determined by good health. There are numerous challenges existing towards attainment of good health (Muhanga and Malungo, 2018). This then makes it mandatory for government and other development partners to significantly promote health research and other related interventions which will result into promotion of good health, consequently high quality population.

Health Literacy (HL) is recognized as one of the prominent challenges towards attaining good health (Paasche-Orlow and Wolf, 2007; Muhanga and Malungo, 2017a). Substantial evidence exists (DeWalt *et al*., 2004) on how HL stands as an important predictor of health outcomes and health care utilization, how HL affects a person's ability to access and use health care, to interact with providers, and to care for himself or herself (Paasche-Orlow and Wolf, 2007). It is also well documented (Gazmararian *et al*., 2003; Nielsen-Bohlman *et al*., 2004; Weiss *et al*., 2005) on how limited HL impacts on health, health outcomes, health care costs and health care utilization. These impacts also include the likelihood of poorer comprehension of medical information, low understanding and use of preventive services, poorer overall health status, and earlier death (Nichols-English, 2000; Nielsen-Bohlman *et al*., 2004).

It is obvious then that, with low HL, the likelihood of maintaining good health is minimized and quality of population impacted negatively. It is also important to note that, much as there is a need for the government and other development partners in Tanzania to significantly promote health literacy research and other related interventions to promote good health consequently high quality population, definitely for these efforts to realize their targets the need for regarding health as one remains imperative.

Evidence exists on how other government's efforts which aimed at improving health services and educating people to become more health literate i.e. to cultivate the knowledge and skills needed to access, understand and use health information, thus enabling and encouraging them to make healthier lifestyle choices (so as to achieve positive health outcomes for both humans and animals) (URT, 2003a) could not attain their intended objectives. Notably, despite these efforts, there has been prominent existence of health impairing behaviours (URT, 2007a:11-12; URT, 2007b: 34) which sometimes resulted into a higher prevalence of infectious diseases (including zoonotic ones i.e. tuberculosis, rabies, Taenia solium infestation, human brucellosis etc.) (see for

example Cleaveland *et al*.,. 2002; Minja, 2002), and varying preferences for Tanzanians in terms of seeking healthcare services ranging from traditional healers, self-treatment, and no treatment instead of going to hospital (McCombie, 2002; URT, 2003b). These initiatives failure could be attributed to numerous factors. In light of what is reported, these initiatives did not take into account that attainment of optimal health for humans, animals and the environment calls for collaboration between humans, animals and environmental health professionals plus understanding consequences of humans, animals and environment interactions on health. Incognisant of that, the government of Tanzania initiated One Health Strategic Plan (2015 – 2020) which recognises the fact that attainment of optimal health for humans, animals and the environment requires collaborative efforts of humans, animals and environmental health professionals and at the same time a higher level of understanding maintained on the consequences of the interactions of humans, animals and environment on health (URT-PMO, 2015). However, how far this plan has realized its target at the local communities' level is not known. Based on that observation, it is also worth noting that, for initiatives to promote good health hence attain their intended goals, such initiatives should take into account the fact that there is an inextricable link between humans, animals and environmental health. Literature (Mbugi, 2012; CDC, 2018; Muhanga and Malungo, 2018a; 2018b) exemplifies this inextricable link very well.

While it is well documented on the influence of HL on health outcomes (Nichols-English, 2000; Nielsen-Bohlman *et al*., 2004) and how good health impacts on quality population (URT, 2003b; URT, 2007a; Lutz, 2014) which is a crucial parameter for economic development, it is not empirically known whether there is substantial research and interventions documented on HL focusing on OHEA in Tanzania. Having noted the previous efforts by the government of Tanzania at improving health services and educating people to become more health literate i.e. to cultivate the knowledge and skills needed to access, understand and use health information, thus enabling and encouraging them to make healthier lifestyle choices; very little is known on the influence of these efforts on HL in the context of One Health Approach. Obviously, understanding associates/correlates of HL in the context of One Health Approach will contribute towards effectiveness and efficiency of interventions meant to promote HL.

It is against this background that the study on which this paper is based investigated the status and extent to which HL in the context of One Health Approach has been researched and documented in Tanzania, incognisant of the fact that this is a very crucial research agenda towards an industrial economy in Tanzania. Further, the study reviewed studies and interventions globally on measurements/assessment of HL. Additionally, in this study, a context specific OHA based HL measurement tool was developed which was used to assess HL under OHA. Also, correlates/associates of HL were established in this study from selected wards in Morogoro, Tanzania.

2 Materials and Methods

The study was conducted in Morogoro municipality and Mvomero districts, both found in Morogoro region in Tanzania. In 2012, Morogoro region had a population of (2.22 million) people distributed in six (6) districts with 506,289 households, the average

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household size being 4.4 people (URT-NBS., 2013). The National One Health Strategic Plan 2015 – 2020 locates Morogoro under potential routes of risks exposure due to identification of some incidences of zoonotic diseases in the area (URT-PMO, 2015:16). Studies (Karimuribo *et al*., 2005; Mgode *et al*., 2014) have also identified health risks presence in the area.

A cross-sectional research design was applied in this survey research. A structured questionnaire guide using a Computer Assisted Personal Interviewing (CAPI) electronic platform was used for data collection. Multi-stage sampling procedures were used in selecting study units, involving four (4) stages (in choosing districts, wards, villages/streets and HHs). Identification of the districts, wards and villages/streets for the study was made through purposive sampling, whereas respondents from the study areas were selected using simple random sampling.

The inclusion criteria for the wards in Mvomero district were those wards where pastoralists were mostly residing, and households keeping animals and selling livestock products to Morogoro urban. The wards which were included in the study in Morogoro urban were those in areas where products from Mvomero district were sold, particularly where meat (mostly offals; utumbo in Kiswahili) and milk from Mvomero district were sold4. . Four wards were purposely selected to participate in the study, two from each district after meeting the criteria. The selected wards were Doma and Melela in Mvomero district also Mazimbu and Kihonda Maghorofani in Morogoro municipality. Thereafter, two villages/streets were selected from the four wards, making a total of eight villages/streets. The reconnaissance visits identified these vendors mostly at Reli and Mazimbu Darajani streets in Mazimbu ward also at Msamvu B and Maghorofani in Kihonda Maghorofani ward.

For sample size estimation, a 95% confidence interval (CI), a margin of error of 5% and a design effect of 1.5 were assumed. A minimum adequate sample size was calculated based on the statistical estimation method of Kelsey *et al*. (1996). A sample size of 1440 respondents was

determined by using the formulae:

$s = X^2 NP (1- P) \div d^2 (N-1) + X^2 P(1- P).$

Where:

s = required sample size.

X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841).

N = the population size.

P = the population proportion (assumed to be .50 since this would provide the maximum sample size).

d = the degree of accuracy, expressed as a proportion (0.05).

The sample size for this study was calculated from the total population of each 2 purposive selected streets/villages from a ward. After obtaining the sub-sample for

[4]These traders are popular in the area as *Wang'ombe* and *Baba Yeyo*.

each ward, proportions of each streets/villages from the total sample were calculated. The sample size was then distributed in the identified study streets/villages. Local leaders were involved in preparing the sampling frame.

After reviewing current knowledge on HL assessment tools and approaches, a context specific HL assessment tool and approach to assess HL in Tanzania under OHA was developed. This was done through modifying HLS-EU Q47 approach to suit the context of OHA in Tanzania, to assess HL in the interface of humans, animals and the environment in the selected wards in Morogoro Municipality and Mvomero in Morogoro Region in Tanzania. The HLS-EU approach confined itself to measure HL, mainly on 47 human health aspects. In order to fit in the context of OHA, 47 animals and 47 environmental health (47) aspects were included the developed HL assessment tool in the study conducted in Morogoro-Tanzania. A total of 141 health related aspects were included in the tool.

A questionnaire was developed reflecting health and related issues under the interface of humans, animals and the environment. This tool involved activities reflecting a number of aspects which have influence towards realizing optimal health for humans, animals and the environment. The developed tool comprises of a 4- point self-report scale (very easy, easy, difficult, and very difficult) to measure the perceived difficulty of selected One Health relevant tasks in the selected research sites in Morogoro, Tanzania. Data obtained unveiled the realities with respect to HL of the people under OHA through respondents' self-reporting (perceived) HL. Developed scale was tested for its reliability. Internal consistency of a scale according to Pallant (2007), among other, is a very important reliability aspect to the scale. Cronbach's alpha coefficient is a most commonly used indicator of internal consistency. According to DeVellis (2003) the Cronbach's alpha coefficient of a scale should be above 0.7. In this study, the Cronbach's alpha coefficient was 0.975, the value indicates a very good internal consistency reliability for the scale with the sample for the study.

HL was measured by asking respondents "On a scale from very easy to very difficult, how easy would you say it is to: i.e (find information about symptoms of illnesses that concern you?)". The items which were asked in these questions mainly reflected three(3) health relevant areas (health care, disease prevention, health promotion) and four (4) information processing stages (accessing, understanding, appraising, application) related to health relevant decision-making and tasks on health and other associated aspects under the interface of humans, animals and the environment. An index of score was constructed to measure HL by assigning four (4) points to "very easy" response, three (3) points to "easy" response, two (2) points to "difficult" response, and one (1) point to "very difficult" response.

Using IBM-SPSS (v20) HL scores were cut into 3 equal groups to represent HL categories into Inadequate Health Literacy (IHL) (below the scores of 211.0000), Marginal Health Literacy (MHL) (between 211.0000 and 261.0000 scores) and Adequate Health Literacy (AHL) (the scores above 261.0000). A similar categorization has also been employed by Gazmararian, *et al.*, (2003) in their study on HL. Frequencies and percentages were used to present HL categorization. Descriptive statistics were

employed in the analysis of the HL. An individual's HL was indicated by how that particular individual finds it 'very difficult', 'difficult', 'easy' or 'very easy' if s/he was to engage herself in a task related to a particular health relevant area(s) (health care, disease prevention, health promotion) and information processing stages (access, understand, appraise, apply) related to health relevant decision-making. This means an individual responding 'very difficult' for all items would have scored 141 points and 'very easy' scoring 564.

A documentary review research method was used to collect relevant information on the status and extent to which HL in the context of One Health Approach has been researched on and documented in Tanzania. Similarly, documentary review was employed to collect information on current knowledge on HL assessment tools and approaches. A bivariate Pearson correlation was used to analyze the strength and direction of linear relationships between HL and some other continuous variables under the study.

IBM-SPSS v20 and Gretl software were used to compute frequencies, percentages, mean and maximum scores, chi-square and coefficients of correlation. All statistical tests were considered significant at p-value < 0.05.

3.0 Results

3.1 Socio- demographic characteristics of the respondents

The findings in Table 1 show that about 29.2% (95% CI: 23.3 to 35.0) were aged from 30 to 39, and 3.8% (95% CI: 1.7 to 6.2) were above 70 years. The average age was 43.7 years (95% CI: 43.1 to 44.4 years), and the highest age and the lowest age were 21 and 72 respectively. The majority (52.1 %) (95% CI: 49.6 to 54.7) were women. More than one-third (39.2%; 95% CI: 36.6 to 41.7) had not gone to school at all, and 57.5% (95% CI: 50.9 to 63.8) were married. The average HH size was 5 (95% CI: 5.08 to 5.28) members; the smallest HH size (minimum) had 1 member while the largest household size (maximum) had 10 members; and 62.9% of the HHs had 1 to 5 members.

Table 1: Socio-Demographic Characteristics of the Respondents (n=1440)

Variable	Categories	Percentage
Age in years	21-39	42.1
	40-49	26.3
	50-59	17.1
	60-69	10.7
	[illegible]	3.8
Level of Education	Not gone to school at all	39.2
	Universal adult education	2.5
	Primary school	30.0
	Secondary school	8.8
	Post-secondary /vocational	10.4
	University	9.2
Sex	Male	47.9
	Female	52.1
Marital Status	Never married/Single Married	30.4

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	Married	57.5
	Separated	1.7
	Widow	5.4
	Widower	2.5
	Cohabiting	0.8
	Too young to marry	1.7
Household Size	1-3	21.7
	4-7	65.9
	>8	12.4

3.2 Health Literacy under the Humans, Animals and the Environment Interface

The results indicate that the HL mean score was 261.9 (95% CI: 257.6 to 266.4) while the maximum and minimum scores were 141.0 and 501.0 respectively with a Std. deviation of 85.0 (95% CI: 81.4 to 88.3). Table 2 presents HL results in categories; the results indicate that 36.3% (95% CI: 33.7 to 38.9) of the respondents had IHL, 30.8 % (95% CI: 28.4 to 33.3) with MHL and 32.9% (95% CI: 30.3 to 35.3) had AHL.

Table 2: Health Literacy categories (n=1440)

Health Literacy Categories	Frequency	Percent	95% Confidence Interval	
			Lower Bound	Upper Bound
Inadequate Health Literacy (IHL)	522	36.3	33.7	38.9
Marginal Health Literacy (MHL)	444	30.8	28.4	33.3
Adequate Health Literacy (AHL)	474	32.9	30.3	35.3
Total	1440	100.0		

3.3 Correlates/ Associates of HL

The results from Pearson correlation indicate that HL is significantly associated with group of attitudes ($r=0.135$, $p<0.01$: the higher HL, the positive attitudes HEB), levels of engagement in health related discussion ($r=0.609$, $p<0.05$: the higher engagement, the higher HL), health behaviours categories ($r=-0.648$, $p<0.05$: the larger HL, the lower involvement in HIB) and category of information seeking ($r=0.753$, $p<0.05$: the higher level of information seeking, the higher HL). The results indicate that when these variables change, HL also changes. Literally the results signify that a higher HL reflects negative attitudes towards HIB, while the higher engagement in health related discussion was found to correlate to higher health literacy whereas higher HL was found to influence lower HIB and active information seekers were found to have higher HL.

3.4 NNBHL Research Initiatives and Interventions under OHEA in Tanzania

Notwithstanding the growing attention for the concept of HL globally among health policymakers, researchers and practitioners (Sørensen *et al*., 2015; European Commission, 2007; United Nations Economic and Social Council, 2009; WHO, 2012a), the situation in Tanzania is not different from situations in the rest of Africa, where very little has been researched and also documented on HL. In most countries in Africa, national overall initiatives for HL have not yet been institutionalized, that is there is no governmental policy related to health literacy (WAHO, 2009; IOM, 2013). It can be noted that there exist no health data sets with the HL variable. Obviously, the reality with respect to the population wide HL is then not known in Tanzania.

No evidence exists in the literature on having HL researched and documented adequately in Tanzania; what exists is very limited. For example, a study by Stone *et al*. (2011) dealt with evaluation of the utility of IEC materials for increasing patient HL and how patients perceive such materials on HIV/AIDS. Freer (2015) conducted A Comparative Study of Health Literacy and How Rural Communities Understand Hypertension Information in Uganda and Tanzania. Despite having very limited studies on HL, still none of the few available have focused on OHA which takes into account the interface of the interaction of animals, humans and the environment. This, however, does not point out to the fact that the place and relevance of HL is not recognized by health policymakers, researchers and practitioners in Tanzania. Studies by Kambarage *et al*., (2003) and Karimuribo (2007) indicate the value of public health education programmes and how they could impact on public health outcomes under One Health Approach.

3.5 HL Measurements/Assessment: A Global Overview

In order to develop a context specific OHA based assessment tool, numerous empirical studies covering tools and approaches on HL measurements/assessment were reviewed. A study by Sun *et al*. (2013) was conducted to develop and validate a HL model at an individual level that could best explain the determinants of HL and the associations between HL and health behaviours even health status regarding infectious respiratory diseases. Skill-based HL test and a self-administrated questionnaire survey were conducted among 3222 Chinese adult residents.

The European HL Survey (HLS-EU, 2012:4) was conducted across eight European countries. In each country, a random sample of approximately 1000 EU-citizens, 15 years and older, were interviewed yielding a total sample of approximately 8000 respondents. Data were collected face to face via a standardized questionnaire. To measure HL, HLS-EU-Q was derived from the conceptual model and the definition developed by the HLS-EU consortium (Sorensen, 2012). The conceptual model integrates three health relevant areas (health care, disease prevention, health promotion) and four information processing stages (access, understand, appraise, apply) related to health relevant decision-making and tasks. These areas and stages, combined, create a matrix for measuring HL (HL) with 12 sub-dimensions, which were operationalized by 47 items. The 47 items were assessed using a 4-point self-report scale

(very easy, easy, difficult, and very difficult) to measure the perceived difficulty of selected health relevant tasks. Therefore the HLS-EU-Q refers to self-perceived measures of HL and reflects interactions between individual competences and situational complexities or demands.

The National Assessment of Adult Literacy (NAAL) was extremely important as the first national measure of literacy, providing systematic feedback to the education system and to the health care system about how literate American adults are. (IOM, 2009). Through the NAAL, an overall assessment of the level of literacy of American adults was obtained, among other. Out of that, numerous research measures (i.e. Test of Functional HL in Adults -TOFHLA and the Rapid Estimate of Adult Literacy in Medicine-REAL) have been used to analyse the impact of numerous interventions on individuals with limited HL. Researchers have used these measures to conduct studies that have shaped the field of HL (Baker *et al*., 2006). Obviously, the feedback from the National Assessment of Adult Literacy (NAAL) demonstrated that the level of information conveyed by these systems did not well match with the abilities of most adults hence contributed to problematic, inadequate or low HL (IOM, 2009). This feedback created a very important entry point to the designing of the study conducted in Morogoro. This is simply the observation made was that the government in Tanzania had made efforts in improving health services and educating people to become health literate; still notable existence of health impairing practices/behaviours and varying preferences for Tanzanians in terms of seeking healthcare services instead of going to hospital (URT; 2003a; 2007a; 2007b). This then reflected the fact that there is a need to investigate whether the level of information conveyed through these efforts was a good match with the information requirements among Tanzanians towards HBs change.

4 Discussion

4.1 Health Literacy under the Humans, Animals and the Environment Interface

The trend indicates that IHL is reported to be a common occurrence throughout the world ((IOM, 2004; Kutner, *et al*. 2006; WHO, 2013). Both low and limited HL levels have been observed to be common even in economically advanced countries with strong education systems (Sørensen *et al*., 2015), though the situation is reported to be worse in the developing part of the world (Muhanga and Malungo, 2018a). Such individuals have problems with interpreting statistics and evaluating risks and benefits that affect their health and safety. This implies that lack of skills needed to manage health and prevent disease appears regardless of a country's level of development.

4.2 Associates /Correlates of HL

Innumerable studies (see for example; Paasche-Orlow and Wolf, 2007; Sun *et al*., 2013; WHO, 2013; Nutbeam *et al*., 2017; Clouston *et al*., 2017) have discussed the determinants of HL. Similar findings are reported on the correlates of HL. In a study by Sun *et al*. (2013), a significant difference between the unmarried and married groups in terms of their level of HL is reported. In the same study, HL was found to be affected by prior knowledge (β = 0.245). Other studies are also reporting prior knowledge to influence HL (Lee *et al*., 2004; Paasche-Orlow and Wolf, 2007; von Wagner *et al*., 2009). The

implication here is that a person with more health knowledge is better able to obtain, comprehend and use health information. Adams, (2010) reports on correlation between HL and attitudes towards health impairing behaviuor, while US Department of Health and Human Services-HRSA, (2015) documents correlation between HL and levels of engagement in health related discussion. Others (Davis, 2002; Sun *et al*., 2013; Schwartzberg and Wang, 2005; Miller, *et al*., 2007; Nutbeam, 2008) reported correlation between HL and health behaviours and HL and information seeking correlation has been documented by Gutierrez *et al*., (2014) and Jeong and Kim, (2016).

4.3 HL Research Initiatives and Interventions under OHA in Tanzania

Despite the situation observed with respect to HL research initiatives and interventions under OHA in Tanzania, it can be observed that there are several policy landmarks that are encouraging comprehensive HL initiatives. These policies include National Health Research Priorities (2006-2011) which has listed health information being among priorities (NIMR, 2013), One Health Strategic Plan (2015 – 2020) which recognizes the fact that attainment of optimal health for humans, animals and the environment requires collaborative efforts between various stakeholders from humans, animals and the environment health related matters (CDC, 2018); National eHealth Strategy (2012–2018) which supports improved multi-way communication and sharing of information among clinicians, patients, and caregivers within the health sectors and across partner agencies (Ministry of Health and Social Welfare, 2013). Together with these policies, the National Health policy of 2007 aims at creating awareness in individual citizens of responsibility for personal health and health of their family (URT-MOH, 2007). Obviously, such policy landmarks can influence effective HL Research Initiatives and Interventions under OHEA in Tanzania.

4.4 HL Measurements/Assessment

Through a review of literature, it has become apparent that most of the approaches used to measure HL had limitations. A study by Sun *et al*. (2013) concentrated at individual levels and but the rest of other studies (Sun *et al*., 2013; HLS-EU, 2012:4; IOM, 2004) were conducted in a different socio-economic and political reality of Tanzania and did not examine the role of cognitive variables (such as health beliefs, attitudes, self-efficacy) as described in psychological models in understanding the distribution/prevalence of HL and HB. It is worth noting that all these studies reviewed (Sun *et al*., 2013; HLS-EU, 2012:4; IOM, 2009; IOM, 2004) none of them took into account the inextricable link existing among humans, animals and environmental health.

HL is context specific, i.e. its function, acquisition and application should be studied and understood in the light of distinct contextual conditions (Kickbusch and Maag, 2006; Pleasant and Kuruvilla, 2008; Freedman *et al*., 2009). It is obvious that public health and clinical settings may each require a different research approach to HL (Sorensen *et al*., 2012). This means a need for a context specific approach to measure it. In this study, an approach was developed that takes on board the observed limitations from the review, and it was employed in this study.

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5. Conclusion and Recommendations

Obviously, attainment of quality of population in Tanzania depends much on the health literacy which also influences health. It can be noted that attainment of good health relies on the HL up scaling through research and interventions under the interface of humans, animals and the environment (OHEA). It is apparent that for HL to effectively influence quality of population, hence improving health the stakeholders (the government and non-governmental organisations) have to put emphasis in terms of interventions which will improve on the factors which have been found to associate/correlate with HL. These interventions should facilitate engagement in health-related discussion and health information seeking which are likely to impact on health behaviour.

Policy landmarks in Tanzania do provide an avenue which could best provide room for effective HL research and interventions despite little that has been done. This study has developed a tool specifically for measuring HL in the context of the interaction of humans, animals and the environment. Other studies can be conducted to assess HL in other areas of Tanzania and beyond using this tool; these studies will fill in the gap in the national health research which at the moment has been very little on this important aspect. Understanding how health literate people are in the context of OHA will facilitate attainment of optimal health for humans, animals and the environment. Since low HL has been observed, it is worthwhile for HL initiatives to be promoted by the government and non-governmental organisations. Definitely, the findings from this study will assist to fill a gap in national health data sets which lacked measurements in HL and can provide baseline information towards formulation of HL interventions, research agenda and programmes.

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Accelerating Industrialization through Agro-Processing: Access and use of Knowledge on Mango Processing Technologies by Smallholder Farmers in Tanzania

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Abstract

The Government of Tanzania strategy on reducing post-harvest losses to promote economic development, reduce poverty and increase food security is to support farmers to transition from subsistence to commercial. To support mango farmers, processing and preservation technologies are being transferred through training. However, the training provided is not wide-spread and is undertaken by multiple agencies with variations in the training content and approach. This study was conducted to assess the access and use of knowledge on mango processing technologies in Kibaha district in achieving the industrialization agenda of the country. The farmers was randomly selected from 21 trained farmer groups to obtain a sample size of 100 farmers for data collection using a pre-tested interview schedule. Data was analyzed using descriptive analysis and Multinomial LogitModel. The study established three technologies that are appropriate for mango processing; they include pulping for juice, pulping for jams and drying. Seventy-five-percent of the respondents have used these processing technologies at least once for jam and juice manufacture. Twenty-five-percent indicated not having used the technologies that they had been trained on. It was established that processing for home consumption and for sale was significantly influenced by the number of trainings attended, number of technologies trained on, hands-on experience and own fruits production. The study concludes that the farmers have ample knowledge on mangoprocessing particularly from training but the practice is low.It is recommended that: training organizers should equally take advantage of the varied mango processing technologies available to help farmers diversify on the products produced; the government and organisations can take initiatives of setting up a facility for solar drying; the need for smallholder farmers to develop business skills, acquire better access to both processing and market information to be able to reap the benefits of engaging in fruit processing activities.

Keywords: Processing, technologies, training, mango, industrialization

1.0 Introduction

Various mango processing technologies for fruits exist although these are often confined to commercial industry and are not conventionally practiced at the cottage level by most smallholder producers. Some of the technologies like pulping for jam and juice manufacture, drying, fermentation into wine and pickling which are simple and can be transferred to smallholder farmer through tailor-made training. Training of the farmers on these simple processing technologies can address seasonality issues and reduce post-harvest losses. It will also help to diversify the use and markets of the fruits (Gitonga *et al.*, 2014).

There is very high potential of agro-processing in Tanzania (MMA,2008). This is indicated by the fact that most farmers in the country grow Apple, Tommy Atkins which are appropriate variety for processing (AMAGRO, 2016). There is also ready market for the processed product. However the challenge remains in the fact that most

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of the producers are lacking when it comes to processing information and training. Previous studies in Tanzania indicated that only two farmers knew how to process mangojuice and had tried it before (MMA, 2008). Another study by Musyimi*et al*. (2012) indicated that a value added product like mangowine exists but there is no proper documentation of information regarding its processing and production. It is against this background that the study was designed to assess farmers' access to trainings on the technologies and to what extent they practice the technologies. The study was designed as a case study on smallholder farmers in Kibaha district. It is located in the coast region of Eastern Tanzania with high potential for production of high value crops. Therefore, this study aimed at understanding the access and use of trainings received, the study was based on one fruit Mango (Mangiferaindica)as an example of an exotic fruit, because of its high demand/market value and one indigenous fruit in the area with great potential for processing.

There are many missed opportunities for smallholder farmers for adding value to fruits for preservation, nutritional benefits and for income diversification through fruit based enterprise development (Kehlenbeck *et al*., 2013). MMA (2008) indicate that focus on both local and export market on fruits has been on fresh market and not processed fruit products. Therefore, the potential of most fruits in Tanzania remain underutilized (URT, 2016). Processing is quite low and confined to large scale commercial industries. The fruit value chains have not been fully developed (Kehlenbeck *et al*., 2010) and strengthened to mitigate post-harvest loss and wastage. According to Kehlenbeck*et al*. (2013) this is attributed by high losses during the seasonal gluts. Among the most commonly a grown and processed fruit in Tanzania is mango. There are between a 40 and 50% loss in mangovalue chains in the country due to inappropriate post-harvest handling at the smallholder farmer level (URT, 2016). Poor organization of fruit marketing and largely informal, limited information on fruit processing is available to the Tanzanian smallholder farmer which severely limits fruit processing in the sector (MMA, 2008). According to URT (2016), the challenge in the use of processing technologies by farmers is due to many factors including lack of knowledge and training, lack of capacity to operate in a competitive market because of bottlenecks of poor access to the available technologies, poor technical expertise, low production, poor infrastructure, lack of market information and organized markets and failure to meet the required international standards. There has not been any significant expansion of Mango processing in Tanzania. URT (2016) estimates processing operations are not at full capacity and are between 40%-80% due to constraints/limitations in consistent supply of good quality raw material. In Tanzania, the fruit processing sector provides an opportunity for fruit producers and smallholder farmers to engage in due to market potential. The study was designed to assess the access and use of knowledge gained from training in fruit processing technologies by smallholder farmers in Kibaha district. Specifically, it aimed to: (i) identify the available technologies for mango processing with potential for adoption by smallholder farmers in the study area; (ii) establish the socio-demographic and socio-economic characteristics affecting the use of mango processing technologies in the study area and (iii) study the level of knowledge and practice of mango processing technologies by the farmers in the study area.

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2.0 Materials and Methods

2.1 Study Area

The study was conducted in four villages of Kibaha District. The district is one of the six districts of the Coast Region. It is located 40 km west of Dar es Salaam, along the Dar Es Salaam-Morogoro highway. It lies between latitude 6.8o in the South and longitude 38.2o and 38.5o in the East. Kibaha District shares common borders with Bagamoyo District in the North, with Bagamoyo District again and Morogoro Rural District in the West and with Kisarawe District in the South. The District consists of 5 administrative wards: Magindu, Kwala, Soga, Mlandizi and Ruvu. There are 25 registered villages and 71 sub villages. The area is located at an altitude of about 50 m above sea level and has an average annual rainfall of 1000 mm. There are two rainy seasons, long rains from March to June and short rains from October to January. The area has an average temperature of 29.70 C. The population of the area is about 132 045 out of whom 66 296 are females and 65 754 are males. The district has a total arable land of 76 554 ha of which 26 794 ha of the area is cultivated with different types of crops. The fruits most commonly grown include *Mangiferaindica, Caricus papaya, Citrulluslanatus, Passifloraedulis, Citruscinensisand Psidiumguajava*.

2.2 Study Design

The study was cross-sectional as it selects an entire population or a subset thereof and data collected to answer objectives of the study. The study involved both qualitative and quantitative data collection through semi-structured questionnaire, key informant's interview, informal discussions with farmers and personal observations.

2.3 Sampling procedures

The district was purposively selected because of its potential for high value exotic fruit crops production for the market. The study conducted a scoping study to identify trained groups in the area. This was done through consultation with key informants. Snowball effect was also used to further identify the groups. The scoping study established 21 trained groups (900 trained farmers) who participated in different trainings on fruit processing. That is they similarly grow the same crops and attended training on fruit processing. In selecting the number of mango small scale farmers to be interviewed, the sample was calculated using the formula used by BaoThoa (2006), as shown in Equation 1:

$$n = \frac{N}{1 + Ne^2} \quad \text{.....} (1)$$

Where: n is sample size; N is total number of small-scale groundnut oil processors; e is the level of precision or error of detection (10%).

Therefore, $n = \frac{900}{1+900(0.1)^2} = 100.111 \approx 100$

Hence the sample size for mango small-scale farmers was 100 households. Random

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sampling was used to select a sample of 100 from the trained farmers.

2.6 Data Collection

The farmers were interviewed using a pre-tested questionnaire to collect data on socio-economic and demographic characteristics, current knowledge on and use of fruit processing technologies, knowledge sources and training on fruit processing. Both primary and secondary data were collected. Primary data were collected using a survey method. The survey was the main data collection method, complemented by data obtained through focus group discussions (FGDs), Key Informant Interviews (KIIs) and documentary review. Secondary data were collected using documentary review. The methods are explained in detail below.A survey questionnaire was administered to 90 household heads. The survey included both open-ended and closed-ended questions. The survey was conducted in 2018. Respondents were met at their homes and were asked for their consent to participate in the study. Those who agreed to participate in the study were requested to provide information to achieve the objective of this study.

Two focus group discussions were conducted using an FGD guide with pre-determined questions. Each of the discussions consisted of 10 participants, including five female participants. The FGDs were guided by one facilitator, whose duty was to moderate and guide the discussion. The FGD guide consisted of general questions which explored important topics related to the study objectives.A key informant interview was adopted in order to gain in-depth understanding of the mango sub-sector in the study area. Four key informants, including one woman, were interviewed from three wards. The informants were of different ages, ethnicity, religious affiliation and educational level. The informants were selected based on their training and personal knowledge/experience. Five informants in one ward were extension officer who had worked in the study area for more than ten years. The informants were also selected based on their ability to express themselves clearly. Each interview took about one and a half hours and was tape recorded. Notes were made after each interview from which key themes were identified.

Documentary review was employed to gather secondary information which otherwise could not be gathered using the other methods. The documentary sources covered by this study include, annual reports, government reports, acts policies and regulations, newspapers journals and circulars. Relevant literature was obtained from Kibaha district, Regional and District Commissioners office, NGOs offices, district community development office, books and internet.

2.6Data Analysis

2.6.1 Statistical Analysis

The questionnaire data were entered in Statistical Package for the Social Sciences (SPSS) and analysed in the SPSS version 21. This study used descriptive statistics (frequency and percentage) to determine the available mango processing technologies (objective one) and current knowledge on and the use of mango processing technologies by the surveyed farmers (objective two). In addition, the data analysis process utilized

inferential statistics, particularly the regression analysis to achieve objective 3 of the study. Statistical software (STATA) was used to analyze the Multinomial logit (MNL) model which was used to establish the factors (independent) affecting adoption/use (dependent) of mango processing technologies.

2.6.2 Multinomial Logit Analysis

Models are derived from information-theoretic principles which try to find the most arbitrary predictions consistent with the observations and average of the selected populations. Multinomial logit models are applied if the nominal dependent variable has more than two categories andthey cannot be ordered practically (McFadden, 1987). This model is often considered because it doesn't assume linearity, normality or homoscedasticity. This model fits well in this study as the study tried to determine the use for home consumption, use for income and non-use of the processing technologies. In addition the model was adopted for this study as it is easy to estimate and its interpretation is more often quite easy. According to Panda and Sreekumar, (2012) the equation takes the below form:

$$Logit(P_i) = \ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1 x_1 + \cdots + \beta_n x_n + \varepsilon_i$$

Where:

$\ln\left(\frac{P_i}{1-P_i}\right)$ = Logit for different choices of use of the technologies

P_i = non-use of the technologies, $1 - P_i$ = use of the technologies β_i = Coefficient; x = covariates; ε_i = Error term

In the model, use of technologies with three choices, use for home consumption, use for income and non-use was set as the dependent variable. Non-use of the technologies was set as the base outcome and it took a value of zero. Use for sale/income took a value one while use for home consumption took the value two. Since the non-adopters were more than those who practice for sale and less than respondents for home use, they were used as the base outcome for comparison. It was assumed that the use depends on the number of trainings one has attended, the number of technologies one has been trained on, whether or not participants carried out hands-on experience during the training, socioeconomic and demographic characteristics. Unfortunately, other factors influencing use of processing technologies were precluded due to data limitations.

Estimation procedure:The dependent variable included the following as listed in (Table 2). Based on past research by different scholars, a number of suitable independent variables likely to influence use and their expected signs (Mwombe*et al.*, 2014; Ngombe*et al.*, 2014) were identified such as: age,level of education, number of technologies trained on, number of trainings attended, acquired any other information sources, number of fruits cultivated and handson experience.By fitting the dependent variables, the model was presented as:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1 Age + \beta_2 Educ + \beta_3 Tech + \beta_4 AcqInfo + \beta_5 Fruit + \beta_6 Exp + \beta_7 Train + \varepsilon_i$$

Before the model estimation, it was necessary to check for multicollinearity and the test for the Assumption of Independence from Irrelevant Alternatives (IIA).

2.6.3 Special tests

2.6.3.1 Multicollinearity

Independent variables in a model can be related and this brings a problem when interpreting the models outcome. For this study, Variance Inflation Factor (VIF) was estimated using STATA software. As a rule of thumb, if the VIF exceeds 5, the variable is said to be highly collinear.

2.6.3.2 Testing for the assumption of IIA in the MNL

Hausman Specification test is the standard test for Independence from Irrelevant Alternatives (IIA). This test infers that the ratio of selecting any two alternatives is autonomous of the third choice (Small and Hsiao, 1985). "The assumption of IIA is rejected if the probability of chi-square result falls below 0.5, in the 5% level of significance and vice versa" (Nyaupane, 2010).

3 Results and Discussions

3.1 Mango processing technologies

Table 1 lists the technologies applicable to mango that have potential for use by small processors in the study area. These technologies were identified based on availability of the markets for the processed products, simplicity and affordability of the technologies. The technologies were identified from primary sources.

Locally produced juice from mango are available in the market and will effectively compete with imported fruit juice of similar quality from importing countries like South Africa. The fruit pulp can still be pasteurized used in making jam and jelly. Markets already exist for these products domestically and internationally. There is also scope for pulps for use in flavouring ice cream and yoghurt. Tanzania has existing industries for ice-cream and yoghurt manufacture. To ensure availability of the pulps to these industries all year round, processing of shelf-stable pulp should be considered. Dried mango product are already processed in Tanzania and sold in the markets. Mango drying is a simple technology which can easily be practiced by small producers. The low cost solar and sun drying technology is available with both local and international market which makes it a very ideal technology that should be promoted among small mango processors. The small producers should only work hard to improve on the quality of the dried mangoes as quality is an issue with the smallholder farmers.

Table 1: Fruit processing technologies of mango appropriate for the smallholder farmers

Technology	Methods	Products	Reasons for choice of
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			technology
Production of pulps	Pulping	Juice Pulps for use in flavouring ice cream and yoghurt	Market pulp and juice available, Products can be prepared locally
Drying	Sun drying Solar drying Artificial driers	Dried slices, pieces	Market available (local and export) Can be applied locally Low cost sun and solar drying technology
Pickling	Lactic acid fermentation	Pickles	Both domestic and international market available
Fermentation	Yeast fermentation	Wine. Pulps are fermented into wine. However, grapes are the main raw materials for wine production but production of wine from mango fruits will offer cheaper alternatives especially in regions/districts in the country where grapes are not grown	Market potential
Production of vinegar	Oxidation	Vinegar. Vinegar from mango is a superior food additive over synthetic vinegar. The high carbohydrate content and sugars in the mango fruit makes it ideal for production of vinegar.	Both domestic and international market available

Source: Field survey, 2018

Green mango can be used to make pickles as they have both domestic and international market and hence a very feasible product for the small processors to undertake. mangopulp can be used for fermentation into wine, however as Musyimi*et al*, (2012) suggests, grapes are the main raw materials for wine production but production of wine from these fruits will offer cheaper alternatives especially in countries where grapes are not grown. Vinegar from fruit fermentation is a superior food additive over synthetic vinegar as fruits are high in vitamins and minerals. This is an important technology especially in the Mangiferaindicasub-sector. The high carbohydrate content and sugars in the mango fruit makes it ideal for fermentation and production of vinegar. There is a great market potential of vinegar for use as a food preservative, dressing and as a disinfectant.

3.2 Factors influencing use of processing technologies

Variance Inflation Factor (VIF) test was used to check if multi-collinearity exists among the independent variables. The VIF was found to be less than five therefore multi-collinearity does not exist in the selected variables. The likelihood ratio test P-value found was less than 0.0000, indicating that the coefficients of independent variables are not jointly equal to zero. Moreover, the model fit is within the range commonly seen using cross-sectional data with pseudo R2 of 0.30. Also findings revealed that there was

no reason to conclude that MNL model violates IIA assumptions as all choices gave a P-value of 1. Parameter estimates (coefficients and marginal effects) from the multinomial logit model are presented in Tables 2 and 3. The parameter estimates of the multinomial logit provide direction and not probability or magnitude of change. The marginal effects measure the actual effect of a unit change in each of the explanatory variables on farmers' use of the technologies.

Table 2: MNL parameter estimates for determinants of use of processing technologies (Non-use set as base outcome)

Variables	Use for sale			Home use		
	Coeff	Std error		coeff	Std error	
Age (25–75)	-0.000	0.000	0.197	-0.000	0.000	0.322
Level of education (1=none, 2=some primary, 3=primary finished, 4=secondary, 5=tertiary)	0.096	0.473	0.838	-0.241	0.325	0.458
Number of technologies trained (1-4)	0.972	0.544	0.074*	0.436	0.372	0.242
Number of trainings attended (1–3)	1.922	0.647	0.003***	-1.326	0.489	0.00***
Acquired any other information sources (1=Yes, 0=No)	0.521	0.982	0.596	-0.130	0.594	0.826
Number of fruits cultivated (0–6)	0.152	0.485	0.754	-0.670	0.325	0.039**
Handson experience (1=Yes, 0=No)	2.501	0.466	0.011**	1.072	0.569	0.059*
Constant	-5.562	2.897	0.055	-2.476	1.906	0.194

N=100;Pob> :0000; Pseudo R2:0.2095;Log Likelihood-69.673239*:significant at 1% level;**:significant at 5 level;* significant at 10 level; base outcome non-use.**

Field survey, 2018

Coefficients from multinomial logit can be quite difficult to interpret because they are relative to the base outcome; therefore a better way to assess the effect of covariates is to examine the marginal effect of varying their values on the probability of observing an outcome. Table 3 shows the marginal effects computed.

Table 3: Marginal effects of the MNL regression model for determinants of use of fruit processing technologies

Variables	Use for sale			Home use		
	Discrete change of dummy variable 0 to 1	Std error		Discrete change of dummy variable 0 to 1	Std error	
Age (25–75)	-0.000	0.000	0.285	-0.000	0.000	0.651
Level of education (1=none, 2=some primary, 3=primary finished, 4=secondary, 5=tertiary)	0.007	0.035	0.851	-0.048	0.066	0.465

Number of technologies trained (1-4)	0.054	0.040	0.174	0.039	0.073	0.591
Number of trainings attended (1–3)	0.079	0.044	0.074*	0.182	0.089	0.042**
Acquired any other information sources (1=Yes, 0=No)	0.33	0.065	0.610	-0.000	0.120	1.000
Number of fruits cultivated (0–6)	-0.028	0.036	0.436	0.141	0.063	0.024**
Handson experience (1=Yes, 0=No)	0.142	0.077	0.063*	0.090	0.125	0.047**

****, * significance levels at 5 and 10 % respectively**

Source: Field survey, 2018

3.2.1 The number of technologies participants had been trained on

This factor was significant at 10% when it comes to use for sale for income generation in the MNL parameter estimates. This was not the case in the marginal effect. This might be explained by the fact that the respondents were relatively homogenous in those factors.

3.2.2 Number of trainings attended

This factor was highly significant at 5% for use for sale and significant at 10% for home use. The number of trainings attended increases the probability of the respondent using the technologies by 8% for use for sale and 18% for home use. It was observed that those who attended more than one training adopted the technology both for home use and for sale to generate income. Non adopters did not attend more than one training program. This study is consistent with Ngombe*et al.* (2014) who also found that the more the trainings farmers attended the more the adoption of conservation agricultural technologies.

3.2.3 Availability of fruits

The cultivation of fruits on farm by the respondents was quite significant at 5% when it comes to use for home consumption. There was a greater likelihood of processing fruits for home use (14%) if fruits were grown on farm. This is because it is usually observed that those who grow a variety of fruits tend to do so mainly for subsistence use. They usually grow many varieties on a small piece of land. It is also observed that most people who engage in commercial processing tend to grow only one variety of fruit for commercial purposes and on a large piece of land.

3.2.4Age and education

Household characteristics such as age and education level were found to be insignificant. This contradicts with Mercer (2004); Okello*et al.* (2012) who suggested and found that farmers with more education are earlier and more proficient users of technologies. The insignificance may be because of the respondents' being relatively homogenous in those factors.

3.2.5Other sources of knowledge

Other information sources which include radio, farmers field days and agricultural shows, extension officers, friends and neighbours were found to be insignificant. This contradicts Tarnoczi and Berkes (2009) who found that the greater the number of information sources farmers had, the more likely they were to adopt new practices. The study however agrees with Läpple (2010) who reported no correlation between the number of different sources of information and the use adoption of organic farming.

3.3 The level of knowledge on fruit processing technologies

The study sought to determine the respondents' knowledge about processing technologies and whether they had used the technologies before. It was established that 75% of the farmers admitted to having carried out mango processing at least once while 25% indicated not having ever processed previously. Among the reasons indicated for having used processing and value addition technologies were; to 'add value (20%)', for income generation potential (8%), 32% for home consumption and 20% indicated for purpose of practicing the knowledge and skills acquired from trainings attended. Other reasons as mentioned by 20% of the respondents were to utilize available resources and fruits. Similar reasons for the use of processing technologies have also been found in studies by others (Msabeni*et al*., 2010).

4.0 Conclusion

On the basis of this research, the study concludes the following; there is existence of varied technologies for mango processing identified in this study. The technologies included production of pulps, drying, fermentation, production of vinegar, fermentation and pickling. The findings of this study suggest that socio-demographic and socio- economic factors are central in determining farmers' use of fruit processing technologies. The factors found to influence use of training were the number of technologies trained on, the number of trainings attended, the cultivation of fruits on own farm and the hands-on experience during the training. Trainings are therefore important in promoting the use of the technologies. The study also concludes that the respondents are quite knowledgeable on the fruit processing technologies but the practice is still quite low.

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Attitudes and Perceived Impact of Insecticide Treated– Bed Nets on Malaria Control in Rural Tanzania

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Abstract

Insecticide-treated nets (ITNs) are the most powerful malaria control tool if used correctly. Yet up to date, utilization is still low. The aim of this study was to investigate the intra-household factors that affect the utilization of ITNs in rural households in MorogoroUrban district. In addition, this study analysed the reasons for ITNs non-use in households with children under five years. Questionnaire, interviews and observation were the key tools for data collection for thestudy. The intra-household factors affecting the utilization of ITNs reported in this study include, chemical substances impregnated in the nets (36%), household financial inadequacy (24%), warmth and discomfort of the nets (24%) and skin irritability (17%), among others. The general community knowledge about mosquito nets was found to be high (91%); however, the knowledge of ITNs was low (30%). In addition, it was found that the ITNs were inadequately accessible in the study community. Based on the results of this study, adequate accessibility of ITNs and community education related to the use and their significance is recommended.

Key words: Insecticide treated bed-nets; attitude; malaria; Morogoro CBD

1 Introduction

Insecticide-treated nets (ITNs) are the current widely adopted malaria preventive measures in endemic regions (Ikeako *et al*., 2017). ITNs are impregnated with insecticides such as pyrethroid, permethrin or deltamethrin which have an excito-repellent effect and kill the malaria vectors that come in contact with the (Ikeako *et al*., 2017; Kawada *et al*., 2014; WHO, 2015). ITNs have approximately 50% of mean efficiency strategy for combating malaria in endemic regions such as sub-Saharan African countries (Ikeako *et al*., 2017; Obol *et al*., 2014). The ITNs are estimated to reduce children and pregnant women mortality by 60% (Obol *et al*., 2014).

In 2015, approximately 212 million new cases of malaria and 430,000 malaria deaths occurred worldwide, with more than 90% occurring in Africa (Tizifa *et al*., 2018; WHO, 2018).In 2017, children aged under 5 years accounted for 61% (266 000) of all malaria deaths worldwide (WHO, 2018). The disease accounts for 40% of public health, 30-50% of inpatient admission and up to 50% of outpatients visitingin areas with high malaria transmission(WHO, 2015).Tanzania is endemic tomalaria and constitutes a major cause of illness and death specifically to children under five years of age and pregnant women(WHO, 2015).Ninety three percent of Tanzanians population live in areas where malaria is transmitted in which 20% unstable seasonal malaria transmission occur in endemic areas and 60% characterized as stable perennial transmission. Tanzania ranked fourth (5%) of the seven countries that accounted for 53% of all global malariadeaths in 2017 (WHO, 2018). The country was preceded by Nigeria (19%), Democratic Republic of the Congo (11%),and Burkina Faso (6%) (Ibid.).There have been efforts to control

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malaria in Tanzania by both governmental and non-governmental organizations. Effective steps to increase the coverage of the use of ITNs to fight malaria transmission are through the National Insecticide Treated Nets (NATNETS) programme. The programme promotes the national use of ITNs by making nets affordable, accessible and acceptable. The fact that uses of ITNs forms the mainstay effective strategy for combating malaria in children under five years and pregnant women, it has never been that smooth tocommon people.

Furthermore, there is a substantial investment by the Government of Tanzania through private partnership approach to promote usage of ITNs as an integral strategy for control of malaria vectors. The U.S. President's Malaria Initiative (PMI), CDC Tanzania promotes malaria prevention and control interventions, including providing long-lasting insecticide mosquito nets and indoor residual spray; preventing malaria in pregnancy; improving diagnostics and case management; and monitoring and evaluating malaria-related activities. Through these efforts and others, the proportion of households owning at least one ITN rose from 63% to 92% from 2010to 2011 (Kramer *et al*., 2017). The use among children under five years in mainland Tanzania increased from 25% in 2008to 73% in 2012(Kramer *et al*., 2017). Despite of the national and international efforts malaria remainsamong the top 10 causes of death in the country(CDC, 2018).In addition, many household members donot own ITNs and even those who own it donot consistently sleep under the net. The study aimed at assessing attitude and perceptions of insecticide treated nets use on malaria control in rural Tanzania.

2. Material and Methods

2.1 Study area

The study was conducted in Kasanga and Kiroka wards in Morogoro rural district and Lukobe ward in Morogoro urban district in Morogoro region. Morogoro region is located between latitude 5° 58" and 10°0"S of the Equator and longitude 35° 25" and 35°30"E.The region is bordered by Arushaand Tanga regions to the North, the Coast region to the East, Dodoma and Iringa to the West, and Ruvuma and Lindi to theSouth.The elevation of the study areas is about 196m above sea level. Farming is the main occupation of the population. The topography and climate together with human activities in the area highly encourage healthy perseverance of malaria vectors and therefore, malaria transmission.

2.2 Data collection

Data were collected using a semi-structured questionnaire from two hundred and fifty randomly selected households. Interviews of respondents and observations complimented the information collected via the questionnaire. The information collected from each respondent included among others net ownership, use of mosquito nets and reasons for non-use of ITNs.

2.3 Data analysis

Each questionnaire responses were cross-checked for accuracy and consistency and

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edited accordingly followed by coding. Thereafter, it was analysed using the Statistical Package for Social Sciences (SPSS version 20) were determined.

2.4 Study Permit

Thepermitfor this study was obtained from the Sokoine University of Agriculture (SUA) through students' special project research unit during their final year of study.

3. Results

3.1 Socio-demographic characteristics of respondents

Table 1 summarizes the socio-demographic characteristics of 250 respondents involved in this study.

Table 1: Socio-demographic characteristics of the respondents (n = 250)

Variable		Frequency (n)	Percentage (%)
Respondents Sex	Male	120	48
	Female	130	52
Respondents Age	18-25	65	26
	25-35	108	43
	35-45	77	31
Repondents Education Level	Primary education	35	14
	Secondary education	150	60
	Tertiary education	25	10
	Vocational training	40	16

3.2 Knowledge on malaria

Table 2 below summarizes the results for respondent's knowledge on malaria.

Table 2: Respondent's knowledge on malaria

Variable		Frequency (n)	Percentage (%)
Causative agent of malaria	Mosquito	179	72
	Plasmodium/protozoa	71	28
Transmission of malaria	Mosquito bite	211	84
	Dirty water	30	12
	Don't know	9	4
Symptoms of malaria	Fever	65	26
	Painful joints	103	41
	Sweating at night	8	3
	Vomiting	74	30

3.3 Atittude towards use of ITNs

Table 3 below summarizes the results for respondents toward use of ITNs.

Table 3: Respondents attitude toward utilization of ITNs (n = 250)

Variable		Frequency (n)	Percentage (%)
The ownership and use of ITNs	Do not have nets	23	9
	ITNs	149	60
	Ordinary bed nets	78	31
Reason for non-use of ITNs	Warmth and discomfort	59	24
	Cause skin irritability	42	17
	Financial problems	60	24
	Presence of chemicals	89	36

3.4 Misuse of mosquito nets in rural communities

The studyobserved various ways (including protecting garden vegetables and chickens) in which the members of the surveyed households misused the mosquito nets including ITNs as presented in Plate1.

Plate 1: Protecting ducklets using ITNs.

4. Discussion

Thestudy investigated household factors affecting the use of ITNs for malaria control among rural communities in Morogoro, Tanzania. The results of thestudy showthat the majority(76%) of the respondentsareaware of malaria vectors and that mosquito bites (84%) are important in the transmission of malaria. However, respondents presented varied symptoms of malaria, which ranged from fever, joint pain, sweating and vomiting. These different responses on the symptoms of malaria among the

respondents may be a result of differences in education level and hence, different symptom presentation although the majority of respondents in this study had secondary school education (60%). About91% of the respondents used mosquito nets of which about 60% used ITNs suggesting a good community approval of nets to avoid mosquito bites and offer protection against malaria infection not only among children under five years and pregnant women but also the general community.

Similar to theObol *et al*. (2014) findings elsewhere, this study also found the reasonsfor non-use of nets being avoiding the perceived side effects of chemical substances impregnated in the nets, increased warmth and discomfort, skin irritability, unpleasant odours as well as financial problems. Some respondents informally reported that when they use nets they become vulnerable to bad dreams and suffocation. Some respondents did not use ITNs for associating them with forced family planning, poor pregnancy outcomes and bearing defective babies. The factors for non-use of ITNs in combination with socio-cultural believes may explain the community motive to misuse the nets for malaria control especially ITNs donated by the Government and other donors. To avoid the side effects of the perceived ITNs the rural community use ITNs, among others, to protect vegetable seedling and fence livestock such as chickens. Furthermore, old nets are used to hang washed clothes. Misuse of mosquito nets spares no East African Country (Minakawa *et al*., 2008; Taremwa *et al*., 2017). In order to increase community approval in using ITNs negative community perceptions should be clarified through education. This study also reports financial inadequacy in many households as a barrier in accessing ITNs in the absence of Governmental intervention. Financial problems may also be a barrier for alternative means of malaria control such as use of mosquito repellents. The results of this study are consistent with previous studies, which reported that the cost of ITNs impregnation, regular re-impregnation and the availability of ITNs are determinant factors for use of ITNs in malaria prevention(Ikeako *et al*., 2017; Obol *et al*., 2014).

Conclusion

Thestudy has showntha t a good number of community members in the study area were knowledgeable about malaria transmission. Nonetheless, there are knowledge gaps on the causative agent of malaria. These gaps must be filled by empowering community members with information about malaria causation and prevention strategies so that such knowledge could be passed on to all people. The use of ITNs for malaria prevention among the study area was not quite low though most respondents cited financial costs and presence of chemicals of ITNs as the main reasons for non-use of ITNs among the community members. Owing to the fact that, malaria can be prevented by simple interventions, schools can serve as a gateway to teaching prevention measures that can be carried out by the students for life and shared within the community. Community members need to acquire positive attitudes such as believing that using ITNs is a safe way of preventing mosquito bites. Also at school, students need communicationskills to convince their parents/guardians to obtain ITNs for them, know how to use theITNs effectively, safely treat a net with insecticide and use mosquito repellent or wear protective clothing when an ITN is not available.

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Are Targeted Farm Subsidies Pro-poor?: An Assessment of GESS Input Support program in Kano, Northwest, Nigeria.

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Abstract

Agricultural subsidies that encourage production and productivity have been widely criticized and perceived to be far from reaching the targeted beneficiaries . The aim of this study is to examine the pro-poorness of the newly introduced farm subsidy scheme in Nigeria. We use a cross-sectional survey design to collect data from 40 farming communities in Kano state North West, Nigeria. Benefit incidence analysis (BIA) and ordinary least square (OLS) model was used to estimate the distribution of subsidy benefits base on some selection criteria, to check the effect of fertilizer used on household crop production The benefit incidence analysis results showed that 67% of the subsidized fertilizer was captured by smallest farmers suggesting that the subsidy program was pro-poor and targeting was effective on the basis of accessibility, quantity of fertilizer used gross revenue from maize, farm size but women participation was poor. The result from OLS analysis show that fertilizer is the main driver of production among small farmers but land size, labour and years of the farmer are more significant drivers of production than fertilizer for the larger farmers. A reduction in fertilizer subsidy is, therefore, likely to have adverse impact on fertilizer used ,farm production and income of small and marginal farmers as they do not benefit from higher output prices but do benefit from lower input prices. This paper therefore justifies the use of farm input subsidies in improving production and income of smallholder farmers. The Study concluded that Improving targeting criteria of GESS would enhance smallholders access of farm inputs.

Key words: Pro-poor, Targeted subsidies, Benefit incidence analysis, Kano, GESS

1.0 Introduction

1.1 Background Of The Study

In the last two decades Farm input subsidy programs have once again become popular development programs aimed at increasing agricultural productivity and reduce poverty across Sub-Saharan Africa (Ricker-Gilbert *et al.,* 2011). Farm input subsidy programs were implemented across SSA in 1970s and 1980s but these subsidy programs relied on universal coverage, which was costly and spread benefits beyond target groups and were later abolished . However in the recent time we saw the resurgence of farm input subsidies across Africa . In contrast, current efforts have been rebranded as targeted subsidies because they are said to rely on new institutions and improved implementation strategies that can encourage private sector development and more accurately target intended beneficiaries.

In 2011 the Government of Nigeria launched an innovative mobile technology system of input distribution called Growth Enhancement Support scheme (GESS) to target resource poor farmers with two bags of fertilizer and a bag of improved maize seeds in order to improve their productivity and reduce poverty.. The selection criteria of the GESS subsidy program is based socio-economic characteristics which includes age,

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farm size, phone ownership and place and main occupation and place of residence . The biometric data of each participant was captured by National identification management council (NIMC) and each farmer given an identification number (Electronic -wallet) with which to redeem inputs at any of the redemption centre across the country. The E-wallet entitled farmers to buy subsidised inputs (usually inorganic fertilizer and improved seeds) from participating input retailers at a subsidized price. Targeted subsidies refers to the mechanism of using input vouchers to target rural farmers with key farm inputs and simultaneously create input demand in private in market Hiroyuki and Liverpool Tasie (2013).However there are concerns that under the targeted subsidy programs , subsidized inputs end up in the hands of unintended beneficiaries creating serious doubts on the basis, application, impacts and sustainability of farm input subsidy in Nigeria Kabir,(2014) .

Liverpool-Tasie 2013 found that the focus of the voucher program was to reach farmers and not necessarily the poorest as is often cited as an appropriate targeting criterion in subsidy programs. To the best of researchers knowledge the pro-poorness or equity considerations of targeted farm input subsidies remains largely under researched. Hence this study intends to examine the pro-poorness of GESS farm input program in Kano. This findings will have implication for policy in terms of program transparency, equity and inclusiveness .Whether the new generation of input subsidy programs is indeed more robust against the shortcomings of the past is ultimately an empirical question . This paper explores this question within the context of GESS subsidy. It is first examined the beneficiaries of the input subsidies in practice, which is subsequently compared with whom they should have been going in order to evaluate the targeting performance. Secondly examine the program on the bases of economic principles of efficiency, equity and sustainability. The distributional impacts of the GESS program was also examined focusing on sources of heterogeneity: gender and farm land size, location .. The paper also examined the impact of subsidized fertilizer on input demand in the study area . Generally, the study examines the pro-poorness of GESS Subsidy in the study area.

3.0 Materials and Methods

3.1 Study area and Data Sources

This study was carried out in Kano, North-west Nigeria. It is situated in the Sudano-Sahelian region South of the Sahara suitable for both cereal crop and livestock rearing .Kano lies between 130 and 110 North Latitude and between 8.30 and 100 East Longitude. The state also occupies a land area of 20,706 km2, Kano consists of 44 local government with a population of 11 million (NBS). Kano state was the first state to implement the program in Northern Nigeria with about 3000 registered farmers .The study made use of a cross-sectional household surveys collected from 390 crop farmers in 30 rural communities in Kano. These datasets were supplemented with additional data and information from International fertilizer development centre (IFDC), International fertilizer association (IFA) fertilizer supplies association of Nigeria (FEPSAN) and National Bureau of statistics report. Data on expenditure on fertilizer subsidy were obtained from Kano state Agricultural and Rural Development agency

(KNARDA). A two-stage stratified sampling procedure was employed to select 30 farming communities base on probability proportional to size in the first stage and in the second stage 390 crop farmers were randomly selected and stratified into participants and non-participants. Survey questionnaire was designed and used to gather detailed information on socio-economic characteristics of households, , input use and allocation, crop production , output for maize, and other cereals crops.. In addition, data were collected on the quantity of seed and fertilizer allocated to registered farmers as well as the final quantity collected and the price paid by .the participants of the GES program.

3.2 Method of Data Analysis

3.2.1 Benefit incidence Analysis Approach

This study employed the benefit incidence analysis approach to examine the pattern of fertilizer consumption by quartiles of farm size and the share of subsidy across sex, location, literacy level. The first step is to analyze the net unit costs of providing on subsidy we based it u on officially reported public spending on subsidy. The second step is to analyze the pattern of utilization of the subsidy how many units are utilized by poor households and how many by rich households. We estimated the degree of inequality subsidy by Gini coefficient. In doing this, the fertilizer subsidies used by the farmers were ranked according to their associated farm size and subsidy expenditure. The fertilizer subsidy scheme is considered pro-poor if the concentration index is low. A non-pro-poor subsidy scheme has a high concentration index.

The Gini ratio technique:

The Gini ratio technique was used to estimate the degree of inequality in the distribution of benefit incidence of fertilizer subsidy across the income and per capital consumption quartiles of smallholder farmers as follows.

$$Gini = 1 - \sum_{i=1}^{N} (x_i - x_{i-1})(y_i - y_{i-1}) \quad \ldots\ldots (1)$$

N= Number in quintile or group. i=1 to N over all inequality is related to the percentage of each stratum of farmers in the scheme and the share of each stratum of farmers in the total money value of fertilizer at both household level and group levels. Quartile -level distribution by farm size per quartile:

The value of total government subsidy enjoyed by group i (on number of farmer basis) is given s follows

$$G_i = \sum_{i=1}^{N} \frac{F_i}{X_n} \quad \ldots\ldots (2)$$

Where Gi = benefit incidence for farmer group i, Xi = number of farmers in quartile i buying subsidized fertilizer, Xn ~ total number of farmers in group i, Fi= value of subsidy based on total units of subsidized fertilizer bought by farmers in quartile i. Gi, equity in terms of distribution and to also know if the subsidy is reaching the marginal farmers and to what extent in terms of total fertilizer consumed.

Farmer- or household-level distribution indicator:

On the other hand, the total subsidy spending enjoyed by individuals in terms of units of subsidized fertilizer consumed is:

$$H_i = \sum_{i=1}^{n} \frac{F_i}{F_n} S_i \quad \ldots\ldots (3)$$

Where Hi = benefit incidence for person i, Fi ~ number of units of subsidized fertilizer consumed by farmer i; Fn = total number of units of fertilizer consumed by farmer i; Si = money value of subsidy based on the total units of subsidized fertilizer consumed.

3.2.2 Econometrical approach

We use a simple OLS micro-model to examine effect of fertilizer usage on maize production and the effect of fertilizer subsidy on fertilizer consumption
We Linearised the function as

$$Log(prod)=\alpha+\beta_1 lnQfert+\beta_2 lnsd+\beta_3 lnlsize+\beta_4 lnlcost+\beta_5 lnrainfall+\beta_6 lnedc+\beta_7 lnage+\beta_8 ln msts +\varepsilon i \ldots\ldots (4)$$

Where Quantity of fertilizer used is the fitted value of the regression it becomes

$$Log(Qfert)=\alpha+\beta_1 lnpfert+\beta_2 lnpsds+\beta_3 loglsize+\beta_4 lnpoutput+\beta_5 lnlcost+\beta_6 lnedu+\beta_7 lnage+\beta_8 lnmstat+\beta_9 logarain+ v \ldots\ldots (5)$$

Table 13: Definition of variables used in the model

Variable	Description	Expected value
Log (fertilizer used)	Quantity of fertilizer used in Kg/hectare	
Lsize	Total land area cultivated in hectares	+/_
Lcost	Labor cost in Naira/man-day	+/_
Mrain	Average number of months of rainfall per years	+
Edu	Number years of schooling of household head	+
Age	Number of years of household head	+
Mstatus	Marital status of household head(married=1)	+
Qseeds	Quantity of improved maize seeds used in kg/hectare	+
Pfert	Average price of fertilizer in #	_
Poutput	Average value of crop production	+
Pseeds	Price of seeds in naira	

4.0 Results and Discussion

4.1 Descriptive Statistics of the Respondents

As shown in table 1, about 76.0% of the respondents had farming as their main occupation. The majority of the respondents (82%) were males, while only 18% were females meaning low female participation. The average age of household head was 46 years. This shows that the majority of the respondents were in their active and productive age and this could have a positive influence on maize productivity. The average household size was 12 persons. The average year of residence in the

community is 27 years. We also found that the average years of education of the participants was 13 years ,this is not surprising because the literacy rate in Nigeria is high according to the UNDP 2017 report. About 42 % of the respondent with a household size of 11-15 members meaning that the dependency ratio is likely to be high. So also 82% of the program participants are male with about 31 -40 years of residence in the communities. Similarly findings have been reported by Kemisola *et.al,*,2018, Tesfamicheal et.al,2017 and Mulubrhan *et.al.,* 2017 who examined the impact of farm subsidy programs in different parts of Nigeria.

Table 14: Socio-economic and Demographic characteristics of the respondents

Socio-economic / Demographic characteristics	Frequency	Percentage
Age of the household head		
20-30	25	6.4
31-40	30	7.6
41-50	194	49.7
51-60	81	20.7
>60	60	15.4
Average age of household:46		
Gender of household head		
Male	310	82
Female	80	18
Years of formal education		
1-6	80	20.5
7-12	100	25.6
13-16	164	40.1
>16	46	11.8
Average years of formal education:13years		
Household size		
1-5	50	12.8
6-10	76	19.5
11-15	164	42.0
>15	100	25.6
Average household size :12		
Household main Occupation		75.9
Farming	220	24.1
Non-farming	70	
Years of residence in village		
1-20	68	17.4
21-30	74	19.0
31-40	161	41.3
>40	87	22.3
Average years of residence in village:26.8 years		
Landholding		
1-2 ha	80	20.5
3-5ha	210	53.8
>5ha	100	25.6
Average landholding: 3.56		
Native of Village		
Native	325	83.3

Non-native	65	16.7

4.2 Distribution of subsidy benefits among the respondents

4.2.1 Distribution of Fertilizer Subsidy across Farm Sizes

We computed fertilizer subsidy on per hectare basis as well as share of different farm size groups in total subsidy and the results are presented in Table 2 below .We see an inverse relationship between farm size and average fertilizer subsidy per hectare. Per hectare subsidy on marginal farms doubled compared with large farms. The average subsidy was the highest (#. 397/ha) among small farms and the lowest on large farms (# 271.4/ha). The share of small farmers in total fertilizer subsidy was the highest (25.6 percent), followed by marginal farms (20.5%) and the lowest on large farms (8.8 %).

Table 15: Fertilizer subsidy on different farm size holdings in Kano

Farm size	Subsidy per unit area(#/ha)	Ratio of subsidy to all households	Share in total fertilizer subsidy (%)
Marginal	350.7	134.8	20.6
Small	397.8	107.1	25.4
Medium	299.1	369.1	23.0
Large	271.4	66.4	8.8
All households	408.6	100.0	100

4.2.3 Distribution of Fertilizer Consumption by Farm Size

Table 4 below shows farm size wise consumption of fertilizers in the study area. As it is evident from the Table 4, the share of small and marginal farmers in total land holding was 67.4% , while the share of large farms was 14.8%. The Medium and large holdings had a farm size of more than 5 ha with a share of 32.6 . In contrast, the small and marginal farmers, who has about 67.4% percent of total land holding, consumed 54.5 percent of total fertilizers . On the other hand medium and large farmers, which accounted for 32.6% of operational area, consumed 46.5 percent of total fertilizer used 67.5% of the fertilizer was utilized on marginal holdings while nearly 50.1 % went fertilized on large farms. An inverse relationship between farm size and proportion of fertilized to cropped area was witnessed in the farming season. The intensity of fertilizer use was significantly higher on small and marginal farms compared to large farms (Table 4). The average fertilizer consumption per hectare of total cropped area was the highest (193.4 kg) on marginal holdings and the lowest on large farms (143.1 kg). The quantity of seeds consumed per hectare was also higher marginal and small farms (95kg) than those with medium and large plots (55kg).

Table 16: Pattern of fertilizer consumption by Quantiles of farm size

Distribution (Share) variables	Q1 Marginal(<2ha)	Q2 Small(2-3.5ha)	Q3 Medium(4-5ha)	Q4 (>5ha)	All households
Distribution of holdings	47.1	20.3	17.8	14.8	100
Share in total cropped area	27.6	27.3	28.8	14..3	100
Proportion of fertilizer to total maize cropped area (%)	67.5	56.8	49.0	50.1	55.6
Share in total fertilizer consumption	30.7	23.8	20.9	25.6	100

Fertilizer used intensity					
Consumption per hectare of fertilizer area	193.4	194.6	151.3	143.1	173
Quantity of improved seeds consumed in kg per ha	50	45	25	30	30

Source: Authors calculation

4.3.4 Subsidy spending by farm size

We also estimated the relationship between fertilizer spending captured and the size of cultivated land. The results does not raise equity concerns because the income differences between these farmer groups are striking: the smaller farmers in quartile 1 generated on average gross revenues from production three times greater than the larger crop growers in quintile 4. The total subsidy spending that benefited quartiles 1and 2 was greater than the combined share captured by farmers in quartiles 4, these findings are independent of the assumed market price for fertilizers. Thus, decreasing the market price of fertilizer by 10 percent will further alter the findings on the distribution of benefits and of captured spending by smaller farmers.

We also examined the share of subsidy based on income from crop production .We used the Gini concentration index to examine the share of poor based on quartiles of farm-size (total area cultivated). The results in table 4 shows that, the Gini concentration index was 0.322, meaning that the distribution of crop income across quartiles of farm size was about 54% and 17% among the poorest and richest quartiles respectively, suggesting that the subsidy programme was well targeted and was pro-poor. Similar findings have been reported by Camilo *et.al* 2011 in Indonesia and Stein and Lunduka 2012 in Malawi.

Table 17: Distribution of farmers according to share in crop revenue

Income per capita/month	**Frequency Y**	**Relative frequency**	**Proportion of Households Y**	**Total maize income**	**Proportion of total Maize income**	**Cumulative proportion of Maize income**	**XY**
<20000	92	0.541	0.00541	2100101.87	54.1	54.1	0.29
20001-30000	21	0.124	0.00124	481354.22	12.4	67.5	0.08
30001-40000	12	0.07	0.0007	271732.22	7.0	74.5	0.05
40001-50000	15	0.088	0.00088	341606.21	8.8	83.3	0.07
>50000	30	0.017	0.000176	683212.43	17.6	100.	0.18
TOTAL	170	1.00	1.00	3881888.863	100.		0.68
Gini index	1-$\sum XY$ =1-0.6779 = **0.322**						

4.4 Incidence Analysis for fertilizer by Quartiles of crop Gross Revenue

We grouped farmers according to the size of their crop gross revenues. In the absence of

household income reported in the surveys, we examined whether gross revenues from crop production can be a good proxy for a farmer's income. The benefit incidence analysis by gross revenues from crop production shows a similar picture as the analysis by land size. Benefits captured by the farmers with the highest crop gross revenues stood at 67 percent (in contrast to 65 percent when grouping farmers' by their land size. However, the differences in gross revenues across quartiles were wide and the individuals in quartile 1 and 2 earned 3 times more than those in quartile 4. In the absence of an income variable, there is evidence showing that farmers with small plots and higher gross revenues are better-off. Since farmers in the study area derived more than 50% of their household income we can conclude that gross revenue from crop production is a good proxy for rural income and can be used to classify farmers poorer farmers into lower quartiles and wealthier farmers into lower quartiles income assuming other asset variables are held constant. The results corroborate the findings that there was targeting of subsidized fertilizer benefits and the progressive nature of the fertilizer subsidy. As in the case of the larger farmers' gross crop revenue, an average of 67 percent of farmers report receiving subsidy benefits. This was independent of the size of their gross crop revenues, which suggests that the fertilizer subsidy did target the needy farmers. Francis (2013) also reported that effective targeted of farmers with subsidised inputs in Zambia between 2010 and 2013 might have played a role in the reduction in income inequality between small and large farmers.

Table 18: Crop revenue and fertilizer used by quartile of Land size

Quantile	Value of production(kg/ha)	Fertilizer used(Kg)	Average land size(ha)
1	294000	100	2.5
2	400000	125	2.75
3	180000	110	3.15
4	260000	120	4.58
AVERAGE/TOTAL	**1113900**	**112**	**3.56**

Impact of Fertilizer Consumption on crop production

Having explored the distribution of benefits of the fertilizer subsidy, one question remains unanswered. Has fertilizer usage translated into greater agriculture production in Kano? We suspected that estimating the relationship between fertilizer consumption and value of Production presents a potential endogeneity problem. We perform an F-test and chi-square following the methodologies called the Wu-Hausman and Durbin-Wu-Hausman test respectively. We fail to reject the null hypothesis and conclude that quantity of fertilizer used is exogenous, implying that OLS is a better model than IV-Model in estimating the impact of fertilizer used on maize yield.

We examine the relationship across the overall sample and also within each quartile of land size. Estimating the model linearly shows that a 1 percent increase in fertilizer used use increases value of production by 0.32-0.35% and 0.16% for small and large farms respectively. Similarly, the fertilizer consumption of the bigger farms in quarile 4, mostly reflect the lowest boost in value of production for the sample. This suggests that

other determinants (land size, labor and age of the farmer due to experience) are more significant drivers of production than fertilizer for the larger farmers, and it is not surprising, since large farmers are less credit constrained and have access to better information, other determinants are better able to explain their variation in value of production. Most control variables behave as expected: land size is negatively associated with value of production, while agricultural inputs (labor and seeds) are positively associated; number of extension visits per month though is positive but not significantly related to maize yield. Land size is negatively associated with value of production, as anticipated given that smaller plots are farmed more intensively. Increased labor (including non-wage labor or unpaid family members) is also positively associated with higher maize yields, and this is particularly true in larger farms (quartiles 4), where the effect is greater in magnitude and significance. As expected the findings show that the effect on value of production from using diverse inputs varied between small and larger farmers. Similar findings have been reported in Indonesia by Camilo *et.al*.,2011. The elasticity of land agricultural productivity to person days devoted to agricultural production is about 11%. Similarly, fertilizer use have significantly positive effect on agricultural productivity. These may suggest that adoption of any of the farm management practices may have a significant role in increasing agricultural productivity. Our results are consistent with a number of studies that have demonstrated that input use has substantial effect on the farm productivity (e.g., Janvry and Sadoulet, 2010; Mendola, 2007; Amare *et al*., 2012).

Table 19: The effect of fertilizer used on production in Kano (Dependent variable (Log value of production)

Dependent Variable: value of production(#/ha)	**Overall (1)**	**Quartile 1 (2) ≤ 3ha**	**Quartile 2 (3) 3.1-4.0ha**	**Quartile 3 (4) 4.1-6.0ha**	**Quartile 4 (5) >6ha**
Log fert used	0.3336	0.3523	0.3269	0.3199	0.2006
	(4.89)	(5.26)*	4.54)**	4.28)**	3.77**
Log land size	-0.24832	-0.0685	-0.0472	-0.1029	-0.2004
	(-3.56)***	(-3.27)**	(-2.25)*	(-4.56)**	(-7.59)***
log labour cost	0.229864	0.0561	0.0540	0.0740	0.0760
	(3.51)**	(5.50)**	(4.84)**	5.84)**	(7.24)**
Number of ext visits	0.04358	0.01234	0.0016	0.2400	-0.03
	(1.70)	(-1.95)	(1.68)	(2.10)	(1.67)
Plot dummy(fertile=1)	0.0937	-0.1625	0.1384	-0.096	0.0021
	(-4.49)**	(-4.49)**	(-4.49)**	(4.39)**	(-0.06)
Years of education	-0.0006	0.0034	0.0042	0.0026	0.0003
	(-0.32)	(1.32)	(1.64)	(1.01)	(0.09)
Age	-0.0937	0.0007	-0.0013	0.0019	-0.0014
	(-1.82)	(-1.04)	0.34)	(-2.43)*	(-2.43)*
Price of output	-0.566234	0.1343	1.301	0.109	0.0329
	(7.40)**	(7.29)**	3.37)**	(0.86)	(4.07)**
improved seeds	0.37	0.3000	-0.020	.0003	-0.14
	(3.30)***	(4.56)***	(1.25)	(0.15)	(1.78)
fertilizer price	-0.23767	0.1343	-0.0118	0.1108	-0.0436
	(8.92)***	(6.50)***	(-0.74)	(3.36)***	(3.84)***

Wu-Hausman F-test	**2.901281**	**F(1,01115)**	**P-value =0.119289**
Durbin-Wu-Hausman chi-sq test	**chi-sq(1)**	**P-value= 0.110811**	

NOTE: z statistics in parentheses. Significant at 10%; * significant at 5%; ** significant at 1%. All variables are estimated in natural logarithm

5.0 Conclusion and Recommendation

The results from the benefit incidence analysis shows that distribution of subsidy benefit across farm size, fertilizer consumption per hectare was progressive ,while while total subsidy spending was captured by small farmers, 67 percent of the smallest farmers capture by more than 60 percent of the total quantity of fertilizer purchased and used ,the effect of this policy is therefore said to be progressive fertilizer prices was fairly equitable across farm quartiles. Analysis of farmers on the basis of gross crop revenue, we found that gross crop revenues can be a good proxy for a farmer's income and for classifying farmers into poor and wealthier farmers .While the result of the OLS model show that show that fertilizer is the main driver of production among small farmers but land size, labour and age of the farmers are more significant drivers of production than fertilizer for the larger farmers. A 1% increased in fertilizer used increases yield by 0.32% to 0.35% among small farmers and 0.16% with large farms. The study concluded that GESS subsidy programme is pro-poor in their design and implementation. Targeting is more efficient at raising fertilizer use as smallholders they are less likely to be able to acquire the inputs from the market and deliver more benefits to the farmers. We recommended that any innovation or reform that improves targeting and distribution would assist smaller farmers in making farm inputs available because input usage is a greater determinant of their output. Programme should increase access to modern inputs among poor and vulnerable smallholders (e.g. by giving priority to female headed households).

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Attitudes and Perceived Impact of Insecticide Treated– Bed Nets on Malaria Control in Rural Tanzania

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Abstract

Insecticide-treated nets (ITNs) are the most powerful malaria control tool if used correctly. Yet up to date, utilization is still low. The aim of this study was to investigate the intra-household factors that affect the utilization of ITNs in rural households in MorogoroUrban district. In addition, this study analysed the reasons for ITNs non-use in households with children under five years. Questionnaire, interviews and observation were the key tools for data collection for the study. The intra-household factors affecting the utilization of ITNs reported in this study include, chemical substances impregnated in the nets (36%), household financial inadequacy (24%), warmth and discomfort of the nets (24%) and skin irritability (17%), among others. The general community knowledge about mosquito nets was found to be high (91%); however, the knowledge of ITNs was low (30%). In addition, it was found that the ITNs were inadequately accessible in the study community. Based on the results of this study, adequate accessibility of ITNs and community education related to the use and their significance is recommended.

Key words: Insecticide treated bed-nets; attitude; malaria; Morogoro CBD

1 Introduction

Insecticide-treated nets (ITNs) are the current widely adopted malaria preventive measures in endemic regions (Ikeako *et al*., 2017). ITNs are impregnated with insecticides such as pyrethroid, permethrin or deltamethrin which have an excito-repellent effect and kill the malaria vectors that come in contact with the (Ikeako *et al*., 2017; Kawada *et al*., 2014; WHO, 2015). ITNs have approximately 50% of mean efficiency strategy for combating malaria in endemic regions such as sub-Saharan African countries (Ikeako *et al*., 2017; Obol *et al*., 2014). The ITNs are estimated to reduce children and pregnant women mortality by 60% (Obol *et al*., 2014).

In 2015, approximately 212 million new cases of malaria and 430,000 malaria deaths occurred worldwide, with more than 90% occurring in Africa (Tizifa *et al*., 2018; WHO, 2018).In 2017, children aged under 5 years accounted for 61% (266 000) of all malaria deaths worldwide (WHO, 2018). The disease accounts for 40% of public health, 30-50% of inpatient admission and up to 50% of outpatients visiting in areas with high malaria transmission(WHO, 2015). Tanzania is endemic to malaria and constitutes a major cause of illness and death specifically to children under five years of age and pregnant women(WHO, 2015).Ninety three percent of Tanzanians population live in areas where malaria is transmitted in which 20% unstable seasonal malaria transmission occur in endemic areas and 60% characterized as stable perennial transmission. Tanzania ranked fourth (5%) of the seven countries that accounted for 53% of all global malaria deaths in 2017 (WHO, 2018). The country was preceded by Nigeria (19%), Democratic Republic of the Congo (11%), and Burkina Faso (6%) (Ibid.).There have been efforts to control malaria in Tanzania by both governmental and non-governmental organizations.

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Effective steps to increase the coverage of the use of ITNs to fight malaria transmission are through the National Insecticide Treated Nets (NATNETS) programme. The programme promotes the national use of ITNs by making nets affordable, accessible and acceptable. The fact that uses of ITNs forms the mainstay effective strategy for combating malaria in children under five years and pregnant women, it has never been that smooth to common people.

Furthermore, there is a substantial investment by the Government of Tanzania through private partnership approach to promote usage of ITNs as an integral strategy for control of malaria vectors. The U.S. President's Malaria Initiative (PMI), CDC Tanzania promotes malaria prevention and control interventions, including providing long-lasting insecticide mosquito nets and indoor residual spray; preventing malaria in pregnancy; improving diagnostics and case management; and monitoring and evaluating malaria-related activities. Through these efforts and others, the proportion of households owning at least one ITN rose from 63% to 92% from 2010 to 2011 (Kramer *et al.*, 2017). The use among children under five years in mainland Tanzania increased from 25% in 2008 to 73% in 2012 (Kramer *et al.*, 2017). Despite of the national and international efforts malaria remains among the top 10 causes of death in the country(CDC, 2018).In addition, many household members do not own ITNs and even those who own it do not consistently sleep under the net. The study aimed at assessing attitude and perceptions of insecticide treated nets use on malaria control in rural Tanzania.

2. Material and Methods

2.1 Study area

The study was conducted in Kasanga and Kiroka wards in Morogoro rural district and Lukobe ward in Morogoro urban district in Morogoro region. Morogoro region is located between latitude 5° 58" and 10°0"S of the Equator and longitude 35° 25" and 35°30"E.The region is bordered by Arushaand Tanga regions to the North, the Coast region to the East, Dodoma and Iringa to the West, and Ruvuma and Lindi to theSouth.The elevation of the study areas is about 196m above sea level. Farming is the main occupation of the population. The topography and climate together with human activities in the area highly encourage healthy perseverance of malaria vectors and therefore, malaria transmission.

2.2 Data collection

Data were collected using a semi-structured questionnaire from two hundred and fifty randomly selected households. Interviews of respondents and observations complimented the information collected via the questionnaire. The information collected from each respondent included among others net ownership, use of mosquito nets and reasons for non-use of ITNs.

2.3 Data analysis

Each questionnaire responses were cross-checked for accuracy and consistency and edited accordingly followed by coding. Thereafter, it was analysed using the Statistical

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Package for Social Sciences (SPSS version 20) were determined.

2.4 Study Permit

The permitfor this study was obtained from the Sokoine University of Agriculture (SUA) through students' special project research unit during their final year of study.

3. Results

3.1 Socio-demographic characteristics of respondents

Table 1 summarizes the socio-demographic characteristics of 250 respondents involved in this study.

Table 1: Socio-demographic characteristics of the respondents (n = 250)

Variable		Frequency (n)	Percentage (%)
Respondents Sex	Male	120	48
	Female	130	52
Respondents Age	18-25	65	26
	25-35	108	43
	35-45	77	31
Repondents Education Level	Primary education	35	14
	Secondary education	150	60
	Tertiary education	25	10
	Vocational training	40	16

3.2 Knowledge on malaria

Table 2 below summarizes the results for respondent's knowledge on malaria.

Table 2: Respondent's knowledge on malaria

Variable		Frequency (n)	Percentage (%)
Causative agent of malaria	Mosquito	179	72
	Plasmodium/protozoa	71	28
Transmission of malaria	Mosquito bite	211	84
	Dirty water	30	12
	Don't know	9	4
Symptoms of malaria	Fever	65	26
	Painful joints	103	41
	Sweating at night	8	3
	Vomiting	74	30

3.3 Atittude towards use of ITNs

Table 3 below summarizes the results for respondents toward use of ITNs.

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Table 3: Respondents attitude toward utilization of ITNs (n = 250)

Variable		Frequency (n)	Percentage (%)
The ownership and use of ITNs	Do not have nets	23	9
	ITNs	149	60
	Ordinary bed nets	78	31
Reason for non-use of ITNs	Warmth and discomfort	59	24
	Cause skin irritability	42	17
	Financial problems	60	24
	Presence of chemicals	89	36

3.4 Misuse of mosquito nets in rural communities

The study observed various ways (including protecting garden vegetables and chickens) in which the members of the surveyed households misused the mosquito nets including ITNs as presented in Plate 1.

Plate 1: Protecting ducklets using ITNs.

4. Discussion

The study investigated household factors affecting the use of ITNs for malaria control among rural communities in Morogoro, Tanzania. The results of the study show that the majority (76%) of the respondentsare aware of malaria vectors and that mosquito bites (84%) are important in the transmission of malaria. However, respondents presented varied symptoms of malaria, which ranged from fever, joint pain, sweating and vomiting. These different responses on the symptoms of malaria among the respondents may be a result of differences in education level and hence, different symptom presentation although the majority of respondents in this study had secondary school education (60%). About91% of the respondents used mosquito nets of which about 60% used ITNs suggesting a good community approval of nets to avoid mosquito bites and offer protection against malaria infection not only among children under five years and pregnant women but also the general community.

Similar to theObol *et al*. (2014) findings elsewhere, this study also found the reasons for non-use of nets being avoiding the perceived side effects of chemical substances impregnated in the nets, increased warmth and discomfort, skin irritability, unpleasant odours as well as financial problems. Some respondents informally reported that when they use nets they become vulnerable to bad dreams and suffocation. Some respondents did not use ITNs for associating them with forced family planning, poor pregnancy outcomes and bearing defective babies. The factors for non-use of ITNs in combination with socio-cultural believes may explain the community motive to misuse the nets for malaria control especially ITNs donated by the Government and other donors. To avoid the side effects of the perceived ITNs the rural community use ITNs, among others, to protect vegetable seedling and fence livestock such as chickens. Furthermore, old nets are used to hang washed clothes. Misuse of mosquito nets spares no East African Country (Minakawa *et al*., 2008; Taremwa *et al*., 2017). In order to increase community approval in using ITNs negative community perceptions should be clarified through education. This study also reports financial inadequacy in many households as a barrier in accessing ITNs in the absence of Governmental intervention. Financial problems may also be a barrier for alternative means of malaria control such as use of mosquito repellents. The results of this study are consistent with previous studies, which reported that the cost of ITNs impregnation, regular re-impregnation and the availability of ITNs are determinant factors for use of ITNs in malaria prevention(Ikeako *et al*., 2017; Obol *et al*., 2014).

Conclusion

The study has shown that a good number of community members in the study area were knowledgeable about malaria transmission. Nonetheless, there are knowledge gaps on the causative agent of malaria. These gaps must be filled by empowering community members with information about malaria causation and prevention strategies so that such knowledge could be passed on to all people. The use of ITNs for malaria prevention among the study area was not quite low though most respondents cited financial costs and presence of chemicals of ITNs as the main reasons for non-use of ITNs among the community members. Owing to the fact that, malaria can be

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prevented by simple interventions, schools can serve as a gateway to teaching prevention measures that can be carried out by the students for life and shared within the community. Community members need to acquire positive attitudes such as believing that using ITNs is a safe way of preventing mosquito bites. Also at school, students need communication skills to convince their parents/guardians to obtain ITNs for them, know how to use the ITNs effectively, safely treat a net with insecticide and use mosquito repellent or wear protective clothing when an ITN is not available.

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Natural Antioxidants from Clove for Protecting Omega-3 Fatty Acids in Sardines (*Rastrineobola argentea*) during DeepF Process

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Abstract

Sardines (Rastrineobola argentea), popularly known as "dagaa" is one of the leading commercial fish species of Lake Victoria. The fatty fish species are attracting great attention because they are good source ofomega-3 polyunsaturated fatty acidswhich are vital for a wide range of biological functions and are implicated in the prevention of numerous diseases. While nutritionally valuedomega-3 fatty acids are highly susceptible to oxidation during fish processing due to their unsaturated nature. Oxidation reactions result in loss of omega-3 fatty acids and production of undesired off-flavours which discourage consumption and limit diversification of sardine products.Synthetic antioxidants may be used to prevent lipid oxidation but have been claimed to becarcinogenic at higher levels. The replacement of synthetic antioxidants with ones of natural origin is now in demand. In this study, natural antioxidants rich extracts from clove buds were applied on sardines in a bid to impede lipid oxidation during deep frying process.Lipid oxidation was assessed by peroxide value (PV), volatile compoundsand fatty acid profilesusingGas chromatograph (GC-MS and GC-FID).The results showed that natural antioxidants from clove buds reduced peroxidation and protected highly unsaturated omega-3 fatty acids from oxidation during deep frying process.Total polyunsaturated fatty acids amounted 7.30 % in pre-treated deep fried sardines.Retention of omega-3 fatty acids was 0.70 % more in pre-treated than untreated fish. Significantly lower amounts of representative volatile compoundswere produced in sardines pre-treated with clove extracts. The study demonstrated feasibility to pre-treat sardines with natural antioxidants for protecting omega-3 fatty acids against oxidation during deep frying.

Key words: Omega-3 fatty acids, natural antioxidants, lipid oxidation, *dagaa*, Lake Victoria

1 Introduction

Sardines (*Rastrieobolaargentea*), popularly *dagaa* in Tanzania, aretiny, fatty freshwater fish species of commercial importance in Lake Victoria. The species provide 72.30 % of the total landings by weighton the Tanzanian side of the Lake (URT, 2015).Their proximate composition varies due to environmental factors including the change of seasons and the resultant change of food supply in the Lake(Kilema-Mukasa, 2012;Abdulkarim*et al.*, 2016). Sardinesare attracting great attention because they are good source ofpolyunsaturated fatty acids (PUFAs) including omega-3 which are vital

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for a wide range of biological functions. Omega-3 fatty acids are implicated in the prevention of numerous diseases such as cardiovascular diseases, inflammation, high blood pressure, atherosclerosis, thrombogenesis, cancer, skin diseases and are necessary for the brain development in fetuses(Finley *et al*., 2001;Sidhu, 2003; Minhane *et al*., 2008; Gladyshev *et al.*, 2012).

Sardines are perceived negatively and considered as an inferior food for poor and pro-poor communities despite its economic and nutritional values. This may be attributed to poor handling and processing technologies along the sardine value chain. Roberts *et al.*, (2014) found that*dagaa*is richerin omega-3 fatty acids than *Oreochromisniloticus*, *Tillapia zilliii*and *Latesniloticus* of Lake Victoria. Sun dried and fresh *dagaa*are reported to contain 18.50 to 20.88 % and 13.5 to 21.2 % omega-3 fatty acids respectively (Mwanja*et al.,* 2010; Masa *et al*., 2011;Chaula *et al*., 2019).

*Dagaa*can be preserved by open sun drying, smokingand deep frying processes. The traditional open sun drying of *dagaa* has significant effect on the composition and hence quality of the dried product.Owaga*et al.*(2010) reported a significant decrease in total fat content(from 14.8 to 13.9 %) of *dagaa* after sun drying.Open sun drying process promotes lipid oxidation and in some instances the production of secondary lipid oxidation products in sun dried sardines exceeds acceptable levels with regard to development of off-flavour (Chaula *et al*., 2019). Off-flavours emanating from lipid oxidation discourage consumption and limit diversification of sun dried *dagaa* products. Deep frying has emerged as an important sardine value addition process. Deep frying involves immersion of sardines in hot oil, typically at temperatures ranging from 165 to 195 °C. At such high temperatures, frying oils and lipids in fish undergo chemical reactions including oxidation, polymerization and decomposition, resulting in off-flavours, nutritional loss and other deteriorative changes (Naz *et al*., 2004; Secci*et al*., 2016).Lipid fraction of deep friedsardinescontains significantly lower amounts (16.56 and 8.46 %)than sun dried (29.29 and 20.88 %) of PUFAs and omega-3 fatty acids respectivelyindicative of oxidative damage of PUFAs during deep frying process (Chaula *et al*. 2019).

Commercially available synthetic compounds such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), and *tert*-butylhydroquinone (TBHQ) are known to be strong antioxidants. However, different regulatory authorities such as the United States Food and Drug Administration (FDA), the European Food Safety Authority (EFSA), and the World Food and Agricultural organization (FAO) have placed limits on the amount of synthetic antioxidants allowed for use in foods typically to levels at or below 200 ppm, due to their potential toxicity (Ito *et al*., 1986; Zheng and Wang, 2001). Such relatively low concentrations allowed do not provide sufficient protection against oxidative damageof PUFAs under frying conditions.Due to safety concerns and increased consumer interest in natural products,nontoxic natural antioxidants of plant origin could potentially be used at higher concentrations than 200 ppm for better protection of PUFAsduring frying process.Therefore, the development of strong antioxidants that suppress oxidation and protect the nutritional quality of highly reactive PUFAs is now in demand. In this study, natural antioxidants rich clove (*Szygium*

*aromaticum)*extracts were applied on sardines in a bid to impede lipid oxidation during deep frying process.

3.0 Materials and methods

3.1 Materials

Fresh whole *dagaa*(25Kg) were collected directly from fishermen at Kijiweni landing site at the shore of Lake Victoria, Tanzania placed in ice in insulated boxes and transported to the National Fish Quality Control Laboratory, Nyegezi, Mwanza for experiment. Dry clove*(Szygium aromaticum*) buds were obtained from a local market in Zanzibar, transported at ambient temperature to Mwanza and kept at 5 to 10°C in a refrigerator.

3.1.1 Preparation of clove water extracts

For water extraction, 5, 10 and 20 g grounded powder(to pass through a 250µm sieve) of clove buds were mixed with 1 L boiling water with continuous stirring to make 5, 10 and 20 g L^{-1} concentrations of extracts.Themixtures were boiled for 15 min and subsequentlycooled to0-5 °C in a refrigerator thereafter gravity filteredto remove the particles present.

3.1.2 Preparation of deep fried *dagaa*

Fresh *dagaa* intended for deep frying were washed with portable water thensoaked in clove extracts (1:1 *w/w*) for 40 min and spread on wire mesh to drip dry in open sun for three hours, thereafter deep fried in hot sunflower oil at 135-180 °C for 5 minutes. Fish samples without clove pre-treatment were prepared in similar way and used as control. Each treatment experiment consisted of four replicates. For each treatment experiment 100 g portion of whole fish was made into mince using a mixer (MoulinexMoulinette S type 643 02 210, Hamburg, Germany).The fish mince was then stored at -40°C awaiting analysis.

3.2 Methods

3.2.1 Dry matter content and lipid extraction

The dry matter content for fish samples was determined by weighing after drying a sample of approximately 2 g of homogeneous fish mince at 105 °C for 18 h according to the AOAC (2012) and results expressed as a percentage dry matter.

Lipids were extracted following the Bligh and Dyer method (1959) with modifications according to Iverson *et al*., 2001. The sample (5 g of fish mince) was homogenized in chloroform, methanol, and water mixture (1:1:0.8 v/v) at the speed of 15,000 rpm for 90 sec using an Ultra Turrax homogenizer (T25 Homogenizer, Staufen, German).The homogenate was centrifuged at 2,800 rpm at 18°C for 10 min using a centrifuge (Sigma 4K15, Osterode am Harz, German) to obtain the extract (Chloroform phase).The lipid content was determined by gravimetry after evaporation of chloroform and expressed as percentage of dried fish sample

3.2.2 Primary and secondary lipid oxidation products

Peroxide values (PV) of the lipid extracts were determined according to the method of Shantha and Decker (1994) based on the formation of an iron−thiocyanate complex. The colored complex was measured by spectrophotometer (Shimadzu UV1800, Shimadzu Scientific Instruments,Columbia,MD) at 500 nm. The analysis was done in duplicate, and the results were expressed in millequivalent peroxides/Kg oil (meq O_2/Kg oil).

The secondary oxidation products were determined as volatile compounds from fish mincecollected using the dynamic headspace technique. The procedure was carried out using 1 g of fish mincein which 30 mg of internal standard, 4-methyl-1-pentanol were added and mixed with 15 mL of distilled water. The volatiles were collected in Tenax GR tubes at 37 °C by purging withnitrogen for 30 min at 150 mL/min. The tubes were flushedwith nitrogen at 50 mL/min for 20 min to remove water. The trapped volatiles were desorbed from theTenax tubes by heat (200 °C) using an automatic thermal desorber(ATD-400, PerkinElmer, Norwalk, CT), cryofocused on a cold trap(−30 °C), released again at 220 °C, and led to a GC an Agilent 5890IIA model (Palo Alto, CA, USA) equipped with a HP 5972 massselective detector.Separation was done on a DB1701 column (30 m × ID 0.25 mm × 0.5µmfilm thickness, (J&W Scientific, Folsom, CA).The carrier gas used washelium atflow rate of 1.3 mL/min. The oven temperature was rising by 2.0 °C/min from initial temperature of 45 °Cto80 °C followed by an increase of 3.0 °C/min to 150 °C and finally increased by 12.0 °C/min to 240 °C. The individual compounds were identified by MS-library searches and addition of the internal standard. Quantification was done through calibration curve made by adding the standard directly on the Tenax tubes as described by Nielsen *et al*. (2007). For the quantification, a stock solution of 19 volatiles was prepared and a calibration curve was conducted in a range from 0 to 1.2 mg/g. The analysis was carried out in triplicate.

3.2.3 Free fatty acids and fatty acid profiles

Free fatty acids (FFAs) content was determined by acidometric titration of the lipid extract using NaOH (0.1 M). The FFAs content was calculated as oleic acid according to the AOCS (1998) and results were reported as % oleic acid.

The fatty acid profiles of deep fried sardines were determined as fatty acid methyl esters (FAMEs)according to the American Oil Chemists' Society (AOCS) officialmethod; Ce 1i-07 (AOCS, 2009).1g of oil extract was evaporatedto dryness under nitrogen.Thereafter, 100µL of internal standard solution (2% w/v C23:0in heptane), 200 µL of heptanes, 100 µL of toluene and 1 mL of boron trifluoride in methanol (BF3-MeOH) were added.Methylation was done in microwave oven (Microwave 3000 SOLV, Anton Paar) for 10 min at 100°C and 500Wand cooled down for 5 min. 1 mL of saturated salt water (NaCl)and 0.7 mL of heptane with BHT were added. The upper phase of thesample (around 0.7 mL) was transferred into vials. Samples were analyzed by gas chromatographysystem (HP-5890 A, Agilent Technologies, Santa Clara, CA, USA). FAMEswereseparated and detected by the GC column Agilent DB-wax (10 m x100µ m x 0.1µm), from Agilent Technologies (CA, USA). The carrier gas was helium with a flow rate of 0.38 mL/min and an inlet pressure of 51psi. The oven temperature

program for separation was from 160 to 200°C, then from 200 to 220°C and from 220 to 240°C at 10.6°C /min. All analyses were done in duplicate. The result of each fatty acid was expressed as g fatty acid/100 g lipid.

3.2.4 Antioxidant activity of clove water extracts

3.2.4.1 Total phenolic content

The total phenolic compounds of the extracts were determined using Folin–Ciocalteu reagent by a procedure described by Farvin and Jacobsen (2013) in which gallic acid was used as a standard. The standard curve was prepared in distilled water at a concentration range of 0–125 µg/mL. The original extracts were diluted with water as necessary to fit within the standardcurve. The absorbance was read at 725 nm using UV-vis spectrophotometer and resultsreported in µggallic acid equivalent (µg GAE)/mL ofclove water extracts. All measurements were performed in duplicate.

3.2.4.2 Free radical scavenging ability

The free radical scavenging activities of clove water extracts were measured by utilizing the stable radical, 1,1-diphenyl-2-picryl-hydrazil (DPPH) as described by Yang *et al.*, 2008. The solutions of prepared extracts were diluted with water *(*1:1 *v/v)*.Diluted solutions (100µL) were added to the microplate and mixed with 100µL of 0.1 mM DPPH in ethanol (96%). The mixtures wereshaken vigorously and maintained for 30 min at ambient temperature in the dark. Theabsorbance of mixtures and the control (100µL DPPH solution + 100µL BHT)was measured at 517 nm against a reagent blank by using a UV–Visspectrophotometer. The scavenging activity was calculatedas inhibition percent by using thefollowing equation:

$$\text{Inhibition } (\%) = \left[1 - \frac{A_s - A_b}{A_0}\right]$$

Where A_s is the absorbance of DPPH after reaction with antioxidant, A_0 is the absorbance of antioxidant and ethanol (blank) and A_b is the absorbance of water and DPPH (blind).

3.2.4.3 Iron (Fe^{2+}) chelatingability

The ferrous ion chelating activity of clove extracts was measured as described by Farvin *et al*. (2010) with 20 µL of 0.5 mM ferrous chloride and 20µL of 2.5 mM ferrozin being

mixed with 100 µL of clove extracts. The mixture was allowed to equilibrate in the darkness at room temperature for 10 min before measuring the absorbance. The decrease in the absorbance at 562 nm of the iron (II)-ferrozin complex was measured. EDTA was used as the positive control and the ability of the extracts tochelate $Fe^{2+}$was calculated using theequation:

$$Fe^{2+}\text{ chelating activity} = \left(\frac{A_{blank} - (A_{sample} - A_{blind})}{A_{blank}}\right) \times 100$$

A_{blank} is the absorbance of blank (only iron chloride and Ferrozin), A_{sample} is the absorbance of sample and $A_{blind}$is the absorbance of blind(only antioxidant).

4.0 Statistical analysis

Data were analyzed using IBM SPSS (SPSS for Windows Version 20.0, 2013, IBM, Bethesda, MD, USA). Data were reported as mean ± standard deviation. Differences between means were determined using one-way analysis of variance (one-way ANOVA) with Tukey's HSD post hoc test, according to the equal variance of different groups. The correlations among variables were determined using a two tailed Pearson correlation coefficient. A p-value <0.05 was considered statistically significant.

5.0 Results and Discussion

5.1 Antioxidant activity of clove water extracts

The clove water extracts analyzed in this study had total phenolic content levels in the range from 18.18 -28.75 µgGAE/mL (Table 1). As expected the 20 g L^{-1} extracts had significantly higher total phenolic content than that of 5 and 10 g L^{-1}.The total phenolic content did not increase linearly with the amount of dry clove extracted in 1 L of water. This suggests that longer time periods might be needed for efficient extraction of phenolic compounds when larger amounts of clove powder are used. The recovery of phenolic compounds from plant matrices during aqueous extraction is known to depend on factors such as temperature, extraction time and solvent to solid ratio (Çam and Aaby, 2010). The ability of clove extracts to donate hydrogen to the DPPH radical, ranged from 93 to 95 % .This could be due to higher phenolic content in clove extracts.There was no linear relationship between total phenolic content and DPPH suggesting presence of compounds other than phenolics (e.g flavonoids) that contributed to the antioxidant activity of clove extract.

Table 1: Antioxidant capacity of clove water extracts

Extracts (g/L)	Total phenolic content (µgGAE/mL)	DPPH scavenging (% inhibition)	Fe^{2+} chelating activity (%)
CL 5	18.18^{a} ± 1.29	93.33^{g} ± 0.21	14.74^{p} ± 0.21
CL 10	25.94^{b} ± 2.62	95.59^{h} ± 1.44	20.87^{q} ± 0.43
CL 20	28.75^{c} ± 1.35	94.34^{i} ± 0.38	22.24^{r} ± 0.32

CL: Clove, GAE: Gallic acid,5,10 and 20:Grams of clove extracted in 1 L water. Means marked with different letters in a column are statistically significant.

The DPPH decreased from 95.59 to 94.34 % when the amounts of clove extracted in one litre of hot water was increased from 10 to 20 g .This could be due to decrease in extraction efficiency of phenolics in boiling water at concentration above 10 g/L (Slavin

et al., 2016). Clove water extract has been found to contain substantial amounts of phenolic compounds and powerful antioxidant activity in linoleic acid emulsion with itsiron chelating capacity beingdependant on concentration and type of solvent used (Gülçin *et al.,* 2004). Essential oils of clove have been tested in omega-6 and omega-3 fatty acids enriched food supplements and found to have high radical scavenging activity, iron-chelating properties and higher hydrogen donating power than the standard antioxidants BHT and α-tocopherol (Bag & Chattopadhyay, 2017).

5.2 Fat, free fatty acids and dry matter content

The dry matter content of clove was 86.40 % and there was no significant difference in mean dry matter content of treated and untreated sardines (Table 2). Fat content in the samples ranged from 39.42 to 41.69 %. Such high fat content in deep fried sardines is because during the process oils tend to replace water in the product and thus, there is a correlation between initial water content and oil uptake(Dana and Saguy, 2006).Free fatty acids in all samples were less than 1% suggesting limited lipolysis because Lipolytic enzymes might have been inactivated at high temperatures during deep frying process.

Table 2: Fat, free fatty acids and dry matter content in deep fried (DCL) sardines pre-treated with clove water extracts

Sample	Fat content (%)	Free fatty acids (%)	Dry matter (%)
DCL 0	$39.99^{e} \pm 0.36$	$0.48^{f} \pm 0.09$	$92.33^{h} \pm 1.13$
DCL 5	$41.69^{e} \pm 0.89$	$0.87^{g} \pm 0.06$	$89.78^{h} \pm 4.90$
DCL 10	$39.42^{e} \pm 0.04$	$0.15^{i} \pm 0.01$	$90.93^{h} \pm 0.10$
DCL 20	$39.95^{e} \pm 0.15$	$0.18^{i} \pm 0.02$	$90.68^{h} \pm 1.60$

5,10 and 20:Grams of clove extracted in 1 L water. Means marked with different letters in a column are statistically significant

5.3 Primary and secondary lipid oxidation products

The peroxide value(PV) and the volatiles analyses were used to determine the primary and secondary lipid oxidation products in pre-treated fish and the control sardine samples. From

Figure 1, it can be seen that peroxidation was more pronounced untreated than pre-treated deep fried sardines. The control sampleshad significantly higher peroxide values and concentrations of most ofrepresentative volatile compoundsthan the clove pre-treated samples (Figure 1&2).The peroxide values and the concentrations of volatile secondary oxidation products among clove treated samples decreased as the amount of clove extracted in 1 L of water increased indicating the effect of extract concentration on lipid oxidation.Soaking sardines in 5, 10 and 20 gL^{-1} clove water extracts for 40 min prior to deep frying resulted in respectively21.20, 10.70 and 11.20 % reduction of peroxide values in products relative to the control samples.

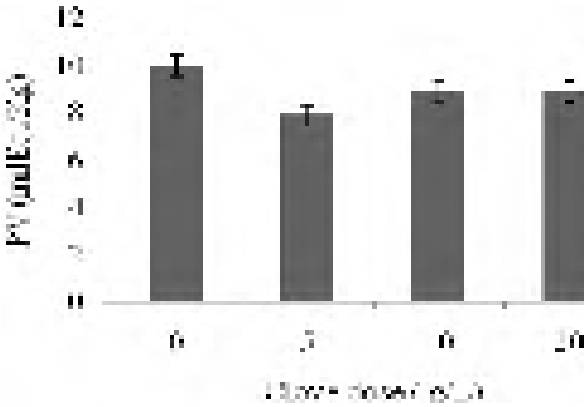

Figure 1: Peroxide value(PV) in deep fried sardines pre treated with different doses of clove extracts.

The pre-treatments resulted into remarkable decrease in concentrations of individual volatile compounds, including 4-heptanal and t, t-2, 4-heptadienal (Figure 2) which are recognized as decomposition products of EPA and DHA (Venkateshwarlu*et al*., 2004).These observations indicate that lipid oxidation reactions were more pronounced in untreated than in clove treated sardines. The peroxide value reduction and lower concentrations of volatile compounds in clove treated samples suggest that phenolic compounds in the extracts played an anti-oxidative role during processing.The anti-oxidative effect of phenolic compounds can be through different mechanisms such as scavenging of free radicals, singlet oxygen quenching, oxygen scavenging, metal chelation and inhibition of oxidizing enzymes (Shobana and Akhilender, 2000; Dudonné *et al*., 2009).The use of whole spices and herbs or their extracts with strong antioxidant activity (Gachkar *et al*. 2007) can control lipid oxidation in muscle food such as mullet fish, frozen chub mackerel and smoked rainbow trout (Emir Çoban *et al*. 2014). Clove essential oils have been applied in smoked and vacuum packed rainbow trout (*Oncorhynchus mykiss*) during refrigerated storage (at 2° C)resulting in reduction of peroxide values(Emir Çoban and Patir, 2013).

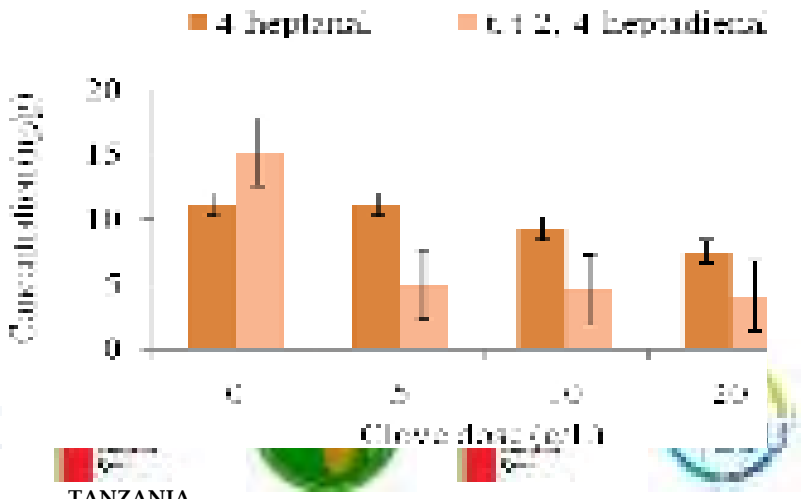

Figure 2: Concentration of representative volatile compounds in deep fried sardines pre-treated with different doses of clove extracts

5.4 Polyunsaturated fatty acids

Lipid fractions of untreated sardines, contained significantly lower amounts (P<0.05) of PUFAs(6.95 %) than those from sardines pre-treated with clove extracts with 7.03- 7.61 % PUFAs (Figure 3). Clove pre-treatment prior to deep frying processes resulted into 0.67 %more retention of total omega-3 fatty acids in the final products relative to untreated fish. With respect to individual omega-3 fatty acids pre-treated samples had significantly higher content of DHA, 2.96 – 3.12 % in pre-treated deep fried than the control (untreated) which had 7 2.77 %ofDHA.

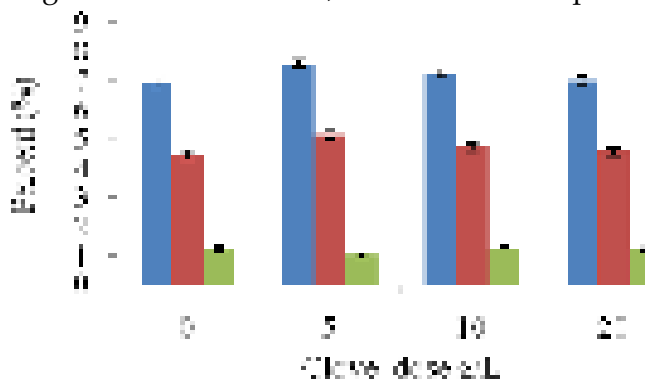

Figure 3: Fatty acid profiles in deep fried sardine pre-treated with different doses of clove extracts. PUFAs; polyunsaturated fatty acids

Higher proportions of DHA and total PUFAs in lipid fractions of treated sardines are evidences that natural antioxidants in clove extracts exert protective effect against lipid oxidation during deep frying process.

Clove has been reported to have high phenolic content and antioxidant components with high thermal stability (Shobana and Akhilender, 2000; Shan *et al*., 2005). The use of spices like clove as natural antioxidant to protect lipids in meat and fish oil has been demonstrated (Falowo *et al*., 2014; Shah *et al*., 2014). Improved retention of long chain polyunsaturated fats and preservation of omega-3 fatty acids in oven dried sardine (R.argentae) pre-treated with clove water extracts has also been shown (Slavin *et al*., 2016).Water extracts of clove are also reported to have as strong peroxidation inhibitory effect as ethanol extract in linoleic acid emulsion (Gülçin *et al*., 2004).The antioxidant activity of clove extracts may be attributed to strong hydrogen donating ability, metal chelating ability, and effectiveness as free radicals scavenger. The major phenolic compounds in clove are phenolic acids such as flavonol glucosides, phenolic volatile oils and tannins, recovery of which is highly dependent on extraction conditions, differences in solvent and extraction method (Wu *et al*., 2004; Shan *et al*., 2005; Dudonné

et al., 2009).

6.0 Conclusion and recommendations

The present study evaluated the efficacy of clove water extracts to retard lipid oxidation during deep frying of sardines. Pre-treatment of sardine with clove water extracts resulted in improved retention of nutritionally valued long chain PUFAs, including the omega-3 fatty acids DHA.However, the success of these pre-treatments to impede lipid oxidation may partly be attributed to small size and weight of sardine fish.Further researches on other sources of antioxidants from edible plant sources are needed. The researches should include investigation on the effects of natural antioxidants applications on sensory attributes of pre treated sardines. The information would be of interest during sardine product diversification through its incorporation into other food product formulation at industrial scale.

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Contribution of Brucellosis to Abortions in Humans and Domestic Ruminants in Kagera Ecosystem, Tanzania.

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Abstract

Brucellosis is aworldwide zoonotic disease with socio-economic importance. Understanding the association of this disease with pregnancy outcome has potential to reduce its reproductive burden in humans and animals among pastoral communities in Tanzania. A prospective cohort study was conducted in Kagera Region onpregnant women (n=76) and gravid ruminants (121 cattle, 125 goats and 111 sheep). Group at risk of exposure and group not at risk of exposure to brucellosis were followed for six months (November 2017- April 2018). Sera were collected after normal delivery or after abortions and were analyzed using Rose Bengal Test (RBT) and Fluorescence Polarization Assay (FPA) test.Measures of effect and logistic regression analysis were computed. Seropositivity to both RBT and FPA tests was 21% (95% CI: 12.5-32) in women and 5% (95% CI: 3.1-8) in ruminants. In aborted cases, the seroprevalence was 44.5% (95% CI: 13.7-78.8) in humans and 28.6% (95% CI: 3.7-71) in cattle; 7.7% (95% CI: 0.9-25.1) in goats and 0% (95% CI: 0.0-28.4) in sheep. Abortion rate in womenwas11.8% and 12.3% in ruminants.Seropositivity to brucellosis was similar in aborted and non-aborted cases in humans (p=0.08) and in ruminants p=0.2). The population attributable risk (PAR) of abortion due to brucellosis was 3.5% in women and 0.5% inruminants.Infections to brucellosis were increased in pregnant womenat risk of exposure to brucellosis (OR=19; 95% CI: 1.8-203, p=0.01) and in cattle (OR=11; 95% CI: 1.3-8, p=0.02).However, absence of malaria like symptoms in pregnant women (OR=0.12; 95% CI: 0.0-1.2, p=0.07) and the good disposal of aborted materialsin gravid ruminants (OR=0.2; 95% CI: 0.0-1.1, p=0.06) were protective for Brucella infections.Brucellosis could be contributing to abortions in humans and domestic ruminants in Kagera. Control of the disease in animals is likely to reduce the threat of abortions in humans.

Keys words: Association, Brucellosis, Spontaneous Abortions, Tanzania.

1 Introduction

Brucellosis is a zoonotic disease which remains a major problem in the Mediterranean region, Western Asia, parts of Africa and Latin America (Corbel, 1997).Human infectionsare acquired through contact, ingestion, or inhalation of organisms from infected animals, principally cattle, goats, and sheep. The sources of infection for animals include aborted materials, vaginal discharges, milk and semen from infected animals. In livestock, brucellosis results in reduced productivity, abortions and weak offsprings. Moreover, *Brucella* species occasionally cause spontaneous human abortions, but theories regarding whether they do so more frequently than do other infectious

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pathogens, remain controversial(Khan *et al.,* 2001; Kurdoglu *et al.,* 2015). In addition, there is limited information about the contribution of brucellosis to abortions in humans and livestock in Africa in general(Ntirandekura *et al.*, 2018) and Tanzania in particular.There are some reports on abortions in domestic animals in Tanzania: 11.3% in Njombe and MbeyaRegions (Mathew *et al*, 2017) and 35% in wildlife- livestock interface and non-interface of Tanzania(Mdetele *et al.,* 2015).In addition, non-negligible pregnancy outcomesin humans (15% of miscarriage at national level) were reported in Tanzania(Keogh *et al.,* 2015).The causes of abortions in humans and domestic animals include infectious disease agents such as *Brucellaspp, Toxoplasma andNeospora*, others are non-infectiouscauses which include genetic, environmental and immunologic causes. In the livestock industry, the economic impact of brucellosis is mainly attributed to abortions which mostly occur during the last trimester periodof pregnancy in animals. In humans, abortions due to brucellosis are mostly recorded in the first and second trimester period of pregnancy(Khan *et al.*, 2001).Brucellosis has been reported in different areas of Tanzania(Kunda *et al.,* 2007;Swai & Schoonman, 2009; Bouley *et al.*, 2012; Assenga *et al.*, 2015; Kassuku, 2017; Asakura *et al.,* 2018; Sagamiko *et al.*, 2018); however, the contribution of this disease to the recorded abortions indiverse species remains to be appraised. Brucellosis was reported previously in Karagwe district and its prevalence seemed to have enhanced the transmission risk of the disease in traditional herds (Kiputa *et al.,* 2008). Due to thesocio-economic importance of brucellosis(abortions, infertilities and reduction of milk production) this zoonoticdisease, in Kagera ecosystem, calls for a research attention.Furthermore, it is unclear how the population and various stakeholders in the ecosystem perceive the impact of brucellosis prevalence on livestock productivity. Therefore, this study was conducted to appraise the role played by brucellosis in abortions in pregnant women and gravid domestic ruminants in Kagera ecosystem, Tanzania.

3.0. Methodology

3.1. Study design

Aprospectivecohort study was conducted for six months(from November 2017to April 2018) to appraise the contribution of brucellosis to abortions in humans and domestic ruminants in pastoral areas of Kagera Region (Ngara and Karagwedistricts). Four hospitals (Nyakahanga, Nyaishozi, Nyamiaga and Rukole) were included in thisstudy on selected pregnant womenattendingprenatal medical care during that period (Figure1). Pregnant woman should have been considered to be at risk of exposure tobrucellosis ifshe was livingwith domestic animals with history of abortions, getting contact with aborted materials, having a habit of drinking unpasteurized milk, assisting animals during parturition without wearing protective gears, living with brucellosis infected herd, beinga livestock keeper. Pregnant woman who are not at risk of exposure to brucellosis was selected based on the opposite of the previous criteriaset for the group at risk of exposure. Were excluded, pregnant women who were not sure to pursue the antenatal care in the hospitals visited for the recruitment period together with those who refused to consent to be sampled at delivery or abortions event.Assisted by local phlebotomists, plain vacutainer tubes were used to collect 5ml of venous blood

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from every woman after delivering normally or after abortion. Prior to this, consent was obtained after explaining the study objectives to the participants. The participants were interviewed for assessment of clinical indicators of brucellosis (malaria-like symptoms, abortion occurrence) and potential risk factors for the disease on following variables: consumption of unpasteurized milk, assisting parturition without wearing protective gears, living in close proximity with domestic animals, livestock keeping activity.

Domestic gravid ruminants wereselectedfrom eight villages(five villages in Karagwe district and three villages in Ngara district) inperi-urban and rural areas (Figure1). Agravid domestic ruminant was considered to be at risk of exposure to brucellosis if it was from herd with history of abortions, a herd with poor or absence in handling aborted materials,a herd in which can be observed hygromasor a herd interacting with wildlife. Pregnant animals which did not fulfill any of these previous criteria were clustered in group which is not at risk of exposure to brucellosis.Were excluded animals destined trade together with those the owners were reticents for biological sampling. Assisted by local veterinary technicians, plain vacutainer tubes were used to collect 5ml of venous blood from each gravid animal after a normal delivery or after an abortion in case of its occurrence.Questionnaires were administered to the owners of animals and factors evaluated included: herd size and location, sharing source of water with other herds, communal grazing, sharing bulls and history of abortion. Sampling and interviews were done after getting the participant's consent.This study was also approved by institutional review board of Sokoine University of Agriculture and the Medical Research Coordinating Committee of the National Institute for Medical Research (ref: NIMR/HQ/R.8a/Vol.IX/2456).

Figure1: map showing study area (humans and domestic ruminants sampling)

Assuming that the anticipated incidences of brucellosis in groupnot at risk of exposureare: 0.43 in humans (Khan *et al.*, 2001)and 0.35 in domestic ruminants (Shirima, 2005), and using a confidence level of 95%, an anticipated relative risk of 3 and applying the formula:
(Lwanga and Lemeshow, 1991), the minimum sample size

o $n = \frac{(p_1 \times q_1 + p_2 \times q_2) \times K}{(p_1 - p_2)^2}$ and 48 sheep wasestimated in each group (the exposed

and non-exposed subjects) for the follow up in this study.**n** = number required in each cohort; **K** = (Zα + Zβ) 2; **p1** = anticipated incidence in unexposed animals; **q1** = 1 - p1; **p2** = minimum incidence to be detected in exposed animals (based on the RR to be detected= minimal Relative Risk that is considered as important) and **q2** = 1 - p2.

3.2. Laboratory analysis

Human and domestic ruminant sera were screened using RBT and were subjected to confirmation usingFPA test. Samples reacting to both RBT and FPA tests were considered to be seropositive to brucellosis.

3.4. Data analysis

Answers from questionnaires and serological data werefilledusing excel sheet (version 2010) for analysisthen, the proportion of positives among pregnant women and animals tested were determined. The relative and absolute measures of effect were computed. Relative risk (RR) = Ra/ Rna (Ra: risk of abortion(s)in group at risk of exposure; Rna; risk of abortion(s)in group not at risk of exposure). The risk difference (RD)isthe difference between the incidence proportion of abortions in cases at risk of exposuretobrucellosis and the incidence proportion of abortions in cases not at risk of exposure tobrucellosis. The population attributable risk (PAR) estimated the excess risk among the group at risk of exposure that can be attributed to the risk factor in terms of the whole population. In addition,all variables were screened by univariable logistic regression analysis for their association with the positivity of brucellosis in Kagera. Using IBM® SPSS® Statistics 21, all variables were included in the risk factors assessment by a multivariable logistic regression model (backward conditional), reporting odds ratio with 95% confidence intervals. A p-value less than 0.05 was considered as significant.

4.0. Results

4.1. Demographic characteristics of pregnant women and ruminants sampled in Kagera Region

A total of 76 pregnant women were followed up in this study and were aged between 17 and 43 years (mean =25±6.3). They were 3 months of gestation period and majority of them (80.2%) were fromfamily of livestock keepers. A total of 357 gravid ruminants (121 cattle, 125 goats and 111 sheep) were selected for a follow up and were between 1 month and 3 months of gravid period (according to species). Their age was between 3 to 8 years for cattle, 2 to 7 years for goats and 2 to 6 years for sheep.

4.2 Seroprevalence of brucellosis and measures of effect of abortionin pregnant women and ruminants in Kagera Region

The seroprevalence of brucellosis in pregnant women and ruminants in Kagera is presented in Figure 2. In aborted cases, the seroprevalence of brucellosis was higher in all species except in sheep. Abortion cases and the positivity to brucellosis in all species are recorded in Table1 and other measures of effect are presented in Table 2. The abortion rate inwomenat risk of exposure to brucellosis was 11.8% and the OR for

abortions inthis group was 4.1 (95% CI:0.8-21). The OR for abortions in women positive to brucellosis was 3.7(95% CI:0.9-15.7). The abortion rate in gravid ruminant at risk of exposure to brucellosis was 12.3% and the OR for abortions was 7.8(95% CI:3.4-17.8). At species level, the abortion rates were 5.8% in cattle, 20.6% ingoat and 10% in sheep.

Table1: Exposure and positivity to brucellosis according to species in Kagera Region.

Variables		Species			
		Humans	Cattle	Goats	Sheep
Group at risk of exposure	Abortion cases	7	5	23	9
	Non-abortion cases	31	45	44	37
Groupnot at risk of exposure	Abortion cases	2	2	3	2
	Non-abortion cases	36	69	55	63
Positive to FPA test	Abortion cases	4	2	2	0
	Non-abortion cases	12	8	5	1
Negative to FPA test	Abortion cases	5	5	24	11
	Non-abortion cases	55	106	94	99

Table2. Measures of effect on abortions in humans and domestic ruminants in Kagera.

Indicators	Pregnantspecies (95% CI)				
	Women	Ruminants	Cattle	Goats	Sheep
RR of abortion (CRE)*	3.5(0.8-15)	6.2 (2.8-13.7)	3.5 (0.7-17.5)	6.6 (2.1-21)	6.2 (1.4-27.6)
RR of abortion (PC)**	3(0.9-9.8)	1.8 (0.7-4.7)	4.4 (0.1-20)	4.4(0.1-20)	0
RD of abortion (CRE)	0.1(-0.0-0.3)	0.2(0.1-0.2)	0.1 (-0.0-0.1)	0.3 (-0.0-0.1)	0.2 (0.0-0.3)
RDof abortion (PC)	0.1(-0.0-0.3)	0.1 (-0.0-0.3)	0.1 (0.0-0.3)	0.1(0.0-0.3)	-0.1 (-0.7-0.5)
PAR of abortion (CRE)	0.06	0.08	0.03	0.03	0.06
PAR of abortion (PC)	0.035	0.005	0.012	0.012	-0.0009

***CRE**: Cases at Risk of Exposure; ****PC**: Positive cases; **RR:** relative risk; **RD**: risk difference (attributable risk); **PAR**: Population attributable risk

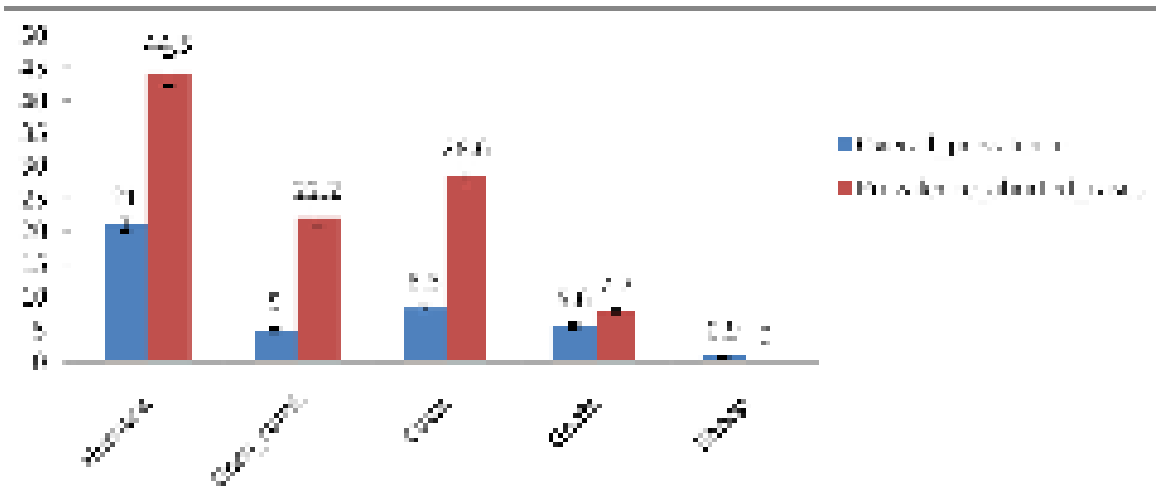

Figure2: Positivity to brucellosis in pregnant women and ruminantsKagera Region

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4.3. Logistic regressions

In pregnant women, none of the variables was associated to brucellosis positivity (Table 3), while in gravid domestic ruminants, cattle (OR=10;95% CI:1.2-78, p=0.03) seemed to be associated to brucellosis positivity by univariable logistic regression (Table 4). Multivariable regression model revealed odds in pregnant women at risk ofexposure to brucellosis (OR=19; 95% CI: 1.8-203, p=0.01) and the risk at exposure to brucellosis in cattle (OR=11; 95% CI: 1.3-88, p=0.02) in gravid ruminants (Table 5).

Table 3: Univariableassociation between positivity to brucellosis in pregnant womenand different variables in Kagera Region.

Variable	Extent	Positive (%)	OR (95% CI)	Wald stat.	p-value
District	Karagwe	26.7	2.4 (0.7-8.4)	2.0	0.16
	Ngara	13	Reference		
*Risk of exposure to brucellosis	Yes	26.32	1.9 (0.6-5.9)	1.2	0.26
	No	15.8	Reference		
Fatigue	Yes	12.5	0.4 (0.1-1.3)	2.3	0.12
	No	27.2	Reference		
Back pain	Yes	9.6	2 (0.5-8)	0.6	0.4
	No	4.8	Reference		
Joint pain	Yes	13.3	0.5 (0.1-2.5)	0.4	0.5
	No	22.3	Reference		
** Manifesting other symptoms different from malaria	Yes	10.53	0.3(0.1-1.7)	1.6	0.2
	No	24.6	Reference		
Abortion occurrence	Yes	44.4	3.6 (0.8-15.7)	3	0.08
	No	18	Reference		
	No	19.6	Reference		
Consuming fresh blood	Yes	23.1	1.6 (0.2-4.8)	0.0	0.8
	No	20.6	Reference		
Livestock keeping activity	Yes	23	1.9 (0.4-9.6)	0.6	0.4
	No	13.3	Reference		

*Risk of exposure to brucellosis: living with domestic animals with history of abortions, getting contact with aborted materials, having a habit of drinking unpasteurized milk, assisting animals during parturition without wearing protective gears, living with brucellosis infected herd, being a livestock keeper.
**Manifesting other symptoms different from malaria: cough, abdominal pain, diarrhea.

Table 4: Univariableassociation between positivity to brucellosis in gravid domestic ruminants and different variables in Kagera Region.

Variable	Extent	Positive (%)	OR (95% CI)	Wald stat.	p-value
District	Karagwe	6	2.3 (0.6-8)	1.6	0.2
	Ngara	2.8	Reference		
Species	Cattle	8.3	10(1.2-8)	4.7	0.03
	Goat	5.6	6.5(0.8-53)	3	0.08

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	Sheep	0.9	Reference		
*Risk of exposure to brucellosis	Yes	6.7	2(0.7-5)	1.7	0.2
	No	3.6	Reference		
Abortion occurrence	Yes	9	2.1(0.7-6.8)	1.6	0.2
	No	4.5			
Herd location	Rural	12.2	0.0(0.1-0.9)	4.5	0.03
	Peri-urban	4.1	Reference		
Good disposal of aborted materials	Yes	2.1	0.3(0.1-1.4)	2.2	0.1
	No	6.1			
Communal grazing	Yes	6	2.7 (0.6-12.2)	1.8	0.2
	No	2.2	Reference		
Sharing bulls	Yes	6.7	3 (0.8-10)	3	0.08
	No	2.3	Reference		

*Risk of exposure to brucellosis: a herd with history of abortions, a herd with poor or absence in handling aborted materials, a herd in which can be observed hygromas or a herd interacting with wildlife.

Table 5: Risk factors for brucellosis in different species in Kagera.

Variables	Extent	Wald statistics	OR	95% IC	p-value
Risk factors in pregnant women					
Risk of exposure to brucellosis	Yes	6	19	1.8-203	0.01
	No		Reference		
Manifesting other symptoms different from malaria	Yes	3.1	0.12	0.0-1.2	0.07
	No		Reference		
Living with domestic animals	No	5.2	0.1	0.0-0.7	0.02
	Yes		Reference		
Risk factors in gravid domestic ruminants (animal level)					
Species	Cattle	5.1	11	1.3-88	0.02
	Goat	3.7	8	0.9-66	0.05
Communal grazing	Yes	3.4	4.1	0.9-18	0.06
	No		Reference		
Good disposal of aborted materials	Yes	3.3	0.2	0.0-1.1	0.06
	No		Reference		

5.0 Discussion

The association of brucellosis prevalence to occurrence of abortions in Africa could be a bit biased at the moment since most of the relationship established are based on odds in history of abortion in the herds, temporal or definitive infertilities with a decrease or a total absence of milk production(Mangen *et al.*, 2002). In this study, the abortion rate in pregnant women (11.8%) was lower compared to the previous report on miscarriage's distribution (15%) at national level including in Lake Zone (Keogh *et al.*, 2015). This may be due to the increased of antenatal medical care in the health facilities in the study area. However, the prevalence of brucellosis in the pregnant women in this study (21%) was lower compared to the previous reports in Tanzania (Chota *et al.*, 2016), but was

higher to that reported from Moshi hospital (Cash-Goldwasser *et al.*, 2018). This situation could be explained by the persistence of exposure to *Brucella* infections in pregnant women. In this study, the exposure to brucellosis (RR=3.5; 95% CI=0.8-15) and the positivity to the disease (RR= 3; 95% CI=0.9-9.8) did not increase the risk of abortions in pregnant women.In fact, the risk of abortions in pregnant women could not be readily associated to the exposure (OR=4; 95% CI: 0.78-21) nor tothe positivity to brucellosis (OR=3.7; 95% CI: 0.9-15.7) in the study area.Abortions might occur due to effects of other contributing factors. Moreover, there was not a statistical difference between positivity to brucellosis in aborted and non-aborted cases (p=0.08). Our results are similar to those reported in Jordan (Abo-shehada and Abu-Halaweh, 2011). However, a study reported differences between brucellosis prevalence in miscarriage and non-miscarriage casesin Mwanza-Tanzania (Mujuni *et al.*, 2018). In addition, abortions were more recorded in pregnant women who were positive to brucellosis in Saudi Arabia compare to those who were negative to the disease (Elshamy *et al.*, 2008). In this study, pregnant women who confirmed not to manifest malaria-like symptoms seemed to be preserved of *Brucella*infections (OR= 0.1; 95% CI= 0.0-1.2). This situation could highlight the necessity of combined method for differential diagnosis of brucellosis and other febrile diseases (Rift Valley Fever, Brucellosis, and Malaria, among others) in the study area. In this study, there were a high association between the exposure and the positivity to brucellosis (OR= 19; 95% CI= 1.8-203). Or, the case definition for a woman at risk of exposure to brucellosis was those who lived in close contact with domestic animals with history of abortions, were in contact with aborted materials, had a habit of drinking unpasteurized milk and assisted animals during parturition without wearing protective gears. These elements could be the important risk factors which favored the estimated prevalence of brucellosis among the group at risk of exposure to the disease in humans.

For gravid domestic ruminants, the prevalence (5%; 95% CI: 3.1-8) was within the range to the previous reports in Tanzania(Shirima, 2005; Sagamiko *et al.*, 2018). Theprevalence of brucellosis found in this study could indicate the endemic character of this disease in domestic ruminants in the study area. In this study, the abortion rate in cattle (5.8%) is lower compared to the previous reports in Tanzania (Mdetele *et al.*, 2015; Mathew 2017). In Zambia, the abortion rate (16.2%) in exposed cattle to brucellosis (history of abortion) was higher compare to our investigation(Muma *et al.*, 2007). In this study there wasn't a statistical difference between brucellosis prevalence in aborted and non-aborted domestic ruminants (p=0.2).In general, gravid domestic ruminants were six times at riskof aborting due to the exposure to brucellosis in this study.This could be explained by the persistence of exposure in animals to traditional risk factors to which there are subjected in different seasons in pastoral areas as reported in Morogoro(Asakura *et al.*, 2018). Elsewherein Africa, cattle with exposure to brucellosis was at risk to get abortions in the traditional livestock sector (Muma *et al.*, 2007; Megersa *et al.*, 2011).However, exposure to brucellosis increased the risk of abortion ingoat (RR= 6.6; 95%=2.1-21) and sheep (RR= 6.2; 95%=1.4-27.6) compared to the group which is notat risk of exposure in the corresponding species. The outcome of infection in animals can be influenced by age, immunologic conditions, and virulence

of pathogens.In addition, where high prevalence of brucellosis can be foundin Africa, there is higher probability to record abortions in domestic ruminants (Domenech *et al.*, 1982; Mangen *et al.*, 2002). Moreover, the risk of abortions was likely to be the same in positive and negative cases to brucellosis (RR=1.8; 95% CI=0.7-4.7) in gravid ruminants. The presence of organisms could not necessarily indicate a causal association between *Brucellainfections* and abortions in risk groups.These results could have been influenced by the small number of animals who reacted positively to the disease. In this study, the abortion rate was higher in goats (20.6%) compare to other species. These abortions could be attributed also to susceptibility of this specie to others infectious abortive pathogens (Rift Valley Fever, Peste des Petits Ruminants) reported in the study area (Sindato *et al.*, 2015; Kgotlele *et al.*, 2016). High abortion rate in small ruminants could lead to the dissemination of infectious diseases (brucellosis included) to others domestic ruminants without excluding the human's infections as reported previously in Northern Tanzania(Cash-Goldwasser *et al.*,2018).

The proportionof abortion occurrence was less estimated in pregnant women at risk of exposure (PAR=6.5%) compared to domestic ruminants also at risk of exposure (PAR=8%) in the study area. This situation could be influenced by the abortions recorded in few positives cases reported in different species in this study. It is believed that brucellosis can cause less spontaneous abortions in women than it occurs in animals due to the controversial presence of erythritol (sugar) in the placenta (Al-tawfiq and Memish, 2013; Petersen *et al.,* 2013).Moreover, it is also stated that *Brucellaspp.* have less activity in human amniotic fluid than in animals (Seoud *et al.,* 1991). In addition, at population level, abortions were less attributable to positivity to brucellosis in gravid ruminant (PAR= 0.5%) compared to proportion of abortions attributed to *Brucell*a infections in pregnant women (PAR=3.5%). This situation could be explained by the endemic prevalence of the disease in domestic ruminants which could expose pregnant women to a high risk of infections in pastoral areas.It is also noted that animals may abort during the first pregnancy, but the subsequent one may be normal birth(Nicoletti, 1980).Furthermore, women handling livestock in pastoral areas are likely to get elevated abortion rate due to brucellosis(Boschiroli & O'Callaghan, 2001), although the disease outcome is associated to exposure and occupation, rather than gender(Khan, 2018).

6.0 Conclusion

Brucellosis is prevalent in pregnant women and gravid domestic ruminants in Kagera Region. In this study, the abortion rate was lower compared to some previous reports in the country. Despite of the statistical similarities of positivity to brucellosis in aborted and non-aborted cases, a proportion 0.5% of the abortions were attributable to *Brucella* infections in gravid ruminant while 3.5% of abortions were attributed to positivity of the disease in pregnant women at population level. Furthermore, positivity to brucellosis was highly associated to the risk of exposureof the disease in pregnant women, whilecattle seemed to be at higher risk of contracting *Brucella* infections compared to other species. In Kagera Region, pregnant women and ruminants are at risk of *Brucella* infections which endemic prevalence could contribute to the

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reproductive failures recorded in these species. A differential diagnosis of brucellosis with other infectious and febrile diseases is recommended for spontaneous abortions in humans and domestic ruminants.More effort is needed using a multidisciplinary approach for prevention and control of brucellosis in humans and animals.

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Conflict of interest

The authors declare that there is no conflict of interest for this study.

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Predicting Soil EC_e based on Values of $EC_{1:2.5}$ as an Indicator of Soil Salinity in Magozi Irrigation Scheme, Iringa, Tanzania

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Abstract

Soil salinity is one of the limitations to sustainable production of rice and other crops in many irrigation schemes of Tanzania. Soil salinity can be assessed from electrical conductivity (EC) measurements. Most soil laboratories in Tanzania appraise soil salinity from measurements of electrical conductivity of 1:2.5 soil:water suspensions ($EC_{1:2.5}$) by virtue of their simplicity. However, the influence of soil salinity on plant growth is mainly based on electrical conductivity of saturated paste extract (EC_e), so it is necessary to convert $EC_{1:2.5}$ to EC_e in order to assess plant response to salinity. This study was conducted at Magozi Irrigation Scheme, Iringa, Tanzania to establish regression model for predicting EC_e from $EC_{1:2.5}$ values. A total of 60 soil samples (45 samples for model training and 15 samples for model validation) were collected and analyzed for soil $EC_{1:2.5}$,EC_e and soil texture. $EC_{1:2.5}$ranged from 0.1 to 9.2 dS $m^{-1}$with a mean value of 0.85 dS m^{-1}. EC_e ranged from 0.3 (non-saline) to 33.3 dS m^{-1} (strongly saline) with a mean of 2.9 dS m^{-1} (slightly saline). In order of dominance, soil textural classes were sandy clay loam, clay, sandy clay, sandy loam and clay loam. Strong linear relationships between EC_e and $EC_{1:2.5}$ were observed in the developed linear regression equations. After validation, the study selected equation $EC_e = 3.4954*EC_{1:2.5}$ with R^2 of 0.956 for combined soil textures to be used for prediction of EC_e from $EC_{1:2.5}$ at Magozi Irrigation Scheme. This model can be tested for its applicability to other similar soils in Tanzania in further studies.

Keywords: Soil salinity, EC_e, $EC_{1:2.5}$, Magozi Irrigation Scheme, soil salinity prediction

1.0 Introduction

The 21st century is marked by various global challenges to agricultural sustainability and food production to feed the growing population (Taddese, 2001; Shahbaz and Ashraf, 2013; Godfray and Garnett, 2014). Land degradation is considered as one of the main threats to sustainable agricultural development (Taddese, 2001; Bai*et al.,* 2008). Increasing pressure on land resources due to increased human population coupled with the effects of climate change lead to different types of agricultural land degradation including soil salinization, which is the process of salt accumulation in the soil profile (Biswas and Biswas, 2014; Taddese, 2001; Shahbaz and Ashraf, 2013).

Irrigated agriculture has been viewed as one of the approaches in ensuring food security under the climate changing world (Rhoades and Chanduvi, 1999; Hanjra and Qureshi, 2010). Unfortunately, extensive areas of irrigated land have been and are increasingly becoming degraded by salinization and water logging resulting from over-irrigation and other forms of poor agricultural management (Rhoades and Chanduvi, 1999; Smedema and Shiati, 2002). Soil salinization leading to soil salinity is an important worldwide land degradation problem and poses a great threat to the development of sustainable agriculture, especially in arid and semi-arid regions (Bai *et al.,* 2008;

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Shrivastava and Kumar, 2015).

Soil salinity is one of the limiting factors of agricultural productivity (Sonmez *et al.,* 2008). It has been estimated that worldwide 20% of total cultivated and 33% of irrigated agricultural lands are afflicted by high soil salinity (Shrivastava and Kumar, 2015). Therefore, soil salinity has been considered as a basic factor which determines to a large extent, soil suitability for agricultural productivity (Sonmez *et al.,* 2008; Shrivastava and Kumar, 2015). Increased soluble salts in the root zone due to soil salinity reduce plant growth, crop yields and in severe cases, cause crop failure (Zhu, 2001; Datta and De Jong, 2002; Allbed and Kumar, 2013; Corwin and Yemoto, 2017). Therefore, soil salinity assessment has been viewed as an important component in agriculture management (Biswas and Biswas, 2014; Lesch*et al.,* 1995; Corwin and Yemoto, 2017). It is essential to assess soil salinity in a reliable and yet relatively easy method (Sonmez *et al.,* 2008; Mattheese*t al.,* 2017).

Soil salinity is generally measured by electrical conductivity (EC) (US Salinity Laboratory Staff, 1954; Sonmez *et al.,* 2008; Landon, 2014; Corwin and Yemoto, 2017). A soil is considered saline if the EC of a saturation extract exceeds 4 dS m^{-1} at 25^0C (Sonmez *et al.,* 2008; Kargas *et al.,* 2018). Soil salinity or EC maybe measured on the bulk soil (EC_a), in the saturation paste extract (EC_e), in soil: water ratio suspensions of 1:1 to 1:5 such as 1:1, 1:2, 1:2.5 and 1:5 or directly on soil water extracted from the soil in the field (EC_w) (Corwin and Yemoto, 2017; Sonmez *et al.,* 2008; Kargas *et al.,* 2018; US Salinity Laboratory Staff, 1954).

Since 1954 to date, the EC_e has been considered as the best indicator of crop response to salinity compared with EC from other soil to water ratio suspension methods (US Salinity Laboratory Staff, 1954; Rhoades *et al.,* 1989; He *et al.,* 2013; Mattheese*t al.,* 2017; Kargas *et al.,* 2018). Soil salinity assessment is therefore, based on measurements of the electrical conductivity of the saturated paste extract (EC_e), which has been established as the standard method (US Salinity Laboratory Staff, 1954; He *et al.,* 2013; Mattheese*t al.,* 2017; Kargas *et al.,* 2018). This approach is however expensive, cumbersome and tedious as it requires more time and skill associated with the manual preparation of the soil paste (He *et al.,* 2013; Kargas *et al.,* 2018) than soil to water ratio methods.

Instead of measuring soil EC_e, a number of researches from various soil laboratories in the world have found it easier to measure the EC of soil: water ratios such as 1:1, 1:2, 1:2.5 and 1:5 which are more easily attainable (Sonmez *et al.,* 2008; He *et al.,* 2013; Landon, 2014; Kargas *et al.,* 2018) as they are easier to prepare, save time and less costly (He *et al.,* 2013). Therefore, it is likely that many laboratories, particularly commercial ones, will continue to appraise soil salinity from EC of soil to water suspensions like 1: 2.5 measurements because of their convenience and speed (He *et al.,* 2013; Mattheese*t al.,* 2017; Kargas*et al.,* 2018). It has however been noted that the soil over water mass ratios are very poorly correlated with the actual soil moisture conditions (Sonmez *et al.,* 2008; Kargas *et al.,* 2018). Therefore, in order to assess plant response to salinity, it is necessary to convert EC from soil to water suspensions values to EC_e (Sonmez *et al.,* 2008; He *et al.,* 2013; Mattheese*t al.,* 2017). Conversion factors obtained from model equations are used to estimate EC_e from EC values of soil to water suspensions

(Khorsandi and Yazdi, 2011; He *et al.*, 2013).

Various studies have shown that highly significant linear correlation exists between EC values measured in saturated paste extracts and EC values from different soil to water ratios (Sonmez *et al.*, 2008). The study by Sonmez *et al.*, (2008) concluded that EC values from extracts of 1:1, 1:2.5 or 1:5 soil to water ratios can be used to estimate saturated paste electrical conductivity (EC_e). Recent study for Greece soils by Kargas *et al.*, (2018) reported that the methods providing $EC_{1:1}$ and $EC_{1:5}$ values are linearly correlated to the EC_e methodology with a high correlation coefficient ($R^2 > 0.93$).

Most of the studies conducted in other countries were mainly based on relating EC_e with $EC_{1:1}$, $EC_{1:2}$ and $EC_{1:5}$ with very few on $EC_{1:2}$ (Sonmez *et al.*, 2008; Corwin and Yemoto, 2017). All equations have shown regional variability (Sonmez *et al.*, 2008; Corwin and Yemoto, 2017) suggesting that there is a need for regional specific equations. Soil testing laboratories in Tanzania run many thousands of samples each year for EC by using an easier method of $EC_{1:2.5}$. A specific benefit for measuring electrical conductivity using extracts of 1:2.5 soil to water ratio is that the measurements can be conducted for samples prepared for pH measurements and thus saving both time and resources for laboratory works (Sonmez *et al.*, 2008). However, there are no conversion factors developed for converting soil $EC_{1:2.5}$ to EC_e for Tanzanian soils. Furthermore, the soil EC interpretation guidelines used are based on EC_e (US Salinity Laboratory Staff, 1954; Sonmez *et al.*, 2008; Corwin and Yemoto, 2017). Literature has documented that the EC_e values are usually higher than the EC values determined by soil to water suspension methods like 1:2.5 (Sonmez *et al.*, 2008; Corwin and Yemoto, 2017). This means that the current approach of using EC_e based interpretation guidelines to interpret $EC_{1:2.5}$ values may lead to unrealistic soil salinity assessment in the country.

Studies have shown that rice (*Oryza sativa L.)* crop production in Tanzania is threatened by salt affected soils among other factors (Kashenge-Killenga, 2010). Irrigated rice is one of the major sources of rice production in Tanzania as one of the efforts to ensure food security and incomes of farmers under the climate changing world (Kashenge-Killenga, 2010; Mtengeti*et al.*, 2015; Rugumamu, 2014). Magozi Irrigation Scheme is one of the rice producing schemes in Iringa region (Mdemu*et al.*, 2017) facing the problem of soil salinity. Assessment and monitoring of soil salinity in this scheme and other areas is important and require relevant salinity measurements (Corwin and Yemoto, 2017; He *et al.*, 2013; Mattheese*t al.*, 2017). Although measurements of electrical conductivity (EC) in 1:2.5 soil to water suspension is possible, no linear model has been established to convert $EC_{1:2.5}$ to EC_e for accurate salinity assessments. This study developed a linear model that can be used to predict EC_e from $EC_{1:2.5}$ in this scheme with potential application in other soils of Tanzania.

2.0 MATERIALS AND METHODS

2.1 Description of the Study Area

The research was conducted in Magozi Irrigation Scheme which has an area of 1300 ha. The scheme is located at Ilolompya Ward, in Iringa Rural District of Iringa Region and composed of three villages namely Magozi, Ilolompya and Mkombilenga. The irrigation water comes from the Little Ruaha River. The scheme is located at about 60 km North West of Iringa town and lies from 7°28'45.74"-7°25'14.08"S to 35°27'37.91"-35°28'45.92"E. The average altitude is 700 m above mean sea level and the climate is semi-arid tropical with a monomodal rainy season between November and May.

2.2 Pre-field work

A reconnaissance soil survey was conducted to understand and establish soil variation in terms of surface salinity features, soil texture and topography at Magozi Irrigation Scheme. The 500m x 500m sampling grid was prepared in QGIS (QGIS 2.6.1-Brighton) using the scheme boundary shape file and the sampling point UTM coordinates were captured by coordinate capturing tool in QGIS and later on transferred into the GPS device (GARMIN GPSmap 62) for navigation during soil sampling.

Plate 1: A section of Magozi Irrigation Scheme showing whitish surface salinity features

2.3 Field soil sampling

The pre field work established soil sampling points based on systematic 500m x 500m grids. However, additional points were included to take care of the observed soil variations in the area during soil sampling. Therefore, a total of sixty (60) surface composite soil samples at a depth of 0-30cm were collected from Magozi Irrigation Scheme and sent to Sokoine University of Agriculture Soil Science Laboratory for analysis of soil $EC_{1:2.5}$, EC_e and soil texture. Soil texture was included as an important parameter which affects soil electrical conductivity (US Salinity Laboratory Staff, 1954; Sonmez *et al.*, 2008).

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2. 4 Soil sample selection for studying ECe prediction from EC1:2.5

Out of 60 soil samples, 45 soil samples (75%) with combined soil textures were used as model training data set while 15 soil samples (25%) were used as model validation data set. The selection considered the location of sample point in the irrigation scheme area as well as the soil textural classes' variation in order to reduce sampling biasness. Fig. 1 is the map of Magozi Irrigation Scheme showing soil sampling points distribution for this study.

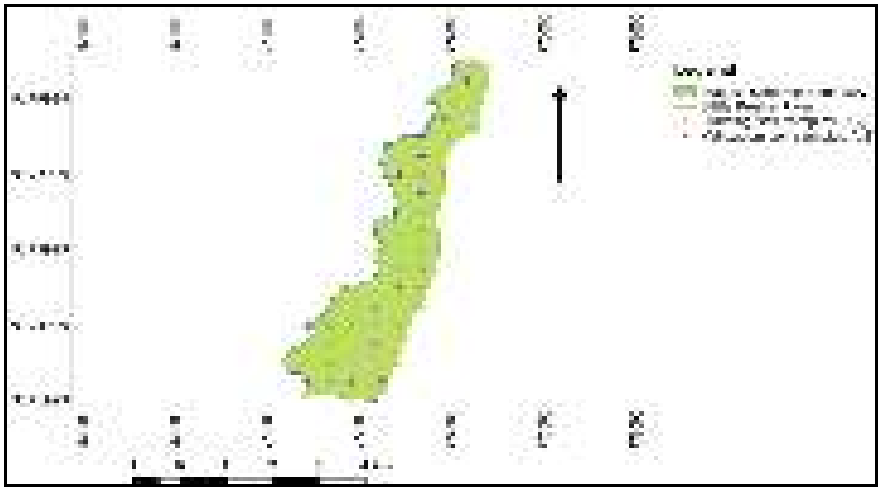

Figure 1: Soil sampling points distributions at Magozi Irrigation Scheme for ECe determination

2.5 Laboratory analysis for soil $EC_{1:2.5}$, EC_e and soil texture

Soil samples were air-dried, ground and passed through a 2-mm sieve for laboratory determination of soil EC1:2.5, ECe, particle size analysis (soil texture) at Soil Science Laboratory of the Sokoine University of Agriculture. Particle size analysis was determined by hydrometer method after dispersion with 5% sodium hexametaphosphate (Moberg, 2001) whereby the soil textural classes were determined using USDA textural triangle (Soil Survey Staff, 2014). Soil electrical conductivity (EC1:2.5) in dS m-1 were measured potentiometrically in water at a ratio of 1:2.5 soil: water (Okalebo*et al*., 2002; Moberg, 2001).

Soil ECe was determined by saturated paste extract method using standard method (Rhoades, 1996; US Salinity Laboratory Staff, 1954) summarized as follows; 200g of air-dry soil was weighed for each soil sample. Distilled water was added to each sample while mixing to saturate the soil to the point where the soil paste glistens, flows slightly when the container is tipped and slides cleanly from the spatula. The soil paste samples were allowed to stand for 4 hours to check if saturation criteria are still met; where distilled water was added and thoroughly combined for samples which became stiffened or which did not glisten. The soil paste samples were left overnight to establish equilibrium. The wet soil was transferred to a Buchner funnel fitted with

retentive filter paper, vacuum was applied and the filtrate was collected for measurement of electrical conductivity expressed in dS m1 by EC meter (Rhoades, 1996).

2.6 Linear relationship between electrical conductivity of the saturated paste extract (EC_e) and of the 1:2.5 soil to water suspension ($EC_{1:2.5}$)

2.6.1 Statistical Analysis

Linear regression analysis to relate ECe and EC1:2.5 for the training data set and the data set for each soil textural class were conducted using Genstat Software and Microsoft Excel 2013 Analysis ToolPak. The linear relationships between ECe and EC1:2.5are presented by the model equations below:

ECe = mEC1:2.5 + c with intercept …… (1)

ECe = mEC1:2.5 without intercept …….. (2)

where ECe is the dependent variable expressed in dS m-1, EC1:2.5 is an independent variable expressed in dS m-1; m is an equation slope serving as the model estimate and c is an intercept constant expressed in dS m-1. All statistical tests were performed at $p \leq 0.05$ significance level. The linear models were assessed by using coefficient of determination (R2) according to Wim *et al*. (2007).

2.6.2 Model selection and validation

A linear regression model for use in this study was selected based on the number of samples used to develop it as compared to others and the size of validation data set available for testing it (Mattheese*t al.,* 2017). Good coefficient of determination (R^2>0.8) was also considered while selecting the model. Higher R^2values represent smaller differences between the observed data and the fitted values.Further selection criteria for the final model was done by testing the prediction accuracy for the equation with intercept and without intercept when subjected to the validation data set (Kargas*et al.*, 2018; Mattheese*t al.,* 2017).To further compare the prediction accuracy between model with intercept and without intercept, a scatter plot was established to relate linear relationship between measured EC_e and predicted EC_e by assessing R^2 and prediction error represented by root mean square error (RMSE) (Kargas*et al.*, 2018; Sonmez *et al.*, 2008). Therefore a model which predicted EC_e from $EC_{1:2.5}$ with smaller mean difference between measured and predicted EC_e, higher $R^2$and smaller RMSE values as compared to other models was selected for use in this study (Mattheese*t al.,* 2017; Sonmez *et al.*, 2008).

3.0 RESULTS

3.1 Status of soil $EC_{1:2.5}$, EC_e and soil texture in the studied soils

The results for the selected 60 soil samples summarized in Table 1, showed that the soil electrical conductivity measured in 1:2.5 soil to water suspension ($EC_{1:2.5}$) ranged from 0.11 to 9.2 dS m^{-1} with the mean of 0.85 dS m^{-1}. The soil electrical conductivity (EC_e)determined by saturated paste extract method ranged from 0.3 dS m^{-1}(non-saline) to 33.3 dS m^{1}(extremely saline) with a mean of 2.9 dS m^{-1} (slightly saline) (Rhoades,

1996; Bannari *et al.*, 2008). The studied soils showed variation in soil texture where the soil textural classes percentage composition per total soil samples were 42%, 28%, 10%, 10% and 10% for sandy clay loam, clay, sandy clay, sandy loam and clay loam respectively.

Table 1: Descriptive statistics for selected physicochemical properties of the studied soils (n = 60)

Parameter	Minimum	Maximum	Mean	Standard deviation
Electrical conductivity (EC)				
Soil $EC_{1:2.5}$ (dS m^{-1})	0.11	9.2	0.85	1.33
Soil EC_e (dS m^{-1})	0.3	33.3	2.9	4.7
Particle size distribution				
% Clay	13.56	59.56	33.68	10.79
% Silt	4.28	33.92	17.27	7.35
% Sand	15.52	78.52	49.05	15.5
Soil textural classes	**Number of samples (n=60)**			**% Textural class**
Sandy clay loam	25			42
Clay	17			28
Sandy clay	6			10
Sandy loam	6			10
Clay loam	6			10

3.2 Relationship between electrical conductivity of the saturated paste extract (EC_e) and $EC_{1:2.5}$

3.2.1 Linear regression equations relating EC_e and $EC_{1:2.5}$

Table 2 summarizes the mathematical equations indicating the linear relationships obtained between EC_e and $EC_{1:2.5}$ after linear regression analysis for the training data set with combined soil textural classes and the equations for individual soil textural classes.

Table 2: Linear regression models relating EC_e and $EC_{1:2.5}$

Soil sample type	Number of samples (n = 60)	Linear model with intercept		Linear model without intercept	
		Equation	R^2	Equation	R^2
Combined soil textures (Model training data)	45	$EC_e = 3.5381EC_{1:2.5} - 0.1337$	$R^2 = 0.9565$	$EC_e = 3.4954EC_{1:2.5}$	$R^2 = 0.956$
Sandy clay loam	25	$EC_e = 3.5326EC_{1:1.25} + 0.2106$	$R^2 = 0.9835$	$EC_e = 3.5811EC_{1:2.5}$	$R^2 = 0.9828$

Clay	17	$EC_e = 1.9719EC_{1:2.5} + 0.3779$	$R^2 = 0.9226$	$EC_e = 2.2413EC_{1:2.5}$	$R^2 = 0.8910$
Sandy clay	6	$EC_e = 3.403EC_{1:2.5} - 0.1125$	$R^2 = 0.9841$	$EC_e = 3.2919EC_{1:2.5}$	$R^2 = 0.9827$
Sandy loam	6	$EC_e = 5.0143EC_{1:2.5} - 0.1091$	$R^2 = 0.9915$	$EC_e = 4.926EC_{1:2.5}$	$R^2 = 0.9910$
Clay loam	6	$EC_e = 2.2794EC_{1:2.5} + 0.3171$	$R^2 = 0.9932$	$EC_e = 2.8622EC_{1:2.5}$	$R^2 = 0.9070$

The linear regression model estimates (m) ranged from 1.9719 in clay soils to 5.0143 in sandy loam soils and ranging from 2.2413 in clay soils to 4.9260 sandy loam soils for equations with intercept and without intercept respectively. This indicates that clay textured soils showed smaller difference between EC_e and $EC_{1:2.5}$ as compared to other coarse textured soils. Sandy loam textured soils indicated higher difference between EC_e and $EC_{1:2.5}$by having the largest estimate which is in line with other literatures (Bannari *et al.*, 2008; Sonmez *et al.*, 2008). The R^2 ranged from 0.9226 for clay soils to 0.9932 for clay loam soils and 0.891for clay soils to 0.991 for sandy loam soils for equations with intercept and without intercept respectively.

3.2.2 Model selection and validation

The linear model for combined soil textures was selected for use in this study because it was developed using relatively adequate samples and it had validation data set of combined texture soil samples. But the small soil sample sizes for individual textures could not provide adequate samples to form training and validation data sets for each soil textural class and for estimates comparison purposes. The models to be selected in this category of combined soil textures (Fig. 2 and 3) were either $EC_e = 3.5381EC_{1:2.5} - 0.1337$ with R^2 of 0.9565 and or $EC_e = 3.4954EC_{1:2.5}$ with $R^2 = 0.956$ for equation with intercept and without intercept respectively. Moreover, the linear model for combined soil textures without intercept was preferred for use in this study to predict EC_e from $EC_{1:2.5}$ because the $EC_{1:2.5}$ cannot be absolute zero for the studied soils (Bannari *et al.*, 2008).

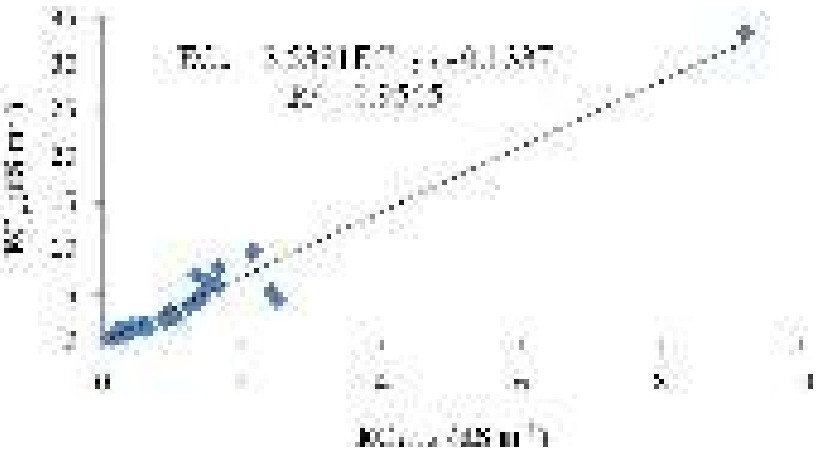

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Figure 2: Relationship between EC_e and $EC_{1:2.5}$ for training data set with combined soil textures (with intercept)

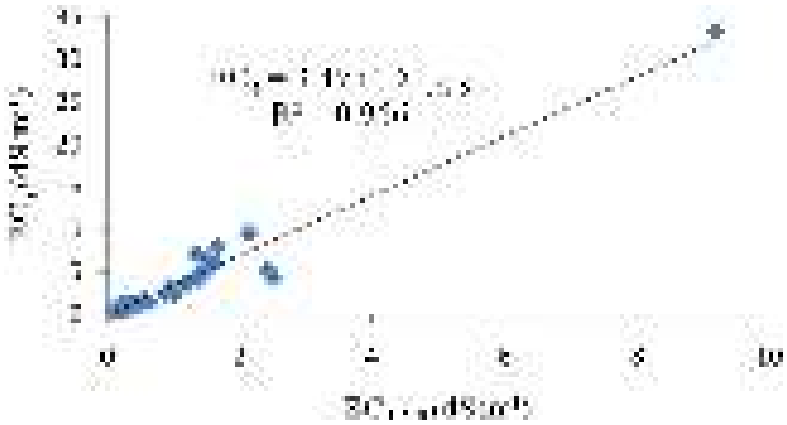

Figure 3: Relationship between ECe and EC1:2.5 for training data set with combined soil textures (without intercept)

3.3 EC_e prediction results on validation data set

The models $EC_e = 3.5381EC_{1:2.5} - 0.1337$ and $EC_e = 3.4954EC_{1:2.5}$ were compared on their ability to predict EC_e from $EC_{1:2.5}$ by using validation data set (n = 15). A summary of predicted EC_e from measured values for both equations is presented in Table 3.

Table 3: EC_e prediction results for linear models with intercept and without intercept on the validation data set

Statistic	Measured EC_e (dS m^{-1})	Predicted EC_e(dS m^{-1})	
		$EC_e = 3.5381EC_{1:2.5} - 0.1337$	$EC_e = 3.4954EC_{1:2.5}$
Minimum	0.65	0.33	0.45
Maximum	12.03	14.66	14.61
Mean	2.70	2.58	2.68
Standard deviation	3.15	3.64	3.60

Further comparison in EC_e prediction accuracy between $EC_e = 3.5381EC_{1:2.5} - 0.1337$ (with intercept) and $EC_e = 3.4954EC_{1:2.5}$ (without intercept) models was performed by scatter plots (Fig. 4 and 5) to relate linear relationships between measured EC_e and predicted EC_e from both models.

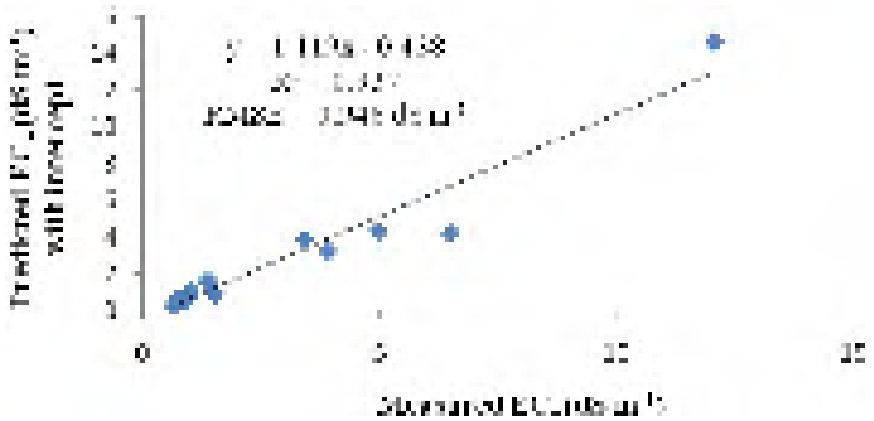

Figure 4: Relationship between measured EC_e and predicted EC_e from

$EC_e = 3.5381EC_{1:2.5} - 0.1337$ (with intercept)

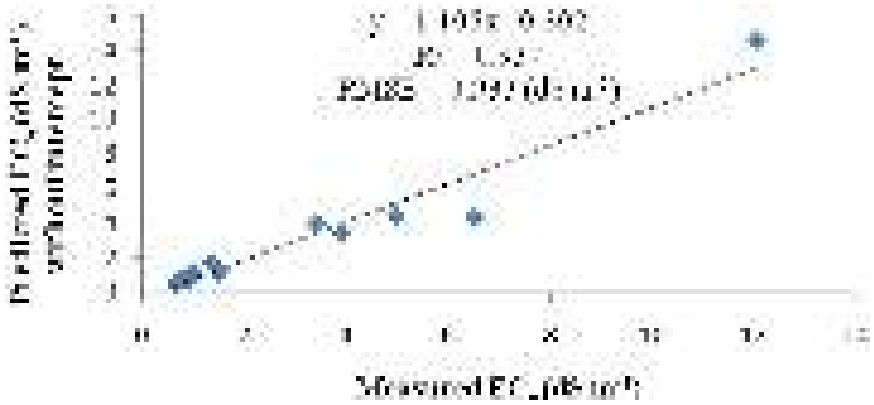

Figure 5: Relationship between measured EC_e and predicted EC_e from

$EC_e = 3.4954EC_{1:2.5}$ (without intercept)

The R^2 and RMSE (prediction error) observed for the measured EC_e versus predicted EC_e from $EC_e = 3.5381EC_{1:2.5} - 0.1337$ (with intercept) scatter plot were 0.937 and 0.946 (dS m^{-1}) respectively. The R^2 and RMSE observed for the measured EC_e versus predicted EC_e from $EC_e = 3.4954EC_{1:2.5}$ (without intercept) scatter plot were 0.937 and 0.933 (dS m^{-1}) respectively.

4.0 Discussion

Significant differences between soil $EC_{1:2.5}$ and soil EC_e values at $P<0.05$ were observed (Sonmez *et al.*, 2008). The soil electrical conductivity (EC_e)of the saturated paste extract ranged from non-saline (0.3 dS m^{-1})to strongly saline (33.3 dS m^{-1}) with a mean being slightly saline (2.9 dS m^{-1}) (Rhoades, 1996; Bannari *et al.*, 2008). The 33.3 dS m^{-1} EC_e which is ratedas strongly saline (Rhoades, 1996) is an alarming result which indicates that some areas of Magozi Irrigation Scheme are at higher risk of developing more salinity. This might negatively affect rice production in this area.

Good correlations ($R^2>0.8$)were observed in all linear regression models for combined

soil textures and in individual soil textural classes. Generally the linear regression models slope estimates for $EC_{1:2.5}$ and coefficient of determination (R^2) varied with soils textural class. This variation may be due to the effects of soil texture in soil electrical conductivity as well as differences in number of samples for individual textural classes. The study conducted by Sonmez *et al.* (2008) at Akdeniz University in Turkey obtained a linear regression model $EC_e = 3.91EC_{1:2.5} + 0.27$ with R^2 of 0.99 for combined soil textures. The observed differences in slope and intercept from those obtained in this study may be due to the soil variability between the two countries.

While the mean value from the measured EC_e of validation data was 2.7 (dS m^{-1}), the $EC_e = 3.5381EC_{1:2.5} - 0.1337$ model predicted mean EC_e of 2.58 (dS m^{-1})while $EC_e = 3.4954EC_{1:2.5}$ model predicted a mean of 2.68 dS m^{-1}. This indicated that the model without intercept ($EC_e = 3.4954EC_{1:2.5}$) predicted mean EC_e more closely to the measured mean EC_e as compared to the model with intercept.All models showed the same R^2 while the prediction error (RMSE) was smaller for $EC_e = 3.4954EC_{1:2.5}$ prediction results than $EC_e = 3.5381EC_{1:2.5} - 0.1337$. According to these results, the linear model without intercept ($EC_e = 3.4954*EC_{1:2.5}$) was selected for use in this study to predict EC_e from $EC_{1:2.5}$ in Magozi Irrigation Scheme due to its higher prediction accuracy as compared to $EC_e = 3.5381EC_{1:2.5} - 0.1337$.

5.0 Conclusions and Recommendations

This study showed that EC_e can be predicted from $EC_{1:2.5}$ for the soils of Magozi Irrigation Scheme. The linear regression model $EC_e = 3.4954*EC_{1:2.5}$ for combined soil textures showed high EC_e prediction precision when tested with the validation data set, indicating that, this model can be used to predict EC_e for the soils of Magozi Irrigation Scheme. This model can also be tested for potential application in Tanzanian soils especially in cases where there is limitation of sample size. However, the other developed linear models according to textural classes in this study can be tested in further similar researches by using adequate validation soil samples of individual textural classes so as to test for their capability in predicting soil EC_e for particular soil textural classes.

Similar studies are recommended to be done in other soils of Tanzania in order to establish more regional specific linear models to be used for prediction of EC_e from the commonly measured $EC_{1:2.5}$. The soil laboratories inTanzania can use such equations to save time and labour resources for determination of EC_e. This will also facilitate more relevant and precise soil salinity assessments in the country by providing EC_e values that are used to assess plant response to salinity as opposed to the current reliance on $EC_{1:2.5}$values for soil salinity assessment in Tanzania.

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Genetic Analysis of the Giant Tiger Prawns Reveals Priority Areas for the Establishment of Marine Protected Areas in Tanzania

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Abstract

Rapid growth of the human population along the Tanzanian coast has led to overfishing and habitat degradation, which might disrupt connectivity patterns and influence genetic diversity and population structure. Since knowledge about this is essential for sustainable management, this study analysed fragments of the mitochondrial control region (534 base pairs) from 123 giant tiger prawns (Penaeus monodon) collected at the Tanzanian coast.The sequences showed high haplotype ($h = 1 \pm 0.024$) and low nucleotide diversity ($\theta_\pi = 1.82 - 2.35$ %). Results of neutrality and mismatch analysis showed that the studied population experienced a bottleneck followed by periods of population growth in its recent history. Analysis of molecular variances did not detect significant genetic differentiation among sites ($F_{ST} = -0.0003$, $p > 0.05$; $\Phi_{ST} = -0.00251$, $p > 0.05$), suggesting that although the decline in prawn abundance is reported in some areas, the fishery is panmictic and it is capable to replenish overexploited areas. The estimates of the number of migrants showed that the estuarine mangroves at Pangani, Saadani, and Rufiji are the net exporters of migrants, implying that if these ecosystems are well protected, they have a potential to replenish depleted areas and improve the resilience of the fishery. Since the country is targeting to increase marine protected areas from 6.5 % to 10 % by 2020, priority should be given to the above mentioned estuaries.

Key words: Giant tiger shrimp, D-loop, Western Indian Ocean, East Africa

Introduction

Since time immemorial, the fishery of the giant tiger prawns (*Penaeus monodon*) has proved to have immense support to fishing communities along the Tanzanian coast and contribution to the National income. The fishery is predominantly artisanal and the main fishing grounds along the coast are associated with estuaries of large rivers(Kyomo, 1999). Adult giant tiger prawns inhabit estuarine mangroves, but because their larvae cannot withstand low salinity, matted females migrate to deep waters to spawn. After hatching, the larvae undergo a series of developmental stages before returning to estuarine mangroves, where they grow until they attain maturity (Garcia, 1988).Because the prawns have to migrate to offshore and estuarine ecosystems to complete their life cycle, degradation of any of these two ecosystems by anthropogenic or natural factors will automatically generate effect to the resources and may lead to the collapse of the resources in case there are no measures in place (Mosha

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and Gallardo, 2013).

Allestuarine mangroves in the country are nationally gazetted but due to poor surveillance, enforcement, and public awareness, the mangroves are threatened with overexploitation; anthropogenic pollution;the reduction of river flow; and mangrove clearing for agriculture, salt production, and urban development(Taylor *et al.*, 2003; Mangora, 2011; Rumisha *et al.*, 2016).Although the intensity of these activities varies among districts, the country lost about 1280 ha of mangroves between 2000 and 2005 (FAO, 2007). The loss threatens the sustainability of the giant tiger prawns which use mangroves as nurseries and feeding grounds. This is due to the fact that the loss of habitat can reduce the population size of the prawns and disrupt dispersal capabilities, which leads to reduced fitness of the population and genetic erosion (Dixon *et al.*, 2007). Significant evidence of genetic erosion and reduced dispersal capabilities due to mangrove deforestation are reported in the fiddler crab *Austruca occidentalis*and the Littorinid gastropod *Littoraria subvittata*from the Tanzanian coast(Nehemia and Kochzius, 2017; Nehemia *et al.*, 2017).

Also, the decline in prawn catches due to overfishing and destructive fishing practices is reported in several areas along the coast (Jiddawi and Ohman, 2002). It is estimated that during 2004 to 2007, the catch of prawns declined sharply from 661 to about 202 tonnes, respectively(Silas, 2011). The decline can have a devastating impact on marine ecosystems as it can destabilise the food chain and transform an originally stable, mature, and efficient ecosystem into one that is immature and stressed (Garcia *et al.*, 2003).Such transformation could have serious effects on the genetic population structure and the sustainability of the fishery, especially if the number of spawning adults is significantly reduced.In response to the decline, several measures were taken to enable the fishery to recover. The measures include a moratorium on prawn trawling, closed seasons, zoning, and rotation of prawn fishing vessels in fishing grounds (FAO, 2001). Furthermore, measures are taken to increase fish sanctuaries along the coast. According to the National Biodiversity Strategy and Action Plan 2015 – 2020, the country is targeting to expand marine protected areas (MPAs) from 6.5 % to 10 % by 2020 (URT, 2015). The MPAs are expected to improve the resilience of the fishery and protect the species from local extinctions by replenishing depleted areas. Despite the perceived benefits, there is limited information regarding the patterns of genetic connectivity among prawn fishing grounds, which is crucial for determining the priority areas for the establishment of MPAs. Furthermore, it is not known whether the giant tiger prawn fishery should be managed as a single panmictic stock or there are demographically isolated stocks which should be treated as separate management units. Since this information is essential for sustainable management,this study used fragments of the mitochondrial control region to establish whether there are genetically distinct subpopulations along the coast and to propose appropriate management measures.

Materials and methods

Study area

The study was conducted along the coastline of the Western Indian Ocean, Tanzania, which extends to over 800 km. Oceanic circulations in the region are driven by trade winds and the East African Coastal Current (EACC) which flows from south to north (Schott and McCreary, 2001). The current transports nutrients and larvae along the coast. Seven sampling sites were selected based on the availability of giant tiger prawns (Fig. 1). The sites included sites 2 (Pangani), 3 (Saadani), and 5 (Rufiji), which are the main prawn fishing areas. The study sites in these areas were located in estuarine mangroves at the mouth of river Pangani, Wami, and Rufiji respectively. Generally, the mangrove forests in these areas are relatively intact. The study site at Saadani (site 3) was located within the Saadani National Park, which is a protected area. The mangrovesites 1, 4, and 7 are located in Tanga, Dar es Salaam, and Mtwara respectively and are the most populated areas on the coastline. From 2002 to 2012, the population at sites 1, 4, and 7 increased by 12.6, 75.5, and 17.5% respectively (URT, 2013). Due to rapid growth in human population, increased fishing pressure and increased use of destructive fishing gears is reported in these areas (Jiddawi and Ohman, 2002; Mosha and Gallardo, 2013).

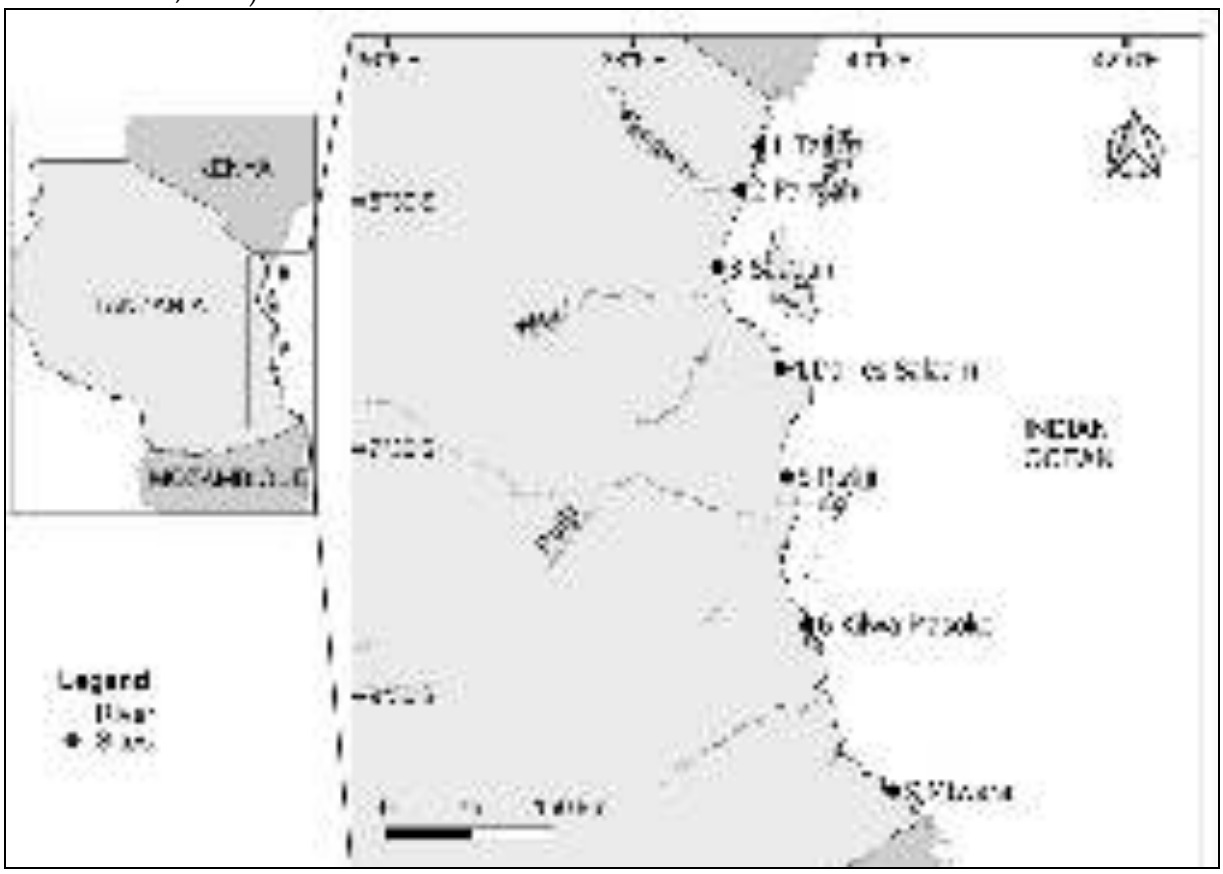

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Figure 1:Map of the Tanzanian coast showing sample sites (adapted from Rumisha *et al*. (2017a))

Sampling

Sampling of giant tiger prawns (P. monodon) was conducted between 2014 and 2016. A total of 123 individual giant tiger prawns were collected (Table 1). A section of the pleiopod tissue (about 50 mg) was collected from each individual and preserved in 95 % ethanol for molecular analysis. The geographical coordinates of each site were recorded with a GPS receiver and it is reported in Table 1.

Table 1:Number of samples analysed and the geographical coordinates of the sample sites

Sites		Coordinates		Number of samples	Sample identification number
		Latitudes (º S)	Longtudes (º E)		
1	Tanga	5.052	39.124	17	CR1 -17
2	Pangani	5.407	38.967	17	CR18 -34
3	Saadani	6.038	38.779	18	CR35 -52
4	Dar es Salaam	6.857	39.290	15	CR53 - 67
5	Rufiji	7.729	39.334	19	CR68 -86
6	Kilwa Masoko	8.926	39.508	19	CR87 - 105
7	Mtwara	10.272	40.214	18	CR106 -123
Total				**123**	

2.3 DNA extraction

Total DNA was extracted from the pleiopod tissue of *P. monodon* using the E.Z.N.A. Tissue DNA Kit (Omega Bio-Tek Inc., Norcross, USA). Tissue lysis, DNA extraction, and purification were performed according to the manufacturer's protocol. Agarose gel electrophoresis was performed to check the quality of the DNA extracts.

Polymerase chain reaction

Polymerase chain reaction (PCR) was performed using an MJ research PTC 200 Peltier thermocycler. A partial fragment (534 bp) of the mitochondrial control region was amplified using the primers 12S 5´-AAGAACCAGCTAGGATAAAACTTT-3´ and PCR-1R 5´-GATCAAAGAACATTCTTTAACTAC-3´ (Chu *et al*., 2003). The PCR was done in a total volume of 25 µL containing 10 ng of the DNA template, 0.45 U of the *Thermus aquaticus*(Taq) DNA polymerase, 0.2 µM of each primer, 0.2 mM DNTP, 3 mM $MgCl_2$, 1x Taq buffer, and 0.5 mg bovine serum albumin. The PCR conditions were: 5 min at 94 °C, followed by 35 cycles of 1 min at 94 °C, 1 min at 48.8 °C, and 1.5 min at 68 °C. A final extension step of 20 min at 68 °C was added to ensure complete amplification. Agarose gel electrophoresis was performed to determine the yield and quality of the PCR reactions. Sequencing of both strands was performed by Macrogen Europe. Pairwise alignment of the forward and reverse sequences was performed using the ClustalW

algorithm as implemented in MEGA ver. 6.0 (Tamura *et al.*, 2013) to generate consensus sequences of 534 base pairs.

Data analyses

A total of 123 mitochondrial control region sequences were obtained from the analysed tissues. A multiple sequence alignment was performed with the software MEGA ver. 6.1 (Tamura *et al.*, 2013). The program FaBox DNA collapser ver. 1.41 (Villesen, 2007) was used to collapse the aligned sequences into haplotypes. The same program was used to generate input files for population genetics software used in subsequent analysis. The number of haplotypes, haplotype diversity, and nucleotide diversity were determined with the program Arlequin ver. 3.5.1.2 (Excoffier and Lischer, 2010). The same programme was used to perform the analysis of molecular variance (AMOVA) and to compute a matrix of pairwise F_{ST}-values. The significance of pairwise F_{ST}-values was calculated by 10000 random permutations of haplotypes between populations. A minimum spanning haplotype network was constructed with the software PopART ver. 1.7 (Leigh and Bryant, 2015), to examine the relationship between haplotypes. Fu's Fs (Fu, 2007) and Tajima's D (Tajima, 1989) tests of neutrality were performed to evaluate the demographic history of the studied populations. Mismatch distribution analysis was performed to estimate the parameters of the sudden expansion model (Harpending, 1994). The program MIGRATE-N ver. 3.6.11 (Beerli and Palczewski, 2010) was used to estimate the mutation-scaled effective population size Θ ($2Ne\mu$) and the mutation-scaled migration rates ($M = m/\mu$) (where Ne = effective population size, m = immigration rate per generation, μ = mutation rate per generation) based on the full model. The program was run according to Rumisha *et al.* (2018). The number of immigrants per generation was obtained by multiplying Θ and M (Beerli and Palczewski, 2010). The net number of immigrants was determined for each site in order to identify potential sources of migrants (net number of immigrants = number of immigrants – number of emigrants).

Results

Genetic diversity and demographic history

A total of 123 mitochondrial control region sequences (534 base pairs) were obtained. Accession numbers were assigned to each sequence and the sequences were published in the GenBank repository(accession numbers: MK879924 - MK880046). The sequences showed 121 haplotypes and a total of 127 polymorphic sites (Table 2). All sites showed high haplotype diversity which is accompanied by low nucleotide diversity (Table 2). The lowest nucleotide diversity was observed at sites 1, 4, and 5.

Table 2: Average molecular diversity indices (± SE) for the giant tiger prawn *Penaeus monodon* from the Tanzanian coast. N = sample size, n_h = number of haplotypes, h = haplotype diversity, θ_π = nucleotide diversity, n_t = number of transitions, n_{tv} = number of transversions, n_{ps} = number of polymorphic sites. For sample sites, see Fig. 1.

	N	GenBank accession number	n_h	h	θ_π (%)	n_t	n_{tv}	n_{ps}
1	17	MK879924 – 40	17	1 ± 0.020	1.88 ± 1.01	50	8	56
2	17	MK879941 – 58	17	1 ± 0.020	2.23 ± 1.19	54	13	59

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3	18	MK879959 – 75	18	1 ± 0.019	2.15 ± 1.14	55	16	64
4	15	MK879976 – 90	15	1 ± 0.024	1.99 ± 1.07	47	10	53
5	19	MK879991 - MK880009	19	1 ± 0.017	1.82 ± 0.98	47	13	52
6	19	MK880010 – 28	19	1 ± 0.017	2.16 ± 1.15	53	17	59
7	18	MK880029 – 46	18	1 ± 0.019	2.35 ± 1.24	58	15	64

The Fu's Fs and Tajima's D test of the pooled mitochondrial DNA sequences showed significant deviation from the neutral evolution hypothesis (Tajima's D = -1.72, $p < 0.05$: Fu's Fs = -24.29, $p < 0.02$). Mismatch distribution of the pooled samples showed a unimodal distribution, which suggests recent population expansion (Fig. 2). The raggedness index and sum of squared deviations (SSD) (raggedness index = 0.00414, $p > 0.05$: SSD = 0.0001; $p > 0.05$) showed that the hypothesis of recent population expansion cannot be rejected. Selective neutrality tests and mismatch analysis were also performed for each population. Each sample site showed significant deviation from the hypothesis of neutral evolution (Table 3). In addition, the estimated raggedness indices for each site were not significant.

Table 3: Demographic parameters estimated under the selective neutrality tests and mismatch analysis of the mitochondrial control region sequences of *Penaeus monodon* at the Tanzanian coast. Bolded values are significant, τ =time in number of generations since expansion. For sample sites, see Fig. 1

Statistics	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Tajima's D	**-1.66**	-1.33	**-1.59**	-1.51	-1.41	-1.29	-1.36
Tajima's D p-value	0.032	0.073	0.044	0.052	0.067	0.086	0.078
FS	**-9.31**	**-8.19**	**-9.32**	**-7.14**	**-11.56**	**-10.23**	**-8.74**
FS p-value	0.001	0.001	0.001	0.001	0.000	0.001	0.001
τ	10.18	10.58	11.24	10.50	9.78	9.11	13.56
SSD	0.011	0.006	0.009	0.006	0.008	0.004	0.003
Model (SSD) p-value	0.26	0.56	0.30	0.60	0.32	0.74	0.81
Raggedness index	0.027	0.018	0.019	0.022	0.019	0.009	0.011
Raggedness p-value	0.21	0.41	0.35	0.44	0.35	0.81	0.79

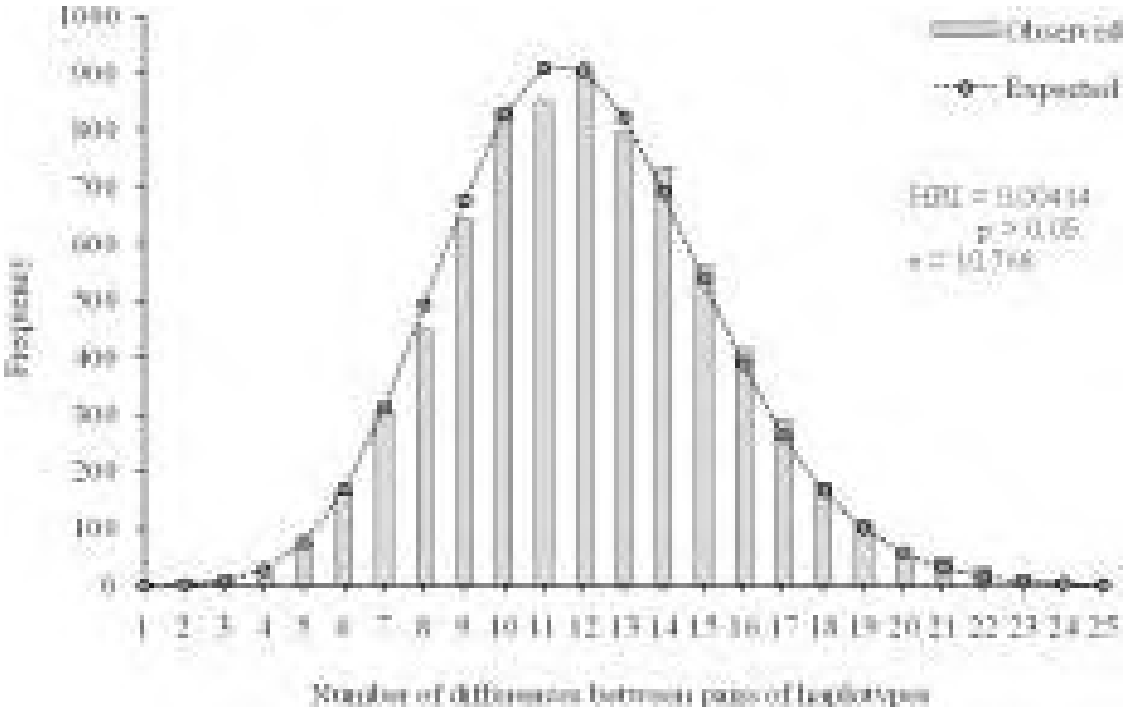

Figure2: Pairwise mismatch distribution showing a unimodal distribution of the mitochondrial control region haplotypes in *Penaeus monodon* from the Tanzanian coast. HRI = raggedness index, τ =time in number of generations since expansion.

Genetic connectivity among sites

The analysis of molecular variance (AMOVA) did not show significant genetic differentiation between sites (F_{ST} = -0.0003, p > 0.05; Φ_{ST} = -0.00251, p > 0.05). The observed lack of genetic structure was also revealed by the haplotype network (Fig. 3). The network did not produce a meaningful phylogeographic structure.The estimates of the number of migrants showed that each site receives migrants from adjacent ecosystems (Table 4). Furthermore, the analysis showed that the estuarine mangroves at sites 2 (Pangani), 3 (Saadani), and 5 (Rufiji) are the net exporters of migrants for recruitment at other sites. The effective population size (Θ) ranged between 0.1044 and 0.4342, with sites 3 and 5 showing the highest Θ (Table 4).

Table 4: Mutation-scaled effective population size (Θ) and gene flow (2Nem) in the giant tiger prawns from the Tanzanian coast

Site	Theta	Total immigrants	Total emigrants	Net number of immigrants
1	0.3531	493	186	307
2	0.1044	35	150	-114
3	0.4302	293	502	-209
4	0.3643	348	328	20
5	0.4342	308	374	-66
6	0.4009	359	300	59

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7	0.3460	407	403	4

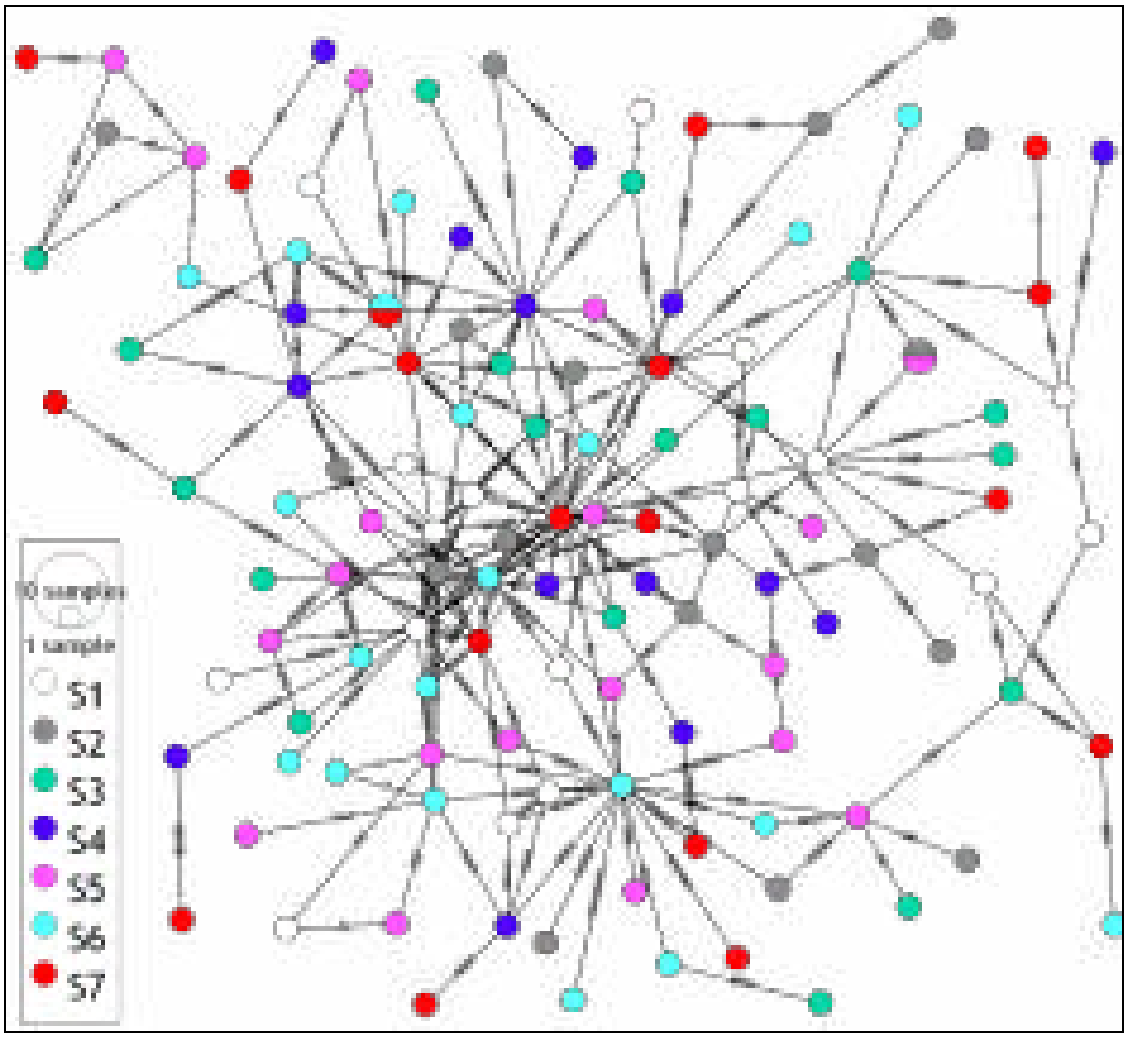

Figure 3: Minimum spanning network showing relationships among mitochondrial control region haplotypes in Tanzanian giant tiger prawns (*Penaeus monodon*). Each circle represents a haplotype. Size of each circle is proportional to the number of individuals carrying each haplotype. Hatch = mutations, S = site. For sample sites, see Fig. 1 and table 1.

Discussion

Genetic diversity and demographic history

The measured estimates of haplotype and nucleotide diversity are comparable to the findings of other researcher in the region (You *et al.*, 2008; Mkare *et al.*, 2014). The prawns showed high haplotype diversity (h = 1 ± 0.024) which is accompanied by low nucleotide diversity (θ_π = 1.82 – 2.35 %; Table 2). The observed high haplotype diversity

results from the excessive number of unique haplotypes and it is indicative of a large sustained population size. The idea that the population size of the giant tiger prawn is probably large, is supported by the fact that the measured indices of the effective population size (Table 4) are higher than those of other mangrove macroinvertebrates from the Tanzanian coast (Nehemia *et al.*, 2017; Rumisha *et al.*, 2017b, 2018). The fact that all sites showed high haplotype diversity coupled with low nucleotide diversity indicates that the population experienced periods of population growth in its recent history. This is supported by the results of neutrality and mismatch analysis which showed that the studied population experienced a bottleneck followed by a sudden population expansion. Furthermore, the hypothesis of recent population expansion was supported by the constructed hyplotype network (Fig. 3). The network revealed that the population contains121 unique haplotypes with close similarities in nucleotide sequences, which suggest that the haplotypes originated recently (Ferreri *et al.*, 2011). Recent population expansion is reported in several other mangrove fauna in the western Indian ocean (WIO) and it is attributed to the last glacial period (Silva *et al.*, 2013; Otwoma and Kochzius, 2016; Nehemia and Kochzius, 2017; Rumisha *et al.*, 2017b). Periodic rise and fall of the sea level during the period could account for the bottlenecks and subsequence expansion of populations in the WIO (Hewitt, 2000).

Genetic connectivity and its implications for fisheries management

The sequences did not show significant genetic differentiation among the sample sites(F_{ST} = -0.0003, $p > 0.05$; Φ_{ST} = -0.00251, $p > 0.05$).The analysis of molecular variance showed that variations among sites accounted for less than 1 % of the total variations. The lack of mitochondrial genetic differentiation is supported by the structure of the haplotype network (Fig. 3) which showed that the haplotypes are closely related, with no clear phylogeographic structure. The same pattern of mitochondrial genetic differentiation is reported in other mangrove macroinvertebrates in the WIO (Mkare *et al.*, 2014; Rumisha *et al.*, 2018) and it suggests that there are no barriers to gene flow among estuarine ecosystems at the Tanzanian coast. The lack of genetic differentiation between sites which are more than 700 km apart (sites 1 and 7),indicate thatthe giant tiger prawns can disperse fairly easily throughout the entire coast. This imply that, although the decline in prawn abundance is reported in some areas (Silas, 2011; Mosha and Gallardo, 2013), the fishery is panmictic and it is capable to replenish overexploited areas. Furthermore, it suggests that the spatial management strategies which are currently implemented or which might be developed in the future, should rather consider other ecological and socio-economic factors than the genetic delineation of the stock.

The estimates of the number of migrants showed that each site receives migrants from adjacent ecosystems (Table 4). Since the breeding season of prawns is associated with the rainy season(Kyomo, 1999), if the closure of fishing from December to February is properly enforced, it will protect the juveniles and enable them to disperse widely to replenish depleted areas. Also, a minimum mesh size should be imposed to protect the juveniles from unsustainable fishing practices. Currently, the minimum mesh size of 50 mm is imposed on commercial trawlers but it is rarely enforced on the artisanal fishers

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(Silas, 2011). The fishers use nets of smaller mesh size,which maximize the catch but also increase the proportion of juvenile prawns in the catch (FAO, 2001). Furthermore, the estimates of the number of migrates showed that the estuarine mangroves at Pangani, Saadani, and Rufiji are the net exporters of migrants (Table 4), implying that if these ecosystems are well protected, they have a potential to replenish depleted areas and improve the resilience of the fishery.According to the National Biodiversity Strategy and Action Plan 2015 – 2020, the country is targeting to expand marine protected areas from 6.5 % to 10 % by 2020(URT, 2015). Based on the observed patterns of migration, it is advisable that priority should be given to the above mentioned estuaries.

Conclusion

Knowledge of the genetic population structure is crucial for identifying biological units for fisheries management and for MPA spatial planning. This study revealed extensive gene flow among the giant tiger prawns at the Tanzanian coast implying that the fishery should be managed asa single randomly mated stock unless there are other ecological and socio-economic factors for spatial delineation of the stock. Furthermore, the study revealed that the estuary at Pangani, Saadani, and Rufiji are the net exporters of migrants for recruitment at other sites. This implies that although decline in abundance is reported in other prawn fishing grounds along the Tanzanian coast, the above mentioned estuaries are capable to replenish depleted areas. Since the country is planning to increase MPAs from 6.5 % to 10 % by 2020 (URT, 2015), it is advisable that priority should be given to the above mentioned estuaries.

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Smallholder Farmers' Beliefs on Quality Seeds of Improved Common Bean Varieties in Tanzania

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Abstract

This paper examined smallholder farmers' beliefs influencing their decision of using quality seed of improved common bean varieties. The study adopted the Theory of Planned Behaviour. Using a serial cross-sectional research design, quantitative and qualitative data were collected in two phases. In the first phase, an elicitation study was conducted to determine smallholder farmers' salient beliefs regarding the use of quality seed of improved common bean varieties. In the second phase, a survey was conducted to collect useful data for determining the influence of beliefs on smallholder farmers' attitudes, subjective norm and perceived behavioural control toward using quality seed of improved common bean varieties. The findings indicate that farmers' decision to use quality seed of improved common bean varieties is influenced by various behavioural, normative and control beliefs. These included quality seed unavailability, low market potential for produces from improved varieties, inadequate extension services, low family income and high costs of associated inputs. The findings indicate further that behavioural, normative and control beliefs significantly influenced smallholder farmers' attitude, subjective norm and perceived behavioural control respectively. Therefore, attempts to increase smallholder farmers' use of quality seed of improved common bean varieties have to pay attention on their beliefs towards quality seed.

Key words: quality seeds, theory of planned behaviour, behavioural beliefs, normative beliefs, control beliefs

Introduction

Efforts have been and are ongoing to come up with various improved agricultural technologies. For instance, landraces have been improved by modifying their tolerance to a/biotic stresses, yield capacity and adding nutritional value to come up with improved varieties. Studies on the contribution of quality seed of improved varieties to increased productivity are well documented. For example, Oyekale (2014) indicates that when quality seed of improved variety is used in production yield increases by 10 to 15%. In a similar vein, Kalyebara and Andima (2006) cited by Rubyogo *et al*. (2010) reported an increase in yield by 30% to 50% when quality seed of improved common bean variety was used in production. Furthermore, Birachi *et al*. (2011) reported an increase by 22% when improved common bean varieties are used in production.

Nevertheless, smallholder farmers' demand for quality seed of improved varieties has remained low for years as reflected by their use. For example, some seed studies show that the use of improved varieties is only 4% (Adetumbi *et al*., 2010; Lazaro and Muywanga, 2008); 5% (ASARECA/KIT, 2014); 3-20% (CTA, 2014); 10% (MAFC, 2013); and <20% (Etwire *et al*., 2013). At the same time, studies on smallholder farmers'

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decision to use improved technologies in agricultural production have broadly identified technological, economic, institutional and human specific factors (Mwangi and Kariuki, 2015) as the major determinants of adoption. As such, studies on adoption of improved agricultural technologies have paid little attention with regard to how beliefs possessed by the adopter as well as the social system that influence the intention to use the recommended technologies.

Theoretical and Conceptual Framework

How beliefs possessed by the adopter as well as the social system influence intention to use the recommended technologies is better articulated by the Theory of Planned Behaviour (TPB), which was thus adopted for this study. Using the theory, this study adds to the existing body of knowledge by establishing beliefs held by smallholder farmers which in turn influence their intention to use quality seed of improved common bean varieties. These beliefs are grouped into behavioural, normative and control beliefs.

On one hand, behavioural beliefs pay attention to the usefulness, easiness and compatibility of quality seed of improved common bean varieties with smallholder farmers' production practices. On the other hand, normative beliefs pay attention to individuals, people, institutions or practices which encourage or discourage smallholder farmers' decision to use quality seed of improved common bean varieties in production.

Adding to behavioural and normative beliefs, control beliefs focus on internal and external factors influencing smallholder farmers' decision to use quality seed of improved common bean varieties. Internal factors stem from the confidence smallholder farmers have in terms of knowledge, skills, experiences, exposure and abilities to use quality seed of improved common bean varieties in production. In contrast, external factors emanate from opportunities and resources available for smallholder farmers to be able to use quality seed of improved common bean varieties in production.

According to the Theory of Planned Behavior, behavioral beliefs, attitudes, normative beliefs, subjective norms, control beliefs, perceived behavioral control and behavioral intention are the major constructs which determine behavior (Ajzen, 1991, 2006; Borges *et al*., 2015; Chiou, 1998; Francis *et al*., 2004; Hasbullah *et al*. 2014; Lee *et al*., 2010). Studies based on the Theory of Planned Behaviour have established that behavioral beliefs, attitudes, normative beliefs, subjective norms, control beliefs, perceived behavioral control and behavioral intention predict famers' decision to use technologies (Ahmed *et al*., 2015; Kühne *et al*., 2014; Herath, 2013; Sharifzadeh *et al*., 2012). Nevertheless, there are hardly any studies that used Theory of Planned Behaviour to predict smallholder farmers' decision of using quality seed of improved common bean varieties.

However, to establish intention, one has to determine beliefs first. Shikuku *et al*. (2019) maintain that the link between beliefs and human behaviour has long been recognized. Therefore, the fact that beliefs influence smallholder farmers' decision to use quality seed of improved common bean varieties need to be explored. The problem then is how

does this take place? Therefore, this study elicited behavioral beliefs, normative beliefs, and control beliefs as indirect predictors of intention to use quality seed of improved common bean varieties.

Methodology

The study was conducted in Iringa, Kigoma, Kilimanjaro, Manyara, Mbeya, Morogoro and Njombe regions. The sampled regions represented major common beans producing regions in Western/Great lakes, Northern, Southern and Eastern Zones. The study used serial cross-sectional research design. This design, allows data to be collected from more than once in the same study population at different time points (Pandis, 2014). Therefore, using a serial cross-sectional research design, quantitative and qualitative data were collected in two phases. In the first phase an elicitation study was conducted to determine smallholder farmers' salient beliefs regarding use of quality seed of improved common bean varieties.

To obtain representative beliefs possessed by smallholder farmers, multistage sampling technique was used. In the first stage, study regions were randomly selected from all major producing regions. In the second stage, study districts were randomly selected from the sampled regions. This was followed by random selection of one village per study district. Finally, smallholder farmers were randomly selected to participate in the elicitation study. In this process, Kasulu, Kilolo, Mbeya, Moshi, Mvomero, Siha and Wanging'ombe districts were used for elicitation study with 107 respondents. An open ended questionnaire was used to determine beliefs held by smallholder farmers about quality seed of improved common bean varieties.

In the second phase a survey was conducted in Babati, Kasulu, Mbeya and Mvomero districts to collect data to be used for determining the influence of beliefs on the direct determinants of smallholder farmers' intention to use quality seed of improved common bean varieties. Behavioral beliefs, normative beliefs and control beliefs data were collected from 311 randomly selected smallholder farmers to determine the influence on attitude, subjective norm and perceived behavioural control respectively.

Content and thematic analysis approaches were used to establish themes which represented various beliefs. Using descriptive analysis frequencies and percentages were used to determine the most frequently reported beliefs. To determine the influence of behavioural beliefs, normative beliefs and control beliefs on attitude, subjective norm and perceived behavioural control respectively, linear regression analysis was conducted as recommended by Francis *et al*. (2004). Behavioural beliefs, normative beliefs and control beliefs which are the independent variables were regressed against attitude, subjective norm and perceived behavioural control respectively, which are the dependent variables.

Results

Behavioural beliefs

To determine smallholder farmers' behavioural beliefs, the study paid attention on what farmers believe to be the advantages of using quality seed of improved common

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bean varieties. This aimed at capturing valued outcomes from using quality seed of improved common bean varieties. The results are presented in Table 1 and they indicate that 94% of respondents consider quality seed of improved varieties to have attractive agronomic traits. The traits included high germination rate, vigour, attractive colour, early maturity, low fertilizer need, growth uniformity, no climber, not mixed, very productive, high yielding, very attractive, large seeded.

Table 1: Distribution of respondents by believed advantages of using quality seed of improved common bean varieties (n=107)

Advantage	Frequency (n=107)	Per cent
Attractive agronomic traits	101	94
Livelihood improvement	74	69
Attractive traits potential for marketability	56	52
Quality assurance	45	42
Tolerant/resistant to a/biotic stresses	32	30
Uniformity	9	8

Although respondents indicated several believed advantages of using quality seed of improved common bean varieties, concerns were also expressed. Table 2 indicates that they have several disadvantages or they are accompanied by several challenges.

Table 2: Distribution of respondents by believed challenges/disadvantages of using quality seed of improved common bean varieties (n=107)

Challenge/disadvantage	Frequency (n=107)	Per cent
Costs to meet additional inputs	32	30
Low marketing potential	28	26.2
Tolerance/Resistance	25	23.4
Unavailability of quality seed	27	21.5
Inadequate extension services	22	20.6
Microclimate factors	15	14
Non attractive agronomic traits	15	14
Seed quality attributes	13	12.1
Farm management/operational costs associated with using these seed	23	6.5

Attitude resulting from Behavioural Beliefs

Using the formula A = ∑ (Be x Oe), A= +4198.618. Where A=Total attitude score, Be=Behavioural beliefs, Oe=Outcome evaluation. The overall attitude is positive suggesting that smallholder farmers are in favour of quality seed of improved common bean varieties. Possible score could be [7x+/-3] x 311] =6531. Where [7x+/-3] is possible score i.e. scores ranged from -3 to +3, 311 is the number of respondents. Therefore, the possible range could be-6531 to +6531 indicating that smallholder farmers have weak to moderate positive attitude towards quality seed of improved common bean varieties.

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The overall attitude possessed by smallholder farmers toward quality seed of improved varieties is the mean value obtained by using the formula [A = ∑ (Be x Oe)/N = +4198.618/311=13.5004]. The maximum score range is -21 to +21. The average score 13.5004 indicates that smallholder farmers have weak to moderate positive attitude toward quality seed of improved common bean varieties. Besides, this indicates that generally smallholder farmers are in favour of using quality seed of improved common bean varieties.

The influence of behavioural beliefs on attitude

Linear regression analysis was conducted to determine the influence of smallholder farmers' behavioural beliefs on attitude towards quality seed of improved common bean varieties. Paying attention on coefficients, Table 3 below indicate that behavioural beliefs have a significant influence on smallholder farmers' attitude towards quality seed of improved common bean varieties.

Table 3: The influence of behavioural beliefs on smallholder farmers' attitude towards quality seed

	Unstandardized Coefficients		Standardized Coefficients		
Factor	B	Std. Error	Beta	t	Sig.
Constant	4.389	.102		43.104	.000**
Weighted attitude*	.089	.007	.583	12.629	.000**

*Attitude being a product of behavioral beliefs and outcome evaluation

**. Significant at the 0.01 level

Normative beliefs

To determine normative beliefs, the study examined individuals/groups of people who approve respondent's use of quality seed of improved common bean varieties. Using descriptive statistics frequencies and percentages were determined as presented in Table 4 below.

Table 4: Distribution of respondents by individuals/groups of people who approve use of quality seed of improved common bean varieties (n=107)

Individuals/groups	Frequency (n=107)	Per cent
Agricultural experts	107	100
Relatives	99	92.5
Group members	52	48.6
Leaders	27	25.2
Friends	21	19.6
Common bean buyers	19	17.8
Neighbours	15	14
Faith related people	10	9.3
Community members I live with	2	1.9

Table 4 indicates that agricultural experts are the most fore front individuals in advising smallholder farmers to use quality seed of improved common bean varieties. This was indicated by all respondents (100%) involved in the study. Agricultural experts included agricultural extension officers, irrigation technician, NGOs, Company, Institutions, Farmer facilitators, agricultural projects officers, agricultural researchers, and development partners.

Table 4 also indicates that relatives are very important individuals who encourage smallholder farmers to use quality seed of improved common bean varieties. This was expressed by nearly all respondents (92.6%). Relatives included wife, husband, children, uncle, aunt, brother, father, sister, in law, and family members.

Adding to individuals or groups approving respondent's use of quality seed of improved common bean varieties, the study determined individuals/groups of people who disapprove respondent's use of quality seed of improved common bean varieties.

Table 5: Distribution of respondents by individuals/groups of people who disapprove use of quality seed of improved common bean varieties (n=107)

Individuals/groups	Frequency (n=107)	Per cent
Fellow farmers	21	19.6
Businessmen	18	16.8
Neighbours	14	13.1
Relatives	13	12.1
Agroinput sellers-stockists	12	11.2
Friends	10	9.3
Older people	9	8.4
Common bean vendors	8	7.5
NGOs	3	2. 8
Seed companies	2	1.9
Livestock keepers	1	0.9
Farmers sowing by tractors	1	0.9
Farmers with large farms	1	0.9

Table 5 indicates various individuals who disapprove smallholder farmers' decision to use quality seed of improved varieties. This list is long and contains mostly primary common bean stakeholders. Smallholder farmers are surrounded with individuals who have a strong influence on their common bean production practices.

Subjective norm resulting from Normative beliefs

The formula $Sn = \sum (No_{be} \times Mo_{co}) = +3786.813$. Where Sn =Total subjective norm score, No_{be}= Normative beliefs, Mo_{co}= Motivation to comply was used. By this formula a positive (+) Sn score [+3786.813] means that, overall, the participant experiences social pressure to use quality seed of improved common bean varieties**.** The possible score could be [7x+/-3] x 311 where [7x+/-3] is possible score range i.e. score

ranged from -3 to +3, while 311 is the number of respondents indicating that the variable has been scored 311 times. The possible range is -6531 to +6531. Compared with the actual score obtained, the findings indicate that smallholder farmers experience moderate social pressure to use quality seed of improved common bean varieties.

The overall subjective norm possessed by smallholder farmers toward quality seed of improved varieties is an average calculated by the formula [$Sn = \sum (No_{be} \times Mo_{co})/N = +3786.13/311=12.1762$]. The maximum score range is -21 to +21. The average score 12.1762 indicates that smallholder farmers experience a weak to moderate social pressure to use quality seed of improved common bean varieties.

The influence of normative beliefs on subjective norm

Linear regression analysis was conducted to determine the influence of smallholder farmers' normative beliefs on subjective norm towards quality seed of improved common bean varieties. In reference to coefficients, the findings in Table 6 indicate that normative beliefs have a significant influence on smallholder farmers' subjective norm towards quality seed of improved common bean varieties.

Table 6: The influence of normative beliefs on subjective norm

	Unstandardized Coefficients		Standardized Coefficients		
Factor	B	Std. Error	Beta	t	Sig.
Constant	4.954	.096			
Subjective norm*	.014	.007	.121	2.141	.033*

*Resulting from the product of normative beliefs and motivation to comply

* Significant at the 0.05 level

2.3.2.7 Control beliefs

To determine control beliefs possessed by smallholder farmers about quality seed of improved common bean varieties, the study examined things/situations/reasons/environments which simplify/facilitate respondents' ability to use of quality seed of improved common bean varieties. The results are indicated in Table 7 below.

Table 7: Distribution of respondents by factors which facilitate smallholder farmer's ability to use quality seed of improved common bean varieties (n=107)

Factor	Frequency (n=107)	Per cent
Having farming capital	87	81.3
Having fertile land for common bean production	59	55.1
Presence of sufficient rainfall	36	34
Having crop stock for sale to manage farm operations	34	32
Having knowledge on how to use improved seed	33	31
Presence of an agricultural extension officer	27	25.2
Having oxen for managing farm operations	18	17

Availability of producers and distributors of quality seed of improved common bean varieties	9	8.4
Reliable markets	2	1.9

Table 7 indicates that having farming capital 81.3%, fertile land for common bean production 55.1%, sufficient rainfall 34%, crop stock for sale to manage farm operations 32%, education on how to use improved seed 31%, and presence of an agricultural extension officer 25.2% simplify one's ability to use quality seed of improved common bean varieties.

Adding to factors which facilitate respondent's ability to use quality seed of improved common bean varieties, factors which make it difficult or impossible for respondents to use quality seed of improved common bean varieties were also examined. The results are presented in Table 8 below.

Table 8: Distribution of respondents by factors which make it difficult or impossible to use quality seed of improved common bean varieties (n=107)

Factor	Frequency (n=107)	Per cent
Low family income	83	78
Unavailability of quality seed of improved varieties	81	76
Weather variability	40	37
High costs of associated inputs	37	35
Inadequate extension services	36	34
Lack of agricultural land	27	25.2
Lack of markets for produce from improved varieties	18	17
Lack of agricultural machinery	10	9.3
Seed quality	8	7.5
Farm management costs associated with using improved varieties	7	6.5
High seed prices	4	3.7

Table 8 indicates that low family income 78%, unavailability of quality seed of improved varieties 76%, weather variability 37%, high costs of associated inputs 35%, inadequate extension services 34%, lack of agricultural land 25.2%, lack of markets for produce from improved varieties 17%, seed quality issues 7.5% and Farm management costs associated with using improved varieties 6.5% make it difficult or impossible to use quality seed of improved common bean varieties.

2.3.2.8 Perceived Behavioural control resulting from Control beliefs

Perceived Behavioural control is weighted score computed by the formula PBC = $\sum (Co_{be} \times Co_{bepo})$ = +601.084; Where PBC=Total Perceived Behavioral Control score, Co_{be}= Control beliefs, Co_{bepo} = Control belief power. Based on this formula a positive (+) PBC= +601.084 score means that, overall, the participant feels to have control to use quality seed of improved common bean varieties**.** Possible score could be [7x+/-3] x 311 where [7x+-3] indicates the possible score range i.e. from -3 to +3 while 311 represents

the number of respondents indicating the number of times a variable is answered. The possible range could have therefore been -6531 to +6531 which indicates that smallholder farmers had neutral to weak feeling of having control over use of quality seed of improved common bean varieties.

The overall Perceived Behavioural Control possessed by smallholder farmers toward quality seed of improved varieties is an average score determined by the formula [PBC = $\sum (Co_{be} \times Co_{bepo})/N$ = +601.084/311=1.9327]. The maximum score range is -21 to +21. The average score 1.9327 indicates that smallholder farmers feel to lack or have very weak control to use quality seed of improved common bean varieties**.**

2.3.2.9 The influence of control beliefs on Perceived Behavioral Control

Linear regression analysis was conducted as recommended by Francis *et al*. (2004) to determine the influence of smallholder farmers' control beliefs on perceived behavioural control towards quality seed of improved common bean varieties. Paying attention to coefficients, the findings in Table 9 indicate that control beliefs have a significant influence on smallholder farmers' perceived behavioral control towards quality seed of improved common bean varieties.

Table 9: The influence of control beliefs on perceived behavioral control

	Unstandardized Coefficients		Standardized Coefficients		
Factor	B	Std. Error	Beta	t	Sig.
Constant	5.605	.068		82.606	.000
Perceived behavioural control*	-.023	.009	-.141	-2.510	.013*

*****Perceived behavioural control resulting from control beliefs and power of control factors

*Significant at the 0.05 level

Discussion

In a situation where there is low family income, quality seed of improved common bean varieties are not available, high cost of associated inputs, inadequate extension services, and lack of markets for produce from improved varieties, something must be done to promote use of quality seed of improved varieties. These findings are more or less similar to what Mwangi and Kariuki (2015) found when reviewing literature on adoption. In their review they found economic factors which included farm size, net gain from adoption, cost of adopting the technology, and high cost of the technology to influence adoption. They also found access to extension services and credits to be key in adoption of technologies.

ASSARECA/KIT (2014) found that availability of pre-basic seed is highly inadequate which leads unavailability of certified seed. Similarly, Mitschke (2015) when determining constraints to adoption of improved common bean varieties and seed in Hai District Tanzania found unavailability of quality seed of improved varieties and concluded that there is no supply chain in place. Ayoola *et al*. (2015) found seed availability to be a proximate determinant for seed demand in Nigeria. Similarly,

Birachi *et al*. (2011) found lack of improved varieties to influence common beans production and marketing in Burundi. This implies that if they are not available they cannot be demanded. In a situation like this, it becomes difficult if not impossible to use quality seed of improved common bean varieties. This is what made Buruchara *et al*. (2011) to recommend promotion of breeder and foundation seed production. In a more or less similar way, Munyanka *et al*. (2015) recommend agricultural research institutions to promote uptake of their newer varieties through interactions with farmers. They went further to recommend smallholder farmers or community seed enterprises be contracted to produce certified seed in their community for supply in their local communities. The lack of improved varieties was also found by Birachi *et al* (2011) when determining constraints to common beans production and supply to markets in Burundi.

Mneney *et al*. (2016) found unavailability of quality seed of improved varieties to have been caused by limited demand for quality seed. In order to create demand for quality seed of improved varieties agricultural research institutions, Agricultural Seed Agency (ASA) and seed companies have to play their roles. Since seed companies have low interest in common beans, ASA has to be more proactive to ensure quality seed of improved common varieties are available. ASA has to ensure adequate distribution channels at least in major common beans producing regions. This can even be achieved by having contract farmers in major common beans producing regions.

Since low family income is a common practice among smallholder farmers in rural areas, there is no wonder that they do not use quality seed of improved common bean varieties. This is even worsened by unavailability of seed making it difficult to be found. Furthermore, being sold at high prices with high costs of associated inputs, using quality seed of improved common bean varieties excludes smallholder farmers. Although they are unavailable and very expensive, purchasing them is a risk due to adulteration which raises seed quality issues. How can one buy something expensive while is not sure of its quality? Ayoola *et al*. (2016) found attitude to seed price to be a proximate determinant for seed demand. In a situation where farmers perceive seed to have high price while produces from these seeds are sold at lower prices or sometimes lack market for sale. It is difficult for one to easily use them. Mneney *et al*. (2016) found that good quality seeds were not reached by farmers in Arusha and Mbeya due to high prices. In an attempt to establish factors influencing common bean profitability in Babati District Tanzania, Venance *et al*. (2016) found selling price and access to credit to have affected gross margin realized by smallholder farmers.

Conclusions and recommendations

Conclusions

The study examined smallholder farmers' beliefs that influence their decision on using quality seed of improved common bean varieties. The study also determined if these beliefs influences smallholder farmers' attitude, subjective norm, and perceived behavioural control. Generally, smallholder farmers have various behavioural, normative, and control beliefs towards quality seed of improved common bean varieties, and which influence their attitudes, subjective norm and perceived

behavioural control. Smallholder farmers were found to have weak to moderate positive attitude toward quality seed of improved common bean varieties. Moreover, smallholder farmers experience weak to moderate social pressure on using quality seed of improved common bean varieties. Furthermore, smallholder farmers lack or have very weak control over the use of quality seed of improved common bean varieties. These factors are mainly resulting from unavailability of quality seed of improved common bean varieties, low family income, low market potential of produce from improved common bean varieties, high costs of associated inputs, and inadequate extension services.

Recommendations

Since quality seed of improved common bean varieties are not easily available to the farming community, efforts of making them available and accessible have to consider distribution channels which come closer to the farming community mainly smallholder farmers. Evidence has indicated that seed dealers are not interested in trading quality seed of improved common bean varieties due to seed recycling hence unavailability. There is need for seed stakeholders to search for alternative seed delivery systems for common beans.

Since produces from quality seed of improved common bean varieties experience low marketing potential, there is need for strengthening breeding activities which target market led varieties. Several varieties have been released but not easily adopted due to lack of market outlet for these varieties. Smallholder farmers sell their products to common bean vendors and/or common bean businessmen who know where to take the produces. Involving common beans vendors, traders and consumers who play a significant role in distribution and marketing is very important for the adoption of improved common beans among smallholder farmers. There is a need for breeders and seed multipliers to focus on market led varieties

In a situation where there are inadequate extension services, improving access to extension services is essential. There is a need of strengthening extension services dealing with quality seed of improved common bean varieties. There is a need of improving the quantity and quality of extension services. This would increase the possibility for smallholder farmers to use quality seed of improved common bean varieties. Evidence indicated that even vendors, common beans buyers, and consumers are not aware of most of these released varieties. Therefore, strengthening extension services would not only benefit farmers but also other common beans stakeholders. Therefore, extension services providers should play their roles actively.

In a situation where there is high cost of associated inputs coupled with low family income, credits are considered paramount. There is a need of establishing credits scheme, which would be specific to producers of common beans. The main initiative targeting seed is National Agriculture Input Voucher Scheme, but then again this scheme does not pay much attention to quality seed of improved common bean varieties. Therefore, financial institutions should expand their credit schemes to benefit common beans producers. Additionally, the Ministry of Agriculture is expected to

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consider including common beans in the National Agriculture Input Voucher Scheme.

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Livelihood Strategies among Unmarried Adolescent Mothers of Rural and Urban Katavi, Tanzania

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Abstract

Unmarried adolescent mothers (UAMs) in Sub Saharan Africa including Tanzania, face a lot of challenges,one of them being livelihood insecurity. The study sought to examine the various types of livelihood strategies engaged by unmarried adolescent mothers (UAMs) in Katavi region, Tanzania whereby Mpanda Municipality and Tanganyika District were purposely selected to represent urban and rural Katavi respectively. The study further determined association between livelihood strategies and the two localities and to identify the dominant livelihood strategies among the localities. A cross-sectional research design was adopted for the study whereby data were collected using non-probability convenience sampling approach with a sample of 240 UAMs. Descriptive statistics were used to present the livelihood strategies in form of frequency and percentage while Chi-Square Test was used to determine the relationship between adopted livelihood strategies and the localities. Quantitative data were supplemented with rich qualitative data analysed through content analysis. The approach used to classify UAMs' livelihood strategies is based on the main income activities as stated by the UAMs based on a predetermined list of six categories of livelihood strategies established from a pilot study. Study findings show a significant relationship ($p < 0.000$) between livelihood strategies and locality with trading emerging as the dominant livelihood strategy in both localities.The study recommends that governmental and nongovernmental institutions need to provide life-skills and entrepreneurial skills to UAMs to enable them to employ themselves. It is further recommended that for those UAMs aspiring to upgrade their education could do so through the Qualifying Tests programme.

Key words:*unmarried adolescent mothers, livelihood strategies, teenage pregnancy and Katavi*

Introduction

Non-marital adolescent motherhood exposes adolescent mothers to multiple consequences among others being livelihood insecurity. Teenage motherhood is a situation in which a girl in her teenage years becomes a mother as a result of getting pregnant. By definition, an adolescent mother therefore is a young woman, who became pregnant, gave birth to a child and chose to raise the child before the age of 18 (Gallant and Terisse, 2000). The present study operationalizes the concept of an unmarried adolescent mother as a young woman of 19 years or less, who became pregnant, gave birth and chose to raise the child prior to getting married. On the other hand, livelihood strategies are ranges of activities that people carry-out in order to make a living. In addition, the ways in which people access and use livelihood assets in social, economic, political and environmental contexts form a livelihood strategy (IRP and UNDP, 2010).

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Adolescent childbearing has negative consequences to the life of an adolescent mother.According to McDermott *et al*. (2004), adolescent mothers tend to be poor and care for their children in impoverished circumstances that are hard to either escape from or to improve. Women who bear children at a very young age have limited education, limited job opportunities, limited choices for the future and high degree of dependence (Population Reports, 1995 cited in Odu *et al*., 2015) hence, adolescent motherhood is widely recognized as a cause of poor labour outcomes for mothers (Holmlund, 2005). Teenage pregnancy also implies the end of formal schooling or training and restriction to future opportunities to improve one's status. Arguably, adolescent mothers are more likely than older mothers to live in socio-economic deprivation and have low level of education and literacy (Odu *et al*., *ibid*). It is also worth noting that, teenage pregnancy and early childbearing (including non-marital) are higher in economically poor households with low-incomes hence, girls being more likely to experience unintended pregnancies and hence early non-marital childbearing (Ayele, 2013; Marcen and Bellido, 2013; Ajala, 2014).

The incidence of early childbearing According to Becker (1993) tends to raise the opportunity costs of accumulation in human capital. As argued earlier, being a teen mother may hinder human capital investment since it is during adolescence that one's education is attained. Given the high drop-out rates of teen mothers, they are unlikely to attain college degree which is more valuable in labour markets. Moreover, motherhood affects adolescent's education to a great extent because, to an individual adolescent mother the incidence implies living without obtaining the minimum educational requirements needed for entering the labour marketas well as chances of ever getting a good job, being more dependent and hence trapped in poverty (Furstenberg and Teitler, 1994; Petchetisky 1984; Odu *et al*., 2015). According to Odu *et al*. (*ibid*), having a child further implies that an adolescent mother is barred from returning to school hence, being denied opportunities as well as vocational training. In a similar vein, Hofferth *et al.* (2001) conclude that, early childbearing lessens the likelihood that young women will complete their schooling, thereby weakening employment prospects. Due to being less educated and unskilled, most Unmarried Adolescent Mothers (UAMs) are being forced to perform menial or semi-skilled jobs in order to provide for their children and incomes earned by those who did notcontinue with their studies is lower compared with those who finished their studies (Luster and Okagaki;Kiernan 1998 cited in Odu *et al*., 2015; Nyagetia 2015). However, the jobs that they engage in pay very little thus risking the UAMs and their children's wellbeing and livelihood security.

Unmarried adolescent mothers in Sub Saharan Africa (SSA) face a lot of challenges one of them being livelihood insecurity(Nyagetia, 2015). Although a great deal of research has been done on adolescent mothers, very few studies have focused on studying their livelihood strategies and even much fewer have specifically dealt with the unmarriedadolescent mothers. At both global and regional levels, studies on adolescent motherhood have focused on multidimensional nature of the phenomena to include *inter alia* its underlying causes and the associated consequences. Among such studies

are those by Thompson *et al.* (1995); Buvinic (1998); Beutel (2000); Boden *et al*. (2008); Schuyler Center for Analysis and Advocacy (2008) and Ajala (2014). Other studies have focused on the relationship between adolescent motherhood and educational attainment. Such studies include those of Bellamy (2017); Gyan (2013); Tabetando and Ahidjo (2015); and Timaeus and Moultrie(2015). Apart from these few, studies on adolescent motherhood have also focused on many more other issues. It is also worth noting that, studies on livelihood strategies of adolescent mothers are both few and geographically unevenly distributed with a large portion of them existing in regions of Latin America and the Caribbean (LAC). A majority of studies in LAC have been conducted in the Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua and Panama.Most of these studies have been exclusively done in rural context neglecting the urban context. Other similar studies have been carried out in some countries of South Central Asia such as Afghanistan, Bangladesh and Nepal. However, childbearing among unmarried adolescents is relatively more common in the LAC, SSA and the developed countries like United States and United Kingdom compared to other regions such as Asia, North Africa and the Middle East (Singh and Darroch 2000; Smith and Mills, 2012). As argued earlier, in most of the related empirical literature, issues of livelihood strategies of UAMs are rarely mentioned.

Sub Saharan Africa is reported as one of the regions in the world with high Adolescent Birth Rate (ABR) and similarly, WHO (2007) reported a progressive increase in non-marital childbearing among adolescent mothers in some SSA countries. In SSA, each year, births to adolescent girls accounts for 16% of all births in the region (UNFPA, 2013). Since most of the UAMs are from poor family backgrounds, their livelihoods are limited; resulting in lack of basic needs and inadequate care for their children. Despite these realities, studies on livelihood strategies of UAMs in the region are hard to find. Existing empirical studies have, to a larger extent, focused on causes and consequences of teenage pregnancy in various parts of the region. For instance, Ajala (2014) studied factors associated with teenage pregnancy and fertility in Nigeria; Ayele (2013) studied differentials of early teenage pregnancy in Ethiopia; Nyagetia (2015) studied challenges of unmarried adolescent motherhood in Kenya; while Mbelwa and Isangula (2012) studied factors for teenage pregnancy in Tanzania. According to Nyagetia (2015) SSA countries are the most affected when it comes to challenges affecting adolescent mothers compared to other parts of the world as most adolescent mothers come from poor backgrounds hence face difficulties in accessing essential commodities to sustain themselves and their babies. Generally, the majority of adolescent mothers live in rural areas were poverty rates are high among young women (World Bank, 2009). In a nutshell, in most of the studies listed above, less has been reported concerning the livelihood strategies of UAMs as well as comparing the livelihood strategies practiced by urban and rural UAMs. Moreover, even the few related studies available have mainly targeted rural UAMs, neglecting the urban ones.

In Tanzania, the ways in which rural and urban UAMs strive to survive with their children also remains unknown at least in the context of the study area. In Katavi, where the present study was conducted, ABR is the highest among all the regions in

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Mainland Tanzania and the percentage of adolescent mothers is also the highest as well (36.8%) (URT,2016). Therefore, the paper specifically aims at examining the existing types of livelihood strategies that UAMs of rural and urban Katavi engage in as well as assessment of the dominant livelihood strategies with regard to the two localities. This will involve identification and critical analysis of the existing livelihood strategiesto capture the dominant ones as well as justification for their choice. The findings from the study could be of use to various stakeholders such as policy makers, development practitioners, the academia, the private sector, the civil society and anyone directly or indirectly interested with the welfare of adolescent mothers.

2.1Theoretical Framework

The study is guided by DFID's Sustainable Livelihoods Framework that has its origin from the works of Chambers and Conway as early as 1990s (DFID, 2000). At its core, the framework sets out to conceptualize how people operate within a vulnerability context that is shaped by different factors. It further conceptualizes how people utilize their asset base to develop a range of livelihood strategies (*ibid*). Drawing from the framework, the present study perceives non-marital adolescent motherhood as a vulnerability context upon which UAM operates. Non-marital adolescent motherhood is perceived as a shock that affects life of an UAM. Within the particular context, the UAM is therefore obliged to strive to achieve her desired household well-being through adoption of a combination of livelihood strategiesby drawing upon the asset base at her exposure. The framework is built on the belief that people need assets to achieve a positive livelihood outcome. People do possess different kinds of assets that they combine to enable them to achieve livelihoods that they seek (DFID, 2000; Petersen and Pedersen, 2010).Therefore, UAMs adopt a number of livelihood strategies to cope with adolescent motherhood and the challenges related to it. The choice of a particular livelihood strategy isalso strongly related with the livelihood outcomes and hence UAM's well-being.

Methodology

3.1 Description of the Study Area and Research design

The study was conducted in Mpanda Municipality and Tanganyika District in Katavi region. The justification for comparing rural and urban is due to most of the previous studies being rural biased, neglecting the urban contexts. The study therefore sought to get a broader picture of the phenomenon by comparing rural and urban contexts. Katavi regionwas purposely selected for the study due to having the highest Adolescent Birth Rate in Tanzania Mainland, i.e. 140.2 per 1000 live births (URT 2015; URT2016). Mpanda Municipality was purposely selected for the study to represent urban Katavi because as it is Katavi region's administrative headquarters and is a well-developed urban centre relative to the district administrative headquarters. In addition, it provides more urban-related livelihood strategies relative to the district headquarters. On the other hand, Tanganyika District was purposely selected among the other three rural districts (Nsimbo, Mlele and Mpimbwe district councils) to represent rural Katavi. The three other districts were excluded for the study due to being reported to have high

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nonresident populations of refugees from neighbouring countries of which adolescent mothers are inclusive, hence not qualifying for this study which sought to investigate Tanzanian adolescent mothers exclusively. The study adopted a cross-sectional research design thatallows data to be collected at one point in time.

3.2 Study Population, Sampling, Data Collection

The population for this study comprised all unmarried adolescent mothers aged 19 or younger when their babies were born. Household surveys were conducted with 240 UAMs, with 120 UAMs from Mpanda municipality and the remaining 120 UAMs from Tanganyika district. As justified earlier in the sub-section 1.0, the reason for studying unmarried adolescent mothers exclusively is the fact that they are assumed to lack economic support compared to their married counterparts who get support from their spouses.

To get the above-mentioned sample, the study used non-probability convenience sampling approach which assumes that there is an even distribution of characteristics within the population. Among the justifications for opting the particular approach is unavailability of a sampling frame for UAMs. Not every unmarried adolescent mother had an equal chance of being included in the sample as there was neither official census nor a complete list of all unmarried adolescent mothers living in the study area. According to De Vos (1998) convenience sampling is the rational choice in cases where it is impossible to identify all the members of a population. Non-probability convenience sampling has also been used in various similar studies involving adolescent mothers in cases where their censuses are unavailable. These include, among others, studies by Ehlers (2003), Ali *et al*. (2018), Wilson-Mitchell *et al*. (2014) and many more. Snowball sampling technique was adopted for the study. According to Marshall and Rossman (2011), snowball technique is often used in hidden populations that difficult for researchers to access.

The qualitative data were generated from Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) and life histories. Participants for FGDs and KIIs were purposely selected based on their positions and knowledge in relation to the study themes. A total of twelve FGDs were conducted involving participants conversant with the issues of teenage pregnancy and non-marital adolescent childbearing in their respective communities. Given the comparative nature of the study, six FGDs were conducted in Mpanda District Council and the other six were conducted in Mpanda Municipal Council. Thirty two KIIs were conducted whereby sixteen were done in urban and the remaining sixteen in rural. The key informants included representatives from Non-Governmental Organizations dealing with women's welfare, district and municipal community development officers, district and municipal reproductive child health coordinators, religious leaders, school head teachers, district and municipal social welfare officers, ward community development officers, doctors, nurses responsible for mother-child units and coordinators of reproductive child health in health centres. The life history approach was used to supplement data of unique cases among UAMs whose choices of livelihood strategies was influenced by adolescent pregnancy incidence. On the other hand, quantitative data were collected from

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households with UAMs identified through snowball sampling technique. Secondary data were gathered from various sources including the government reports, newspapers and policy briefs.

3.3 Data Analysis

Quantitative data were analysed using the Statistical Package for Social Sciences (SPSS), Version 20. Descriptive data on livelihood typologies were analysed and presented using Frequency and percentage with regard to localities. Chi square test was used to identify the livelihood strategies which were dominant in the two localities and to compare the relationship between locality and livelihood strategies. Qualitative data were analysed using content analysis under which information pieces were organized into different themes and compared against study objectives.

Results and Discussion

4.1 Livelihood Strategies among Unmarried Adolescent Mothers of Katavi

The study revealed that the UAMs in both rural and urban Katavi were engaged in six categories of livelihood strategies as shown in Table 3.

Table 3: UAM'sTypes of Livelihood Strategies (n=240)

Livelihood Strategy	Frequency	Percentage (%)
Petty Trading	137	57.1
Wage employment	27	11.3
Offering labour to household in form of household chores and/or crop production	27	11.3
Crop production on own farm plot	15	6.3
Off-farm self-employment	10	4.2
Casual labour	24	10.0
	240	100

Results show that, petty trading was the most dominant livelihood strategy (57.1%) among UAMs in both rural and urban Katavi. These findings are as well supported by findings from FGDs and KIIs. In such findings, petty trade was also mentioned as the most preferred livelihood strategy among UAMs in both rural and urban Katavi. This was revealed by one of the KII who said:

> "*Petty trading is a very popular undertaking among UAMs here and it is specifically in form of street vending…The secret behind such livelihood strategy is prostitution… Most UAMs are lazy, do not prefer difficult activities and thus they prefer loitering around the streets in search of men for transactional sexual practices. For instance, at Simba and Uwanja wa fisi Streets, it is not a strange thing to find young women with babies on their backs selling fruits in bars at late night. If you ask anyone here, the two streets are renowned for prostitution at Mpanda Municipality*" (KII participant in Mpanda Hotel Ward, Mpanda Municipality, 16th September, 2017).

Study findings are comparable to findings by other similar studies carried out in Nigeria, Ghana and Sierra Leonewhich report that adolescent mothers highly prefer

petty trading as a major livelihood and source of income generationbasically due to their poor education as well as sparse financial resources available to them (Melvin and Uzoma 2012; UNFPA 2013; Asomani 2017; Zibmil *et al*., 2018). Arguably, trading activities carried out by the adolescent mothers are of subsistence nature and normally require low capital for start-up.

Apart from trading, other livelihood strategies were wage employment (11.3%) and offering of labour to household where UAM resides (11.3%) in return of shelter and other basic amenities. Regarding the latter category, it was found out that, for those UAMs who were jobless and lacked income generating activity to earn their living, the option for them was to offer labour to the households of their parents where they are sheltered so as to get a privilege of being provided with shelter, food and other minor basic needs for themselves and their children. It was found that, in both localities, a tendency for an UAM staying at her parents' house with her child just for free wasn't an acceptable tendency but instead, one has to provide labour in return. Those UAMs who fail to adhere to this requirement are normally being evicted by their parents from the family, and in addition, it was further learnt that in most cases male parents are much strict in enforcing this decision. The finding was further described by two KIIs as followed:

> *"We have received several cases being reported here involving male parents chasing away their daughters who are unmarried adolescent mothers. Such male parents have fiercely chased away their daughters to go out and search for incomes for provisioning of their babies who are perceived as unnecessary additional burdens to the households"* (Key Informant, Ifukutwa Ward, Mpanda Municipality, 11th September 2017).

The above findings are supported by Mgbokwere *et al*. (2015) who argue that, an adolescent mother is already disadvantaged socio-economically because of dependence on parents or guardians on subsistence. In the study area, UAMs usually offer labour in two forms: through assisting routine daily household activities or assisting farming activities in family farms.

In addition to the earlier discussed livelihood strategies, the study further observed that some UAMs were engaged in casual labour activities (10%); own crop production on their own farm plots (6.3%) and off-farm self-employment (4.2%). For those engaged in own crop production it was found out that in most cases they were being temporarily given farm plots for free from their parents to cultivate their own crops so as to refrain from dependence on parents. Casual labour or menial labour has also been reported by Melvin and Uzoma (2013) as one of the livelihood strategies preferred by adolescent mothers in Southwest Nigeria. The study findings were also complemented by a life history narrated by one of the UAMs who disclosed the circumstances which brought her in the livelihood strategy that she was currently engaged in as shown in Box 1:

Box 1: Life history of an 18 year unmarried adolescent mother from Mpanda Municipality

When I got pregnant in 2015, I was living with my mother and siblings. My mother became very angry and chased me away from home telling me to go and live with the man that impregnated me. In fact this was due to the extreme poverty that existed in our family whereby getting pregnancy implied an additional burden to my mother in taking care of the family.I went to stay at my boyfriend's house for several weeks. However, after a few weeks he also chased me away claiming that he is neitherready to become a father nor starting cohabitating with me. Therefore, I returned home where I met my mother still bitter with me but she accepted me under the condition that I should not expect any form of support from her towards expenditures related to my pregnancy and my unborn child but only getting free shelter. She told me that I should look for income generating activities to cater for myself and the unborn offspring. She also said I should start contributing funds for household daily expenditures. I had a safe delivery, of course financed by her but, immediately after my delivery, she started harassing me and uttering abusive words to me and insisting that I leave her house. She further claimed that me and my child are unnecessary burdens denying her and my siblings the possibility of eating well as they wanted. I tolerated all that until my daughter reached one year, I managed to secure a small ten thousand loan from my uncle which I used to start my present day fruits business. After five months, I managed to repay the loan through several instalments and I am now proceeding with my business quite well. My business capital now amounts to twenty thousand Tanzanian shillings and I have little savings as well. I am now capable of taking care of myself, my daughter as well as contributing towards household expenditures whenever asked to. (Unmarried Adolescent Mother, 18 years, Makanyagio Ward, Mpanda Municipality).

The self-explanatory life history in Box 1 conforms to the earlier finding that parents of UAMs do not tolerate staying with their daughters and providing them free basic needs without the UAMs getting involved in any income generating activity.

4.1.1 Description of the forms of petty trading activities in the study area

Since it was established that trade was the most dominant livelihood strategy (57.1%) among UAMs of both rural and urban Katavi (see Table 3), the study also found it worthy identifying the actual forms of trading activities engaged by the UAMs and the findings of the same are summarized in Table 4:

Table 4: UAM's Major forms of Trading Activities (n=137)

Forms of trading activities	Frequency	Percent (%)
Owning a kiosk	21	14.6
Selling charcoal and/or firewood	9	6.2
Owning a stall	28	19.4
Selling fish through "Kulangua"	18	12.5
Selling fish through "Kusolola"	9	6.2
Selling used clothes	2	1.4
Food vending "*mama lishe*"	10	6.9
Selling fruits	10	6.9
Selling vegetables	21	14.6
Selling both fruits and vegetables	2	1.4
Selling snacks	14	9.7

"*Kulangua*" refers to a normal practice of buying and selling in pursuit of profit whereas "*kusolola*" means requesting fish for free from fishermen for household consumption but opting to sell them for income generation

Findings in table 4 above show that, the most popular trading activities preferred by the majority of the UAMs were: selling of food stuff through stalls (19.4%); owning kiosks (14.6%); selling of vegetables (14.6%) and selling of fish (12.5%) locally known in the study areas as *kulangua.* The activity involves a normal procedure of procuring fish at lower prices from either the fishermen or agents and selling profitably in the market places or in the streets. It is distinguished from the similar fish trade locally known in the study area as *kusolola* (6.2%) in that, the latter is a traditional old practice whereby needy low income households request for small amounts of fish from fishermen as they arrive at the lake shores from fishing. It is normally the young girls and women who practice *kusolola* along the lake as fishermen are arriving to the shores from fishing. In the first place, the practice was meant to provide the needy families with food, but of recent due to life hardships, the women and young girls have taken advantage of the practice by soliciting fish for trading purposes instead of household consumption. Thus fish traders in the study area are potentially distinguished from those who procure and sell (*kulangua*) to those who beg and sell (*kusolola*). The practice of *kusolola* might have negative consequences to UAMs in that they tend to be vulnerable to subsequent pregnancies and even acquiring sexually transmitted diseases. This is due to the fact that in most cases fishermen tend to persuade young girls practicing *kusolola* (UAMs inclusive) into sexual practices by giving them fish in exchange. The remaining forms of trading activities included: selling of snacks (9.7%); selling of fruits (6.9%); food vending (6.9%) popularly known in Swahili as *mamalishe*; selling of charcoal and/or firewood (6.2%); selling of used clothes (1.4%) and selling of both fruits and vegetables (1.4%).

4.3 Factors Associated with the Choice of Livelihood Strategies by UAMs

An inductive analysis of data from KIIs and FGDscame up with factors explaining why the existing livelihood strategies are popular among UAMs: being easy-to-do livelihood strategies which require relatively small amounts of capital to start; they are easy to make quick little money for daily survival of UAMs; they form alternative options for majority of UAMs who are unemployable due to lacking qualifications; most UAMs are lazy and do lack creativity in livelihood strategies hence end up copying livelihood strategies from one another; most UAMs are only after small amounts of profits hence, no creativity; and those engaged in an array of petty trading activities in form of street vending do prefer such activities as shadows for engaging in prostitution by targeting and attracting men in the streets for transactional sexual practices. The same was supported by observation from a key informant from Mpanda Municipality:
"*….At Mpanda Municipality, sale of fruits and vegetables seem to be the most popular livelihood strategies for most of the adolescent mothers….in fact you can as well observe the higher number of young girls walking in the streets carrying fruits and/or vegetables on their heads with their babies on their backs. This is simply because such undertakings are both easy to start in terms of capital and easy to get customers compared to others*" (Key Informant, Mpanda Municipal Council Office, 11th September 2017).

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In similar circumstances, another key informant from Tanganyika District had the following observation:

> *"It is quite surprising the way these adolescent mothers imitate business types from one another, if you go to the market place at Ikola, you will find most of them doing similar types of businesses"* (Key Informant, Ikola Ward, Tangayika District, 23rd September 2017).

4.4 Livelihood Strategies by District

The study revealed that there were statistical significance association between location (district) where UAM reside and the type of livelihood strategy adopted (P< 0.000). Table 5 summarizes these findings:

Table 5: Distribution of Livelihood strategies by District (n=240)

Livelihood Strategy	District		
	Mpanda Municipality (n=120)	**Tanganyika District (n=120)**	**Chi Square /Sig.**
Trading	69(50.4)	68(49.6)	40.933
Wage employment	24(88.9)	3(11.1)	0.000*
Offering labour to household in form of household chores and/or crop production	11(40.7)	16(59.3)	
Crop production on own farm plot	1(6.7)	14(93.3)	
Off farm self-employment	9(90.0)	1(10.0)	
Casual Labor	6(25.0)	18(75.0)	

NB: Numbers in brackets indicate percentage. *The Chi-square statistic is significant at the 0.000 level

The chi square test was performed to find out whether there is significant association between localities were UAMs are found and the livelihood strategies that they perform. The findings show that there is a statistical significance between location where UAM reside and the type of livelihood strategies (P< 0.000). This suggests that the livelihood strategies adopted by UAMs in the study area are largely context specific.

However, finding s in table 5 show that, despite the fact that trading was found to be balanced in both rural and urban (with 50.4% and 49.6% respectively), there appears a skewed variation in the remaining categories of livelihood strategies with some livelihood strategies being more associated with rural while others with urban. Such findings are highly skewed. For instance, out of the 27 UAMs in wage employment category, 88.9% were found in urban while 11.1% were found in rural. This suggests the availability of more employment opportunities in urban compared to rural Katavi, which is an obvious trend in many countries. Out of the 15 UAMs in own crop production category, 93.3% were found in rural while 6.7% were found in urban, again this is obvious given the availability of more land for cultivation in rural areas compared to urban areas where land resource is quite limited. Furthermore, out 24 UAMs in casual labour category, 75.0% were found in rural while 25.0% were found in urban. Casual labour activities were largely on-farm. These findings do contradict partially with those of Nyagetia (2015) who reported that UAMs of rural areas in Kisii

County are disadvantaged opportunity-wise in the sense that more livelihood opportunities are available in urban areas. For that case, in Katavi, the rural UAMs are only disadvantaged as far as wage employment is concerned and not in other categories livelihood strategies for instance casual labour.

Conclusion and Policy Recommendations

Unmarried adolescent mothers of Katavi, similar to their counterparts from other areas, face challenges of livelihood insecurity.There exist at least six livelihood strategies among UAMs in the study area with the most popular livelihood strategy in both rural and urban being petty trading. In view of the study findings, it appears that UAMs in the study area are faced with limited livelihood options due to varying factors among them being lack of employable qualifications as well as start-up capital. Furthermore, findings show that non-farm wage employment opportunities are relatively more available in urban compared to rural Katavi which is characterized by farm-related livelihoods. The study calls upon various stakeholders both governmental and no governmental with stake in welfare of vulnerable groups particularly women, to design programmes for provision of diversified life skills to UAMs. This will enable UAMs to employ themselves in various sectors and enhance their wellbeing. With regard to trading, UAMs could be trained in areas of entrepreneurship and basic financial management skills. It is further recommended that forthose UAMs aspiring to upgrade their education could do so through the Qualifying Tests programme.

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Governance structures in domestic value chain of non-industrial timber in Njombe district, Tanzania.

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Abstract

Although governance structure of the value chain influences the incomes of chain actors, it has received limited attention in domestic value chains literature. To bridge the gap, this paper is set to analyse the governance structure of non-industrial timber in Njombe district in Tanzania. Non-industrial private forestry (NIPF) is the main livelihood activity among smallholders in Njombe district and a heart of district's revenue. The research adopted an exploratory cross-sectional study design where purposive and snowball sampling was used to obtain respondents. Data were collected through observation, semi-structured in-depth interviews with key informants and the respondents. Analysis was done using deductive thematic analysis. Study findings show that value chain actors of non-industrial timber use both vertical and horizontal governance structures. While smallholders earn more income when a combination of structures is used, modular governance gives more returns when one structure is used. Market uncertainty, incentive to spread risk, institutional environment, trust and financial capability of both the buyers and suppliers determine the governance patterns. In addition, findings show that even though a centralized or global governance structure is absent, informal quality standards are emerging and have far-reaching implication to the incomes of chain actors. The paper concludes that both vertical and horizontal governance structures play an important role of linking value chain actors to markets. Therefore, efforts to improve smallholders' income should be geared toward improving both vertical and horizontal structures because they play a complementary role.

Key words: Non-industrial timber, value chains, Governance, Tanzania

Introduction

In Tanzania grown timber can be categorized as non-industrial and industrial timber plantations. While the non-industrial timber is characterized by individual ownership, the industrial timber is own by the government and corporations (Harrison *et al*., 2002; *Zhang et al*., 2005; PFP, 2015; Pedersen 2017). The two types of timber can also be distinguished based on the types of market where the product is sold. While about 15% of sawn timber is exported outside the country, more than 75% of this comes from the industrial plantationsimplying that most of timber from NIPF is sold to the domestic markets (Indufor, 2011; (Mwamakimbullah, 2016; TPS, 2017). This scenario brings us to the concept of domestic value chain where in this paper it refers to the value chains of the product which is produced and consumed within the country borders. On the other hand, value chain governance refers to the authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain (Gereffi, 1994). It can also be used to describe the coordination system within the value chain (Zamora, 2016). Analysis of governance of the value chain can be done by

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examining three main aspects: institutions (encompassing the formal and informal), private standards and the market governance structures (Gereffi *et al*., 2005; Ponte and Gibbon, 2005; Akyoo *et al*., 2017; Mishra, 2018). All aspects of value chain governance play a double-edged sword role; they may facilitate or impede equitable distribution of benefits among the actors of the value chain (Altenburg, 2006; Nielson and Pritchard, 2009; Henson and Humphrey, 2010; Trebbin, 2014).

NIPF is the main livelihood activity to the smallholders in Njombe district of Tanzania and is a heart of revenue where it contributes to more than 70% of its total revenue (*Personal communication DED, 11thJanuary 2019*). The contribution of NIPF to household income is also significant in other districts in the Southern highlands. For example, in Mufindi, Nkwera (2010) observed that NIPF contributed 61% of the households' income and 73% percent of households' physical assets. Despite enormous contribution to the economy, the potential of NIPF is not yet fully exploited (Singunda, 2010). Literature on value chain undoubtedly points out that smallholder farmers are better positioned to benefit from what they produce if are well integrated into value chains (Weinberger and Lumpkin, 2007). Integration into domestic value chain is a precursor for integration into global value chain (Beverelli *et al*., 2017). Although governance of domestic value chains is regarded as a stepping stone to global value chain integration (Watabaji *et al*., 2016; Beverelli *et al*., 2017), most value chain studies have investigated the governance of global value chains mainly by examining the relationships among actors (Passuello *et al*., 2015; Severine, 2016; David *et al*., 2018). The focus of this literature has been export-oriented, standardized and self-regulated global value chains (Mishra and Dey, 2018).

In Tanzania, as in other countries such as India (Mishra and Dey, 2018), few studies have studied the governance structure of domestic value chain albeit for agro-foods such as milk, spice, fruits and vegetables (see for example Nguni, 2014; Akyoo, 2017; Kilelu *et al*., 2017 and Gramzowa *et al*., 2018). While these studies fill the gap of domestic value chain studies, they are mainly focusing on high value crops. This trend has also been observed elsewhere in the world (see for example Trebbin and Franz, 2010). With a few notable exceptions (such as Singunda, 2010 and Kapinga, 2010), research in Tanzania has neglected the governance structures of NIPF and their implications to the incomes chain actors. To fill the gap, this paper investigates the market governance structures of non-industrial timber value chain in the Southern highlands of Tanzania particularly in Njombe district to contribute to literature. The paper seeks to answer three main questions i) what is the governance structure of non-industrial timber value chain in Njombe district? ii) what determine this structure? and iii) what is the implication of this structure to the incomes of chain actors? This analysis is important because governance structures of domestic value chains like their counterparts in global chains affect the distribution of gains in the chain and influence how production capabilities[5] are upgraded. Analysis the domestic governance structures can provide an

[5] The term production capability is used to describe the skills required by the producers to reduce the cost of production, improving quality and flow of the product (Humphrey and Schimitz, 2001).

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understanding of how and why inclusion[6] takes place and the outcomes.

Conceptualizing governance structures in value chains

Two types of value chain coordination can be identified in the literature; vertical and the horizontal coordination.Vertical coordination can be defined as the process of aligning and controlling price and other incentives, quantity, quality, and the terms of exchange across segments of a production or marketing system (Peterson *et al.*, 2001). Also, Hendrikse and Bijman (2002) define it as the alignment of activities and decisions by two or more independent players that have a seller-buyer relationship in a supply chain. The second type of coordination refers to horizontal coordination (HC) that describes the process of alignment and control among actors within a single segment of the value chain, such as between farmers. The common thread that binds the two types is that they involve interactions between the seller and the buyer i.e. seller-buyer relationships. The system that governs the interactions between parties within any value chain is referred to as governance structure (Ibrahim and Ghanem, 2016). In other words, governance structures are modes that govern transactions between players in a value chain (Williamson, 1993).

Gereffi *et al*. (2005) developed a typology of five governance structures which are markets, modular, relational, captive, and hierarchy governance. The *market* structure is characterized by arms-length transactions and requires little or no formal cooperation between participants and the cost of switching to new partners is low for both producers and buyers. The central governance mechanism is the price of the product. In the modular, buyer-seller relationships are more substantial than in simple markets. Under *relational* governance, interactions between buyers and sellers are characterized by the transfer of information and embedded services based on mutual reliance regulated through reputation, social and spatial proximity, family and ethnic ties. The cost of switching to new partner is high due to long time required to forge relational linkage or partnership. C*aptive* governance occurs when small suppliers are dependent much on larger buyers. Suppliers face significant switching costs and are therefore, 'captive'. The relationship between the suppliers and the buyer is characterized by power asymmetry. The *Hierarchy* is the type of governance characterized by vertical integration and managerial control. Generally, the degree of explicit coordination and power[7] asymmetry increases as one move from spot to hierarchy type. Three variables are said to influence the dynamics of governance structures (Gereffi *et al.*, 2005). They are complexity of transactions, ability to codify information which implies the extent to which tacit information and knowledge can be converted into explicit and concrete to be understood by the producers and capabilities of suppliers that refers to suppliers' ability to utilize complex information or instructions to meet product requirements. Gereffi *et al*'s typology has been extended by other scholars. Altenburg (2006) observed other

[6]Inclusion in this paper is referring to four pillars model for sustainable inclusion of smallholders in the value chain. The elements of this model are access to market, access to training, collaboration and coordination and access to finance (Fernandez-Stark *et al*., 2012; Gerrefi and Fernandez-Stark, 2016)

[7]Power is defined as is the ability of a firm or organization to drive the direction of the value chain, and thus influence and control other firms in the chain (Frederick and Gereffi, 2009)

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factors which also influence governance structures. They comprise the extent of market uncertainty, incentives to spread risk, consumer demands and institutional environments; they include. Other studies (Gibbon and Ponte, 2005; Tallontire *et al.*, 2009 and Bolwig *et al.*, 2010) have raised a concern that Geffi *et al.* (2005) typology dwells on vertical governance structures and pays little to the horizontal structures.

Studies have also identified the link between enterprise upgrading[8] and governance structures. Humphrey and Schmitz (2000) point out that certain types of chain governance favour some forms of upgrading but not others. For instance, they show that quasi-hierarchical governance supports product and process upgrading but not the design and marketing activities of the chain (Humphrey and Schmitz, 2000). In the same vein, Gereffi *et al.*, (2005) maintain that captive governance confines suppliers to a narrow range of tasks such as simple assembly and never allows them to move to the design, logistics and process technology upgrading. Although these observations relate to global value chains, they are also relevant in domestic chains. The current paper applies Gereffi *et al.* (2005) typology to the NIPF value chain to investigate the governance structure; however, it does so cautiously by considering its extension and horizontal structures, its major critiques.

Methodology

The context of the study area

The study was conducted in Njombe region in the Southern Highlands of Tanzania. The region was purposively selected based on the presence of many actors involved in NIPF.To narrow down, the study was conducted in Njombe district in Matembwe village. This village is among those with well-established timber market therefore represents a good case for understanding governance structures of non-industrial timber. Apart from the villagers, people from within and outside Njombe region have been attracted in this village and are involved in a number of activities including tree growing, processing, marketing and consumption. Other actors found in the area are transporters and financial institutions for credit support (both formal and informal money lenders). Although several timber products are produced from NIPF, two thirds of the plantation supply go to sawn timber (PFP, 2016). Therefore, the value chain of sawn timber among other products was studied.

Research design and data collection

This paper adopted an exploratory cross-sectional research design. The main methods used were key informant and in-depth interviews with tree growers and timber traders. These methods were also complemented by observation where several rounds of visits to the timber market were conducted. Purposive interactions with actors were also made through participation in social events such as playing cards and draft in the evening. The number of participants in the group was ranging between 7 and 12 people

[8]Humphrey and Schmitz (2002) identified four types of upgrading including process, product, functional and chain upgrading.

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all men[9].

A list of timber traders owning timber yard at the village market (the Matembwe market) was obtained from the manager of the market. A total of 11 timber traders were selected from the list and interviewed. Other traders who could not be found in the list were identified by a snowball method and they constituted 12 of them. The list of tree growers with membership in the growers' association was obtained from the secretary of the association whereby 13 growers were purposively selected from the list. A snowball method was used to get tree growers without membership in the association and in this case a total of 12 growers were interviewed from this category. Additionally, seven (7) key informant interviews were conducted. The key informants interviewed are the three leaders of Matembwe tree growers' association (the chairperson, secretary and accountant), the manager of Matembwe timber market, the director of Matembwe village company (MVC), ward and district forest officers and the village executive officer.During discussion with key informants it became evident that the mechanisms of selling and buying of timber partly depend on the size of capital of tree growers and timber traders. Therefore, both the tree growers and timber traders were purposively selected to include all categories (small, medium and large). For the tree growers, the size (in acres) of trees owned was taken to be the proxy indicators of wealth[10] whereas for the traders the size of the capital was established based on the number of sawn timber sold per month. Generally, interviews with timber traders and tree growers covered their socio-demographic information, main livelihood activity, experience in tree growing/timber trading, nature of interactions in timber business, factors influencing the nature of interaction, how the interactions affect the income of each actor, challenges and opportunities. For key informants, an edited version of the checklist was used.

Data processing and analysis

All data obtained were transcribed; after which a thematic analysis was done by following the steps as described by Braun and Clarke (2006). After familiarization with the data through reading, a non-systematic labelling of data was adopted (i.e. in some instances sentences were labelled where as in other occasions sections or paragraphs were labelled). This process generated 66 labels or codes. The coding process was done at a semantic level that is the codes communicate explicit meaning of the sentences, paragraphs or sections. Similar codes were grouped together to generate themes and sub themes. Generation of themes used a deductive or top down approach (Hayes, 1997; Braun and Clarke, 2006; Maguire and Delahunt, 2017) where the identification of themeswas driven by the researcher's theoretical interest (a theory-led thematic analysis). However, this was carefully done to allow new insights that may not be explained by the guiding theoretical framework. Theme mapping resulting into

[9]Playing cards and draft are men's activities in Matembwe village.

[10] Wealth ranking study in similar village indicated that tree ownership is the reflection of wealth (unpublished Timber rush project data collected in January 2019).

thematic matrix allowed analysis of relationships between and among themes.

Results and Discussion

Profile of actors

Study findings indicate that all (23) traders interviewed were men with minimum and maximum age of 28 and 46 years respectively. Out of the 23 traders 16 (69.6%) operated at least one timber yard either at Matembwe market or in other regions outside Njombe. Of the 16 traders who operated timber yards, only four (25%) had timber yard outside the Matembwe market. Financial capital was stated to be the limiting factor to operate a yard outside the village because it involves transportation which is costly. Findings also revealed that traders had varied experience in timber trading ranging from three to 16 years. Some traders were employees of companies or worked for individuals in the same industry where they accumulated experience and capital that enabled them to start their own business. Most of traders were motivated to engage in timber business by a host of factors including success of their colleague who were successful in the timber business, the desire to add value to their trees for those who are also engaged in tree growing and the desire to capitalize to their experience after working for others for many years. In the context of Matembwe village, success is related to building good house, being able to pay fees in private schools, owing a car and expanding wood lots. In terms of education, 19 (82.6%) traders had attended primary education and only four had education beyond primary education. Results further revealed that 13(56.5%) timber traders were native of Matembwe village and the rest (43.5%) came from outside Njombe region. Although traders are engaged in other livelihood activities,16 of 23(69.6%) traders reported that timber business is their main livelihood activity contributing at least 80% of their income. For the rest (30.4 %) traders, reported that timber contributed above 60% but less than 80% of their income.

Regarding tree growers, findings revealed that of the 25 growers interviewed 18 (72%)were men and seven (28%) were women and their ages ranged between 47 to 81 years. In terms of their level of education, 8 had attended beyond primary education. Findings also showed that growers had vast experience in tree planting up to 42 years and the lowest experience was 4 years. It was however noted that despite many years of experience in tree growing, tree planting was not the main livelihood activity. It is only towards the end of 1990s when the demand for grown timber appreciated and those who had planted trees reaped a huge profit out of their woodlots. This motivated many smallholders and urban dwellers to start growing trees which is now regarded the main livelihood activity among smallholders in Njombe district and Matembwe village. When asked to report on how much they think on average trees contributes to their income, they reported slightly lower contribution as compared to the traders as the minimum percentage reported was 55 and the maximum was 70%. These findings are in line with what Nkwera (2010) observed in Mufindi district where it was found that NIPF contributed 61% of the households' income and 73% percent of households' physical assets. The difference in contribution of NIPF to household income between growers and traders can be attributed to the fact that timber business was an everyday full-time activity for the most of traders whereas tree growing is a part time activity and

growers may earn income from trees once in a year or after several years. Furthermore, the difference can also be attributed to the fact that most of tree growers sell their trees on stumpage (i.e. without value addition) where as traders add value through different ways such as processing logs to obtain saw timber, seasoning and transporting to urban markets where on overage they get relatively higher profit margin as compared to selling at the village market.

The governance structures

Findings of the study indicate that relationships between actors of NIPF value chain are based on both vertical and horizontal structures. Regarding the vertical structures, spot market is a predominant mode of relationship. Most of tree growers who do not belong to the growers´ association accessed market through this structure. Spot market is practiced within and across the nodes. Across the node, the traders or middle men (also referred to as buyers in this paper) approach tree growers to inquire about the availability of woodlots which are ready for harvesting. Likewise, in some cases a tree grower may approach one a couple of buyers to buy his/her woodlot. In both cases the two parties would go to the field to evaluate the woodlot. The grower may decide to select some few trees (selective harvesting) or to sell the whole woodlot. If the two parties agree on the price, the harvesting takes place. In the context of Matembwe, a woodlot is regarded as mature if it has at least eight years form the time it was planted. Growers are paid instantly before the trader can be allowed to harvest the woodlot. After harvesting and getting sawn timber, traders have many options. Timber can be transported to Matembwe market if the trader owns a yard at the market or can be transported to distant market (outside the region) after being seasoned at home or in the field. For traders who own timber yards at the market, seasoning is done at the market when timber is waiting for customers or when waiting to be transported. Therefore, apart from being a market place, Matembwe market serves as a place where timber is seasoned while the trader is waiting for the customers. Within the node, spot market is practiced between timber traders; the whole sellers and retailers. Some retailers from within and out of Njombe region obtain timber from the market. Selling and buying is not agreed before but rather a retailer goes around the market looking for the required timber and negotiating prices. This type of governance seems to dominate the value chain of non-industrial timber because of its flexibility (Gereffi *et al.*, 2005) on both parties that sellers can sell to anybody; likewise, buyers can buy from anybody.

Like the global value chain, the changing demands of consumers of sawn timber which itself may be associated with increased knowledge of quality timber have led to the emergence of modular governance where wholesalers are being asked by the retailers in urban centres to supply sawn timber that meet specific qualities. Retailers place orders by specifying the types, sizes and quantity of timber required and the suppliers deliver the cargo according to the retailers' specifications. Suppliers who do not deliver according to the specifications are retrenched from supplying timber. Indeed, this type of governance arises where suppliers are highly competent, and it is possible to codify transactions (Alternburg, 2006). There are few retailers as compared to the wholesalers; this structure gives the retailers more power that helps them to dictate the terms of

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trade for instance the mode of payment and the quality standards. In this regard, a piece of sawn timber is regarded to be of good quality if it has no scars, non-bending and with proper dimensions (length and width). These are regarded by most value chain actors as aspects of quality timber and any piece which fall short of these is calledreject. At a retail yard, rejects occur when customers send knowledgeable people to buy timber on their behalf. In most cases the knowledgeable people are carpenters or masons.

After the decision of rejecting some timber has been passed, it is upon the supplier to sell it to the same retailer at a discounted price or look for another buyer; but in most cases the suppliers resort to the former option. Recalling on his last experience of supplying timber to retailers in Dar es Salaam, the wholesaler had the following to say

> *…..You know we suppliers have no unity, we compete among ourselves to maintain relationships with the retailers and sometimes when our timber are termed as reject without reasons we are ready to incur losses. I decided to quit from supplying timber to retailers because almost a half of the cargo was called reject. I have now decided to own a yard here at the Matembwe market where some retailers come to collect timber, and you know what, those who come here they pay cash.*

Although it can beargued that wholesalers have options of opening retailing yards to circumvent the emerging standard requirements, this is not an easy option for most of wholesalers asit requires a lot of capital. Although most of retailers in urban centres buy timber on credit, one must have been able to build trust with the suppliers to be supplied timber on credit. As trust requires time to be built (Lane, 2000; Vieira and Traill, 2008), a starting retailer should be capable of paying cash for some time (ranging from months to several years) before can be trusted. Apart from the cost of paying for the cargo, a new retailer needs to incur cost for hiring site or building and obtaining legal documents for selling timber. Apart from the associated challenges, this type of governance will continue is likely to persist for years due to following reasons. First, it is associated with higher barriers of entry and actors who overcome the barriers have greater profit margin compared to those operating in other structures. Secondly, under this structure, some retailers support the wholesaler with financial support during difficult times especially in the months of January and July which are the months of enrolment and beginning of new term for primary and secondary schools. During these months some wholesalers spend a significant amount of their capital for paying school fees resulting into little capital to buy trees from growers for them to continue supplying timber to retailers.

On the other hand, interview with retailers revealed that so long as the knowledge of quality timber continues spreading among customers, they will continue insisting supply of quality timber by the wholesalers for them to stay in business. The following interview with a retailer reveals that modular offers retailers many advantages than other types of governance structures.

> *With this arrangement you get sawn timber on credit. This is really very helpful instead of taking a loan from the bank you just need to build trust*

> *with the suppliers then you get the number of cargos you want. Apart from being supplied timber on credit, I have significantly reduced the costs per piece of sawn timber because I don't travel instead my suppliers bring timber up to my yard. Because I don't travel, I get enough time to supervise the business which also important to be successful in business. Also, the good thing with this arrangement you avoid a lot of on-transit risks (interview with a retailer who own a timber yard in Morogoro region).*

Due to the advantages offered by the modular governance to retailers, it has become the predominant governance used by them. As already explained in the previous sections, this type of governance is associated with setting and enforcing informal quality standards implying that quality standards are emerging even if not centrally defined. This implies that actors especially in the upstream end of the chain such as tree growers will need to improve the quality of timber for them continue accessing the market. As other growers continue expanding their woodlots and new entrants join and customers increasingly become knowledgeable and demand quality timber, tree growers will need to compete by supplying timber required by the market (i.e. quality timber). Their timber will also need to compete with timber from industrial plantations. Lack of quality improvement by the tree growers will result into receiving very low price of their woodlots/trees as it has already started to happen. Interviews with timber traders revealed that trees that were predicted to produce many rejects of sawn timber were fetchedan average price of 2500 TAS (1.1 USD) per tree instead of 3500 TAS (1.6 USD). For suppliers, they will need to improve their capability of supplying required cargo on time. In the context of Njombe district, growers can improve the quality of timber through adoption of recommended silviculture practices for forest management; harvest mature trees and if involved in processing, adopt technology that can guarantee the required quality.

Relational governance was also found to be used by the actors of NIPF value chain. This was practiced by both timber traders and tree growers where the business relationships are based on family ties. Findings showed that some family members are engaged in timber retailing, others in whole selling and others are engaged in tree growing. This is well captured in the following conversation with a grower in Matembwe village. *For me I have no problem with selling my trees because I have my son who is a timber sawyer and my young brother is a retailer who operates timber yards in different regions. When I want to sell my trees, I call my son to buy my trees and the sawn timber is sold to his uncle who own timber yards in Morogoro and Dar es Salaam.* Another form of relational governance was found to hinge on mutual trust that has been built after many years of repeated transactions. Interviews with suppliers and retailers revealed that when a cargo is delivered, the retailer pays only the cost of transport and the bus fare to enable the supplier to go back home; the rest of money is paid to the supplier when the whole cargo has been sold out. As other research findings revealed elsewhere trust is an important governance aspect in timber value chain because it reduces transaction costs along the chain (Vieira and Traill, 2008).

Horizontal governance was another type of governance found in the non-industrial

domestic timber value chain. This is practiced by tree growers who are the member of UWAMIMA, a tree growers' association in Matembwe village. With the spirit of solving the problem of market access, this association with a total of 75 members attracted resources from donors and government. Matembwe Village Company (MVC) provided an office space for the association, the village government provided the land to build the market, the government of Finland provided financial resources that helped to build the timber market and the district government rehabilitated the road to facilitate easy access to the market. At the Matembwe market, the association owns the space where members of the association are allowed to bring their timber for seasoning and selling. While others must pay 20,000 TAS (9.1 USD) to own a yard in the market, members of the association do not pay anything. This has motivated them to add value to their trees by selling sawn timber instead of standing trees (selling on stumpage). At the market tree growers have many options; they can sell to retailers who come at the market or can sell to wholesalers who collect timber at the market to meet their orders in distant urban markets. Sometimes members of the association sell timber to their fellow tree growers at the discounted rate who later sell the same to retailers or whole sellers. A mechanism has been put in place to control members of the association who can collude with non-members to enjoy the benefit of members. Therefore, the member of the association must proof that the timber brought to the market is from own woodlot.

Determinants and dynamics of governance structures

The findings show that the structure of governance in domestic value chain of timber is influenced by a host of factors. As reported in the global value chain theory, spot market was influenced by the price of timber (citation). However, in addition to the price, avoidance of complicated business relationships and lack of trust between the parties influenced the spot market relationship. Tree growers and whole sellers perceived selling on order or on contracts as complicated and risky business relationships. This is revealed in the following conversation with a whole seller at the Matembwe market…..*I have bad experience of supplying timber on order; those guys (implying the retailers) do not pay on time; if you follow what they want you can go out of this business. So, for me what I do is to collect timber from tree growers, bring them here at the market wait for customers, those who want timber will come and buy on cash not otherwise.* This claim was supported by tree growers who indicated that they do not like to enter into contract of any kind with the buyers. Explaining why they would not like any other relationship beyond spot market, one tree grower said the following…..*I do not want to have any sort of repeated transaction with the same person because once he/she get used to you, next time will request to buy on credit and if you agree that's where the problems will start. We have witnessed our fellows who sold their trees on credit and have made so many phone calls to the buyers without getting their money*

Also, findings indicate that institutional environment (i.e the rules controlling production, distribution and consumption) influenced tree growers and timber traders to resort to spot market because they would like to avoid complicated processes of transporting timber outside their village. *When you get an order from the retailer to supply timber, you bear all the risks along the road. Also, you need to interact with officials of Tanzania*

revenue authority (TRA) by paying 18% VAT, if you are supplying to Dar es Salaam you must go through the 32 road blocks for timber inspection, pay cess and yet the retailer does not pay you on time; so I better get small but which I am sure of, interview with a trader in Matembwe village.

On the other hand, some whole sellers reported that although they would like to have some sort of repeated transactions with the retailers, they resorted to spot market because they lacked capital to supply timber on credit. As highlighted in the previous section, having repeated transactions with retailers reduces the uncertainty of getting access to market on the side of wholesalers; however, this type of relationship requires enough capital because retailers do not pay for the whole cargo upon delivery. As such, payment by instalment affect the wholesalers especially those with little capital. Explaining the challenges of this relationship the trader at Matembwe market had the following to say……*you know when we deliver the cargo basically the buyers pay the cost of transport and may give you the bus fare to go back home. The rest of the money is paid on instalment and can take between one to several months*. Wholesellers especially those with small capital stop business after delivering the cargo on credit, they resume after receiving their final payment. The reason for pausing doing business is because buying trees from growers requires cash; the same applies to buying timber from the Matembwe market. Others who have relatively enough capital who used to buy sawn timber from the market or from the field, start buying trees as a way of getting cheap raw material for sawn timber. The obtained timber is not sold to retailers in cities rather is sold to anybody on cash. Thus, depending on one'scapital, traders are involved in spot or modular relationships.

Contrary to the global value chain theory the emergence of relational governance was not due to the difficulties in codifying the information related to product specifications or high capabilities of the suppliers (Gereffi *et al*., 2005), rather it emerged through sharing experience of timber business within the family circles. When a member of the family become successful, other members become interested in the business and for them acquire experience, they are assigned some activities to coordinate such as becoming casual labourers who are employed as sawyers, collecting sawn timber from different places or going around looking for mature woodlots (middlemen) for their relative who is a trader. Their engagement in various activities, afford them some income and gain experience to start their own businesses but do not sever relationship with their mentors. In other occasions relational governance was influenced by the desire to reduce dependencies within the family. This is demonstrated by the following interview. *Relatives will always blame you if they see you doing business and you are supporting them. In order to avoid supporting relatives who do not like to work, I decided to employ my nephews and young brothers as casual labourers for searching mature woodlots, sawing timber and delivering timber to my yard at the Matembwe market. I did this purposively so that they get money by working*…… a trader at Matembwe market explained.

Although placement of relatives in strategic positions facilitated coordination and hence easy access to market by the actors, the prospect of the business to grow and compete under this arrangement is questionable due to its associated challenges. Some folks

perceive their engagement into business as a punishment for them to request support from their relatives. As such, they do not struggle to become innovate and make profit. This arrangement is also a ground of conflicts within the family. When sanctions are imposed to the person who causes losses due to misuse of funds or other business malpractices, it results into hatred between the parties involved.

Effect of governance structure on incomes of chain actors

As already highlighted in the previous section, four types of governance structures were used in the timber value chain. In some cases, one type of governance structure was used and in other cases actors used a combination of governance structures. Findings showed that tree growers who used a combination of horizontal and vertical structures obtained more income compared to those who used one structure. A key informant who is the leader of tree growers` association reported that in an acre of woodlot of ten years one can get 3,000,000 TZS if is sold through spot mark*et al*one. The same woodlot would make around 3,500,000 TZS if the transaction is made through the association and the spot market. Denoting how selling through a combination of structures affect the income, a key informant had the following to say. *A tree grower who is a member of the grower association does not pay any money when his timber enters the Matembwe market. Others (implying non-members of the association) must pay 50 TAS per each piece of sawn timber entering the market regardless of its size. In addition to this, one must have paid 20,000 TAS for the timber yard in that month (Interview on with a manager of the market on 16/01/209).*

Further to the explanation of the key informant, growers who sell through the association, do so at the prevailing market price, this is contrary to their counterpart non-members who sometimes sell at any price because they either lack information of the current price or compete amongst themselves by lowering the price trees. As reported by the manager of the Matembwe market. *This market has completely changed how tree growers relate with timber traders. Their bargaining power has increased; initially, tree growers were given wrong information related to price of timber; at the market we display the price of all sizes of timber. It is upon the grower to sell according to the displayed price or offer a discount to the customer, but even when they offer a discount, they do it knowing the actual price* (Interview with the manager of the market on 23rd January 2019)

It was also reported that there is a slight difference in profit margin between traders who use spot market and modular governance. Findings showed that, traders who supply timber according to the specifications of retailers in big cities have few rejects compared to those who sell through spot market. In Njombe district, rejects can be associated with many factors such as technology used to saw the logs, field supervision during sawing, harvested, management of woodlot(silviculture practices), experience of sawyers, how timber was stored during seasoning and the age of woodlot.

Conclusion

Both vertical and horizontal governance structures were found in the timber value chain. Spot market, relational and modular governance were the major types of vertical structures while horizontal structure was found to be through the association of tree

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growers. Actors of the value chain used either one or a combination of these structures.However, **s**port market was found to be used mostly by tree growers who were not members of the association. This is not withstanding the fact that tree growers earned more income when a combination of horizontal and vertical structures was used. Market uncertainty, incentive to spread risk, institutional environment and financial capabilities of both the sellers and the buyers were the main determinants of the governance structure. Except for the capability factor, the rest of factors that determined the structure were those proposed by the critics of the global value chain theory. Even with the capability factor, contrary to the global value chain theory which posits that only capability of the suppliers determines the structure, findings of the study showed that capabilities of both the suppliers and the buyers influenced the governance structure. For instance, higher income of timber traders enabled one to become a wholesaler of timber in urban centres where modular was the main governance structure and low income of timber traders was associated with spot market. Even though the timber value chain in Njombe district has previously been without any coordination or centralized governance, standards are emerging through a modular governance between retailers in urban centres and wholesalers. This emerging type of governance which seems to drive the chain has a far-reaching implication to the incomes of actors especially in the upstream part of the chain. Findings show that when one structure is used, modular governance gives a higher benefit albeit associated challenges of delayed payment and the requirement to comply with the informal quality standards. But, in Njombe district smallholders rarely use this type of governance. Therefore, the paper recommends that efforts to improve smallholders' income should be geared toward improving vertical and horizontal structures because they play a complementary role.

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The Use Stem and Root Barks Extracts from *Synadenium Glaucescens* as Acid base Indicators

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Abstract

Currently, the conduction of acid-base chemical reactions involves the use of industrial made indictors which are associated with environment pollutions. This situation necessitates the search for more acid-base indicators from the natural sources. The aim of this work was to study the acid-base indicating capacity of the extracts from Synadenium glaucescens. To study the indicating capacity from S. glaucescens, the extracts from leaves, stem and root barks were studied for their colour change, reversibility, pH range and effectiveness during titration by titration using strong and weak acids and bases. The results indicated that, only the indicators from stem and root barks extracts had indicating capacity as they were capable to change colour due to pH change. The pH range of the two indicators was from 2.9 to 12.7 which make them to be better universal indicators. Both indicators could be reversed clearly while in acidity and alkalinity conditions. Titration showed sharp colour change at the end points. The mean titre of the two indicators were ranging from 24.3±0.31 to 25.4± 0.75 and 18.9±0.17 to 24.1±0.05, respectively with their colour change from brick red to colourless and orange to colourless, respectively. The end points obtained by stem and root barks indicators correspond to the end points obtained by standard indicators, phenolphthalein and methyl orange. Thus, the stem and root barks extracts are suitable to serve as acid-base indicator. Further studies could be done aiming to develop paper indicators and isolate pure compound which is responsible for indicating capacity of S. glaucescens.

Key words: Acid -Base Indictor, Natural Indicator, *Synadenium glaucescens*, Titration

Introduction

Synadenium glaucescens (Euphorbiaeceae), commonly known as 'Mvunja-kongwa in "Kiswahili" or "Liyugi" in "Bena" is an indigenous to East Africa and commonly found growing in several regions in Tanzania (Mabiki *et al*., 2013a). The species has been reported to be of great importance to mankind, for indigenous use for treatment of both animal and human ailments such as excessive menstruation, skin conditions, sores and wounds (Max *et al*., 2014; Mabiki *et al*., 2013b; Chhabra *et al*., 1984). While working with different extracts from *S. glaucescens* during the conduction of various experiments, it was accidentally observed that some of the extracts were changing colour when placed in different media of acids and bases (Faith P. Mabiki, Direct communication, 10 November, 2011). Due to this observation, there was an increased curiosity to investigate the indicating properties of *S. glaucescens* and possible use of the extracts as acid base indicator to serve as an alternative to the synthetic indicators. Furthermore, on the best of the reviewed literatures, there was no any study that report on the use of the extracts from the *S. glaucescens* parts as acid base indicator.

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Theoretically, acid-base (pH) indicator is a halochromic chemical compound that is added in small amounts (dropwise) to a solution so that the pH of the solution can be determined visually and change colour with variation in pH, hence a pH indicator is a chemical detector for hydronium ions (H_3O^+) or hydrogen ions (H^+) (Zumdahl, 2009). Acid-base indicators are generally weak acids or weak bases which form ions by dissociating slightly when dissolved in water (Sharma *et al*., 2016). An indicator which is a weak acid with the formula HIn and its conjugate base have different colours at equilibrium as can be best represented by the equilibrium equation below:

Acid Conjugate
Colour A Colour B

Thus, colour A in the solution is formed due to the presence of high concentration of H_3O^+ which causes the equilibrium to shift the left. This colour occurred at low pH values. On the other hand, colour B in the solution is formed at high pH due to the presence of low concentration of H_3O^+ and consequently causing the equilibrium to shift the right (Sharma *et al*., 2016). In acid-base titration, indicators are used to determine the end point of the titration at which the acid and base are in the exact proportions necessary to form salt and water only (Okoduwa *et al*., 2015). Currently, synthetic indicators such as methyl orange, methyl red and phenolphthalein are used for acid-base titrations (Sharma *et al*., 2016; Okoduwa *et al*., 2015). These indicators are not only that are expensive but proved to cause environment hazardous and harmful to human beings due to carcinogenicity nature (Okoduwa *et al*., 2015). Following these synthetic indicators limitations, the search for natural indicators as acid-base indicator was highly emphasized in order to obtain alternative against the stated limitation (Abbas, 2012). This study aimed at investigating the potentiality of extracts from *S. glaucescens* as acid base indicator during titration. The study focused on the preparation and testing the indicating capacity, determination of the colour changes and their reversibility in different medium, examination of the transition range values, establishment of the colour scales, demonstration of the indicator using a titration reaction and finally, the development of the titration curve of the extracts from *S. glaucescens*.

Experimental Procedures

2.1 Material

Fresh leaves stem and root barks of the *Synadenium glaucescens* were collected in Njombe region. The samples were treated to dryness under the shade followed by pulverization.

2.2 Reagents

Dichloromethane (DCM), Dimethylsulfoxide (DMSO), Ethanol (EtOH), Hydrochloric acid (HCl), Acetic acid (CH_3COOH), Sodium hydroxide (NaOH), Ammonium hydroxide (NH_4OH), buffer solution, distilled water, Ammonia 20% in a closed bottle,

Baking soda, Distilled water, Methyl orange (M.O), and Phenolphthalein (P.O.P) were purchased from the suppliers by the Department of Chemistry and Physics, Solomon Mahlangu College of Science and Education at Sokoine University of Agriculture, Morogoro.

2.3 Extraction by using Water (Total Extraction)

The pulverized leaves, stem and root barks of *S. glaucescens* were obtained and, 10 g of each were measured separately by using digital chemical balance of which were placed in three different beakers. 150 mL of water were added to each beaker followed by gently heating of the content in beakers at 45^0C for 25 minutes. The mixture was cooled. After cooling, the liquid was poured off separately followed by filtration to obtain the supernatant. Finally; the leaves, stem and root barks supernant of the *S. glaucescens* were tested in acids and bases and the results were recorded in the tabular form. The plant part whose extracts showed positive result in changing colour was later considered for extraction by using soxhlet method.

2.4 Extraction using Soxhlet Method

The extraction of the natural extracts using soxhlet involved the stem and root barks of *S. glaucescens*. 10 g of the pulverized stem and root barks of *S. glaucescens* were measured by means of digital balance and placed into different thimbles (1 mm diameter, 33 mm diameter and 80 mm length) in the extraction chamber and extracted using a common Soxhlet apparatus consisting of a condenser, a Soxhlet chamber, and an extraction flask. Extraction time was 4 hours at a temperature of 30°C for dichloromethane and 60°C for Ethanol. The obtained supernatant were concentrated using rotary evaporator to obtain the crude extracts. The crude extracts separately were removed from the flask and used for preparation of the natural indicators by dissolving in DMSO as solvent.

2.5 Preparation of Root Barks of Synadenium glaucescens indicator (RBSGI) and Stem Barks of Synadenium glaucescens Indicator (SBSGI)

A 0.288 g and 0.286 g powders of root bark of *Synadenium glaucescens* extracts (RBSGI) and Stem Bark of *Synadenium glaucescens* extracts (SBSGI), respectively, were weighted using digital chemical balance and dissolved in 50 mL and 25 mL of DMSO, respectively to prepare the natural indicator. The prepared natural indicators were tested in acids and bases and the result were recorded in a tabular form. The experiments were carried out by using various graduated apparatus used for titration reactions, pH-meter, screw driver and Digital camera. Methyl orange (M.O) and Phenolphthalein (P.O.P) (Standard indicators) were prepared and used for control experiments.

2.6 Reversibility of RBSGI and SBSGI

Third (30 mL) of 0.1M NaOH was measured into the beaker. 3-drops of (RBSGI) were added and the colour was recorded. Slowly the solution of 0.1M HCl was added into the beaker containing the solution of 0.1M NaOH and the natural extracts till the colour

change. The colour change was recorded. Finally, the solution of 0.1M NaOH was added slowly till the colour change. Results of the observation made were recorded. The same procedures were repeated by using SBSGI.

2.7 Transition Range Value of RBSGI and SBSGI

Twenty five (25 mL) of 0.1M of NaOH was pipetted into a titrating conical flask. 3-drops of RBSGI were added into the titrating flask. The pH-meter was immersed into the solution in the flask and the pH reading was made. The titration was allowed until the colour changed. The pH and the colour of the neutralized solution were taken and recorded in the tabular form. The experiment was repeated while using SBSGI. The pH transition range of the RBSGI and SBSGI were both evaluated by measuring the pH of the medium just before and after colour change has occurred, taking the two values as the pH range over which colour change occurred to indicate the equivalent point (Izonfuo *et al*., 2006).

2.8 Estimation of Colour Scale of the RBSGI

By means of pH buffer solution and screw driver, the pH meter was set. A solution with pH = 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 were prepared by using hydrochloric acid and Ammonia solution. For the case of pH = 7 tape water was used. 3 mL of the solutions of different pH were measured into different test tubes. 3-drops of RBSGI were added to each test tube. Pictures were taken showing the colour scale of the extract when exposed into different pH scale.

2.9 Effectiveness of RBSGI and (SBSGI) during Titration

The acid-base titration experiments used RBSGI, SBSGI, POP and MO. The reagents were not calibrated. The titrations were performed using 25 mL of titrate in the titrating flask with 3-drops of indicator against titrant from the burette. A set of four experiments each for all types of acid base titrations i.e. strong acid-strong base (HCl v/s NaOH), strong acid- weak base (HCl v/s NH_4OH), weak acid – strong base (CH_3COOH v/s NaOH), weak acid – weak base (CH_3COOH v/s NH_4OH) were carried out. The results in a tabular form were recorded. The mean and standard deviation for each of acid base titrations were calculated from results obtained.

2.10 Titration Curve of RBSGI and SBSGI

Titration curve of both natural indicator (RBSGI and SBSGI) and standard indicators (POP and MO) were obtained from all the four set of experiments for all types of acid base titration following the order of strong acid v/s strong base, weak acid v/s strong base, strong acid v/s weak base and weak acid v/s weak base. The results were plotted on graphs to estimate the titration curves.

3. Results and Discussion

Results showed in table 1 indicated that the extracts from the Leaves of *Synadenium glaucescens* remain unaffected as there was no colour change while in different acid-base media. This indicated that the leaves of the *S. glaucescens* have no indicating capacity. On the other hand, the stem and root barks extracts from *S. glaucescens* behaved

differently in different acidic and basic medium as the colour change was observed. Therefore, both stem and root barks of *S. glaucescens* were observed to have indicating capacity.

Table 1: Colour Observation Chart (0.1M HCl and 0.1M NaOH)

Plant part used	Solvent used to dissolve the extract	Extraction Method	Colour Observed	
			HCl	NaOH
Leaves (L)	H_2O	Total extraction/heat	Yellow	yellow
Stem Barks (SBSG)	H_2O	Total extraction/heat	yellow	orange
Root Barks (RBSG)	H_2O	Total extraction/heat	yellow	Brick red
Stem Barks (SBSG)	DMSO	Soxhlet extraction/EtOH	colourless	orange
Root barks (RBSG)	DMSO	Soxhlet extraction/EtOH	Colourless	Brick red

The results for pH transition range were shown in table 2. The relationship between the pH of an indicator, its dissociation constant, Ka and the concentrations of the conjugate base and acids forms of the indicator is mathematically expressed by the Hunderson-Hasselbalch equation which is reported by (Pradeep & Dave, 2013; Izonfuo *et al*., 2006) as:

$$pH = pKa + log\frac{[In^-]}{[HIn]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where by In^- and HIn are the two forms of the indicator which are usually have different colours. At half the equivalence point; the concentration of the form In^- and HIn are equal and hence the equation 1 above is reduced to:

$$pH = pKa \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Therefore, basing on the pH range data provided on table 2, the pKa and Ka of the RBSGI are 8.3, 6.03, 8.0 and 7.05; and 5.0×10^{-9}, 9.3×10^{-7}, 1.0×10^{-8} and 8.9×10^{-7}, respectively. Likewise, the pKa and Ka of SBSGI are 6.5, 6.4, 7.8 and 7.0; and 3.2 × 10-7, 3.9 × 10-7, 1.6 × 10-8 and 1.0 × 10-7, respectively. The pH ranges of some common indicators used in acid base titration are reported as from 0.0 to 12.0 (Khan & Farooqui, 2011). Most organic compounds of which are weak acids, their dissociation constants are reported to range from 10^{-2} to 10^{-60} (Daley & Daley, 2009). Also, the pKa values for most weak acids are reported to range from 4.7 to 15.7 (Carey, 2000). RBSGI and SBSGI have the pH range that is within the common acid base indicator pH ranges. The pKa and Ka values verify that both RBSGI and SBSGI are suitable to be used as acid base indicator. Furthermore, literatures reports on the pH ranges of both phenolphthalein and methyl oranges indicators to be 8.3 to 10.0 and 3.1 to 4.4 (Pradeep & Dave, 2013). These pH ranges are narrow compared to the pH ranges of RBSGI and SBSGI (Table 2) together with the colour scale of the RBSGI (Figure 1). Therefore, this indicated that the extracted indicators have wider pH ranges compared to synthetic indicators notably, phenolphthalein and methyl orange indicators and hence RBSGI and SBSGI can be widely used as universal indicator.

Table 2: Transition Range of Syna-Indicators

Indicator	0.1M Titrant v/s 0.1M Titrate	Colour Change	pH-Range
RBSGI	HCl v/s NaOH	Brick red to Colourless	3.90 -12.7
RBSGI	HCl v/s NH_4OH	Brick red to Colourless	2.96-9.1
RBSGI	CH_3COOH v/s NaOH	Brick red to Colourless	4.8-11.2
RBSGI	CH_3COOH v/s NH_4OH	Brick red to Colourless	4.7-9.7
SBSGI	HCl v/s NaOH	Orange to colourless	2.9-10.1
SBSGI	HCl v/s NH_4OH	Orange to colourless	3.8-9.0
SBSGI	CH_3COOH v/s NaOH	Orange to colourless	5.6-10.0
SBSGI	CH_3COOH v/s NH_4OH	Orange to colourless	5.4-8.6

Figure 1:Colour Scale for RBSGI Estimated from solution of pH 2 to 11

The reversibility capacity of the extracts from both stem and root barks of *S. glaucescens* are shown on figure 2. The reversibility property of any indicator is important in order to distinguish indicator dyes from other colour forming reagents (Hunger, 2003). Indicator dyes should be able to reverse their colours. The results in figure 2 show that regardless of the method used for their extraction, colours of both root and stem barks of *S. glaucescens* were reversed accordingly. This signifies the presence of the indicating molecule in both root and stems barks of *S. glaucescens* of and hence its qualification for providing indicating potentiality.

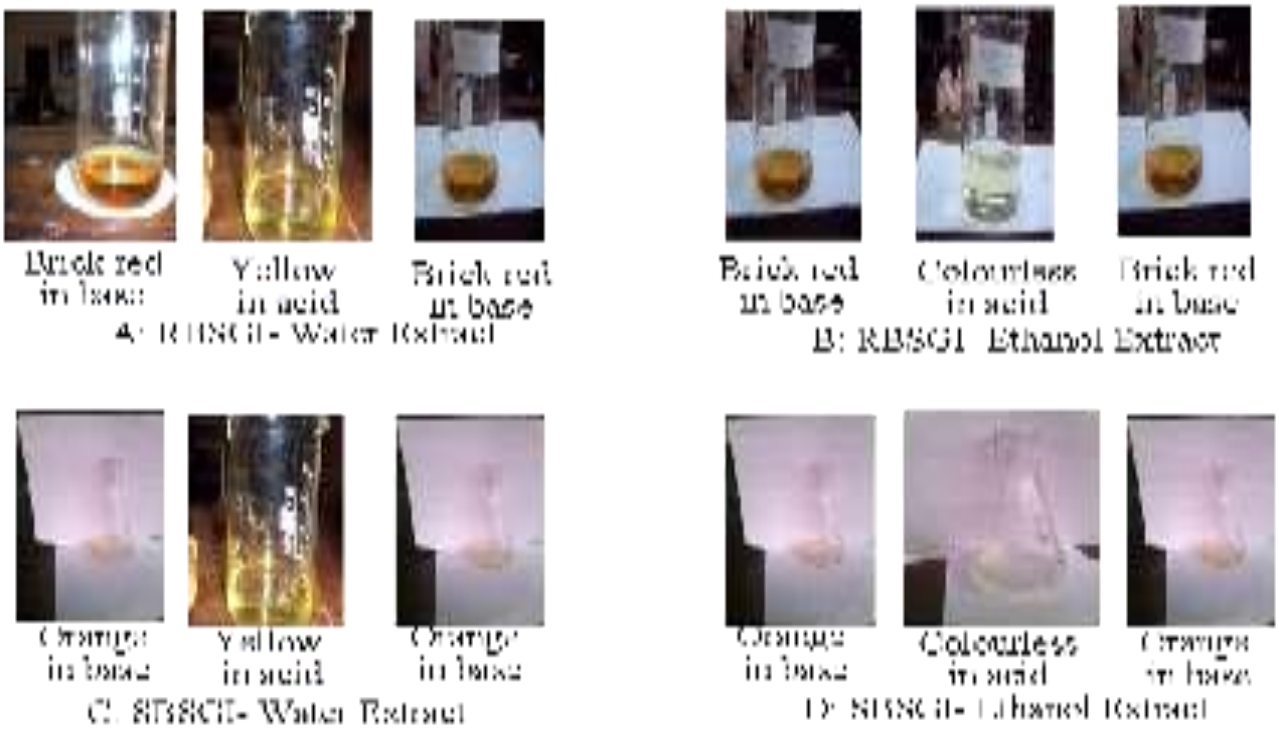

Figure 2. Reversibility of RBSGI and SBSGI

The results in table 3 show the titration end points obtained with SBSGI, RBSGI, POP and MO. The results show that the end points of both RBSGI and SBSGI in the titration of 0.1M HCl and NaOH are comparable to those obtained using POP and MO. The titration of 0.1 M of HCl and NH_4OH which is the strong acid against weak base and that of 0.1 M of CH_3COOH and NaOH which is weak acid and strong base, showed that, the end points of RBSGI and SBSGI are fairly comparable to both POP and MO. On the other hand, the end point of both RBSGI and SBSBI in the titration of 0.1 M of CH_3COOH and NH_4OH which are weak acid and weak base are not comparable to MO, though they are close related to the end point of POP. This indicated that, RBSGI and SBSGI may not be a good indicator for the titration of weak acid against weak base. The results for end points obtained in this work agree to results obtained when *Hibiscus subdariffa* was used as an indicator, of which the end points were comparable to those obtained using POP and MO in the titration of 0.1 M HCl and NaOH (Izonfuo *et al.*, 2006).

Table 3: Titration End Points (0.1M of Titrant and Titrate)

Titrant v/s Titrate	Indicators	Mean±SD	Colour Change
HCl v/s NaOH	P.O.P	24.4±0.23	Pink to colourless

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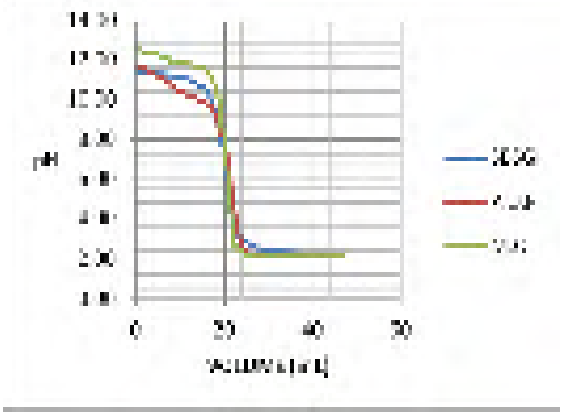
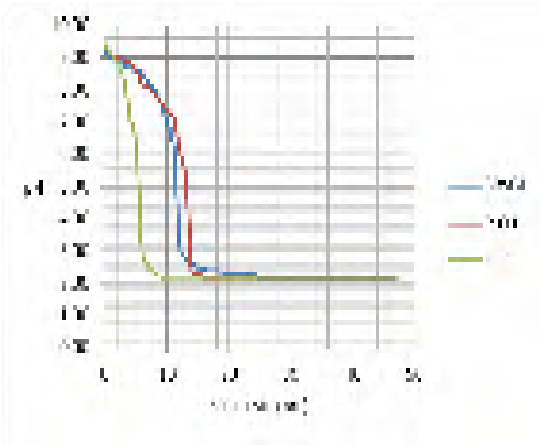
	M.O	24.3±0.21	Yellow to pink
	RBSGI	24.3±0.31	Brick red to colourless
	SBSGI	24.1±0.05	Orange to colourless
HCl v/s NH_4OH	P.O.P	22.1±0.82	Pink to colourless
	M.O	25.1±0.66	Yellow to pink
	RBSGI	25.4±0.75	Brick red to colourless
	SBSGI	18.9±0.17	Orange to colourless
CH_3COOH v/s NaOH	P.O.P	24.3±0.76	Pink to colourless
	M.O	25.2±0.25	Yellow to pink
	RBSGI	25.1±0.20	Brick red to colourless
	SBSGI	22.0±0.40	Orange to colourless
CH_3COOH v/s NH_4OH	P.O.P	24.8±0.25	Pink to colourless
	M.O	30.5±0.92	Yellow to pink
	RBSGI	24.3±1.27	Brick red to colourless
	SBSGI	24.0±0.04	Orange to colourless

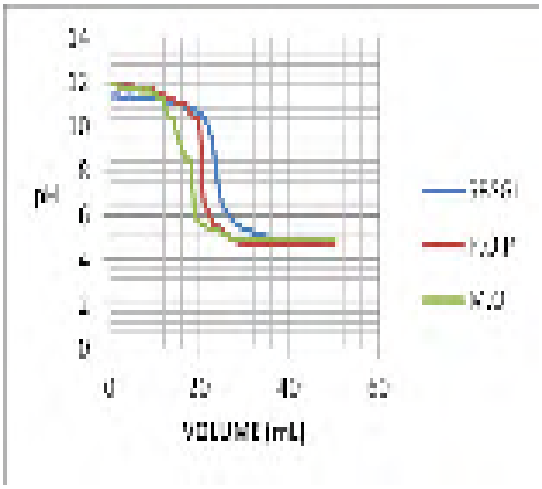
Moreover, the titration curves shown in figures 3a-d and 4a-d below showed the potentiality of using SBSGI and RBSGI during the titrations of strong acid against strong base, strong acid against weak base and weak acid against strong base due to steep bit on the graphs which provide easy detection of the end point. However, the graphs for both SBSGI and RBSGI in the titration of CH_3COOH and NH_4OH, that is weak acid and weak base showed points of inflexion rather than a steep bit. Lack of steep bit causes difficulty in the detection of end points during the conduction of titrations of weak acid against weak base.



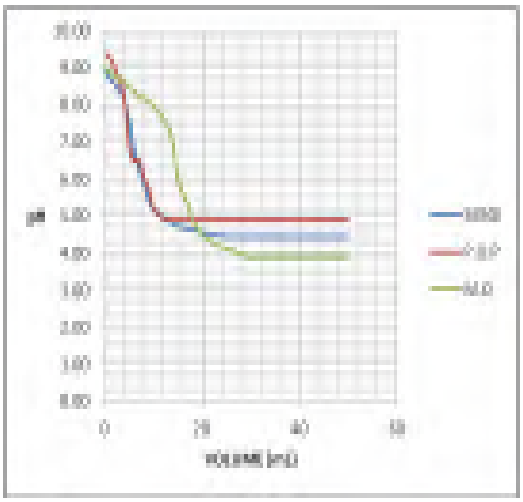
3a: Strong acid v/s strong base base (HCl v/s NaOH)



3b: Strong acid v/s Weak (HCl v/s NH_4OH)

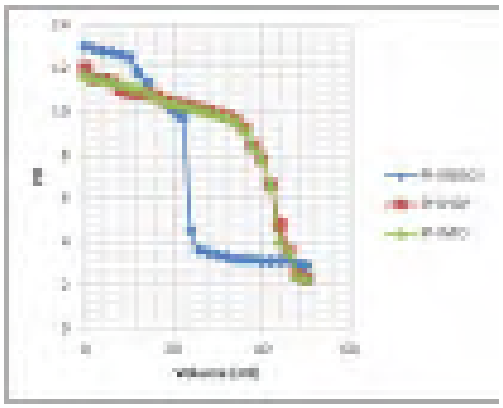


3c: Weak acid v/s strong base
(CH_3COOH v/s NaOH)

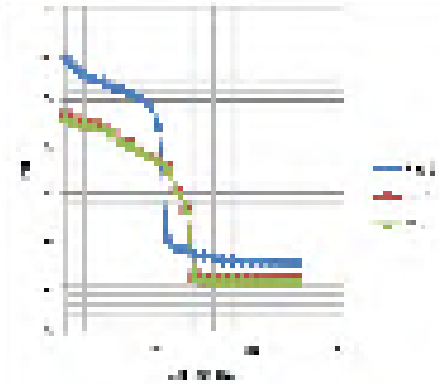


3d: Weak acid v/s weak base
(CH_3COOH v/s NH_4OH)

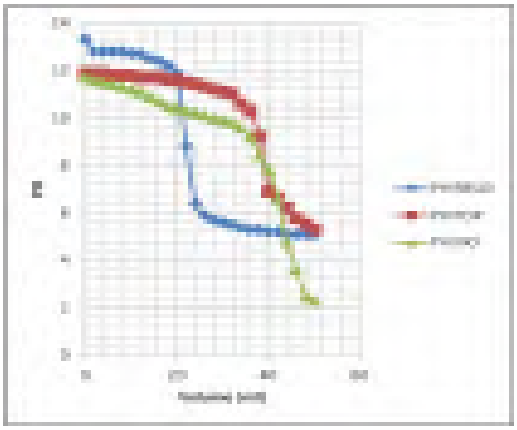
Figures 3a-d: Titration curves for SBSGI, P.O.P and M.O

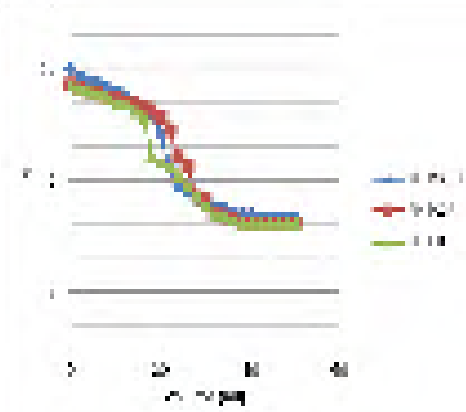


4a: Strong acid v/s strong base
(HCl v/s NaOH)



4b: Strong acid v/s weak base
(HCl v/s NH_4OH)





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4c: Weak acid v/s strong base (CH_3COOH v/s NaOH)

4d: Weak acid v/s weak base (CH_3COOH v/s NH_4OH)

Figures 4a-d: Titration curves for RBSGI, P.O.P and M.O

4. Conclusion

Both extracts from the stem and root barks of *Synadenium glaucescens* are suitable universal acid base indicators for use during acid base titrations. Further studies are recommended to develop paper indicators and simple indicators tools which can be used by farmers onsite. Furthermore, studies on the compounds associated with colour change and their mechanisms will add value on science of natural indicators.

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The Relationship between Women's Reproductive Factors and Household Socio-Economic Status: a Case of Morogoro District, Tanzania

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Abstract

Women's poor SES is linked to multiple contributing factors, most of which are related to performing multiple roles that include family, childcare and reproductive responsibilities in general. However, the relationship between women's reproductive factors and household SES remains uncertain. This study explored the association between selected reproductive factors and households' SES among rural households with women of reproductive age. A cross-sectional study, involving six randomly selected villages from three wards of Morogoro District, Tanzania, were involved in the study on which the paper is based. A total of 542 participants consisting of women from male and female-headed households were involved in the study. Data analyses were performed using Statistical Package for Social Sciences (SPSS). Ordinal logistic regression model wasused to estimate the relationship of study variables. The number of children a woman wished to have had negative association with SES, whereby wishing to have more than 5 children was associated with less likelihood[OR 0.68; 95% CI: (0.46-0.99), p<0.05] to attain the higher SES. The mean age at first pregnancy was 18.5 years, with 56.5% of the participants becoming pregnant for the first time at age 18 or below, which indicates predominance of teenage pregnancies. The age at first pregnancy had significant and positive relationship with SES, whereby being pregnant at the age of more than 18 years increases the chance of attaining a higher SES [OR 1.48;95% CI: (1.02-2.14), p<0.05]. In conclusion, teenage pregnancies and the desire for relatively many children (>5) constrain the attainment of higher SES. The study recommends strengthening reproductive health education particularly family planning and advocacyon teenage pregnancies in rural communities.

Key words: Women; Socio-economic status; Reproductive factors; Rural

Introduction

Socio-economic status (SES) remains one of the areas of interest for researchers in the area of economic development. The phenomenon (SES), is an indicator of well-being of the members of households that is commonly used to depict an economic difference in society as a whole (Abraham, 2016).Since in the 1960s, gender issue has surfaced substantially in analyzing SES in societies particularly when explaining poverty levels (Moser, 2012; Pressman, 2002; Pressman, 2003; Chant, 2006). The gender concern with regard to socio-economic status is based on the paradigms explaining disproportionate level of poverty among men and women particularly with regard to female-headed households (FHHs) andmale-headed households (MHHs). Gender poverty gap is experienced in both developed and under-developed countries. Literature shows that in the World, most of the poor households are those headed by women (Chant, 2012; Cawthorne, 2008). For example, literature shows that by 2008, the gap in poverty rates

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between men and women was wider in America than anywhere else in the Western world (Cawthorne, 2008). In Sub-Saharan Africa, Tanzania inclusive, poverty levels take similar trend whereby majority of the poor are households headed by females (Macro, 2011; Kehler, 2013).

For a long time, researchers have made effort to establish the link between gender and SES. The explanation that women and their households consists majority of the poor is widespread (Peterson, 1987; Pressman, 2002; Pressman, 2003; Chant, 2003; Chant, 2006; Cawthorne, 2008; Moser, 2012). One of the prominent theories is the Feminist Explanations for the Feminization of Poverty (Pressman, 2003); the theorist associate women and poor SES with poor participation in the labor market. Gender poverty disparity is apparent, the debate remains on whether the factors that link women and poor SES as reported in the existing literature apply across different socio-economic groups.

Women are linked with poor SES through a variety of factors such as inequality in wages, segregation of employment in paying occupations and domestic sexual-related violence, whereby women are paid less than men even when they have the same qualifications and work same hours (Cawthorne, 2008). The main argument explaining the link between women and poor SES is that women spend more time in performing reproductive roles that usually are not associated with economic gain (Pressman, 2003). Reproductive role isdefined as activities related to the creation and sustaining the family and the household (Komatsu *et al.*, 2015; Bibler and Zuckerman, 2013). Women are known to perform multiple roles in societies that are productive role, reproductive role, and the role of community management(Moser, 2012), because of these multiple roleswomen are constrained in their involvement in productions(Pressman, 2003; Cawthorne, 2008; Moser, 2012).

The link between reproductive roles and household SES is complex, and it involves several factors, most of which have not been studied.The factors vary from one socio-economic group to another across different communities. Studies explaining women factors that lead to poor household SES were conductedmainlyin developed countries (Pressman, 2002; Pressman, 2003; Cawthorne, 2008; Chant, 2012, Moser, 2012) and thus may not be directly extrapolated to under-developed African communities like Tanzania. For example, number of children, which is likely to influence the time that a woman spends for childcare, differs among rural and urban societies even within the same region like Tanzania (Macro, 2011).

Therefore, this study aimed to examine the relationship between women reproductive factors and household SES in Morogoro District, Tanzania. The key reproductive factors in this study included the number of biological children of the study participants, birth interval, and number of unplanned pregnancy (s) a participant had experienced as well as the age when a participant conceived for the first time. Specifically, the study intended to (i) determine the association between the number of children per woman and household SES (ii) examine the relationship between the birth interval (iii) relate unplanned pregnancies and household SES in the study area and (iv) analyze the link between the age at first pregnancy and household SES,.

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Participation of women in socio economic development is inevitable if higher SES is to be attained. This is because they makehigher proportion in the productive workforce. In agricultural sectors in Tanzania, women constitute majority (54%) of the work force (Leavens, 2011; Palacios-Lopez *et al.,* 2015), meaning that their contribution on economic development is important in order to realize positive change in development not only in their households but also in the whole community. Moreover, the government of Tanzania is committed to transform the economic status of its citizens. This is demonstrated in the development plans formulated that include the frameworks of the first Five Year Development Plan (FYDP I, 2011/2012-2015/2016) and the National Strategy for Growth and Reduction of Poverty (NSGRP/MKUKUTA II, 2010/2011-2014/2015) (National Planning Commission, 2013). Findings from this study will provide valuable information concerning the reproductive factors in relation to household SES in rural context, whichcan be used by development stakeholders to design appropriate interventions for improving living standards of rural residents.

Methodology

Description of the study area

The study was conducted in Morogoro district because of the prevalence of poverty in the area, where 55% of households (HH) in the district are considered as poor based on headcount ratio (Lusambo, 2016).The district is one of the rural areas where fertility rate is very high. The Total Fertility Rate (TFR) for women 15-49 years of age in Tanzania was 6.1 in rural areas compared to 3.7 in urban (Macro, 2011). This indicates existence of potential reproductive issues in rural areas. Six villages were involved in this study. The villageswere Kinonko and Maseyu from Gwata ward; Madamu and Kibwaya from Mkuyuni ward as well as Tandai and Ludewa from Kinole ward.

Sampling Procedure

The sample size was calculated by considering the standard normal deviation set at 95% confidence level (1.96) and 55% as the estimated prevalence of poverty in the study population (Lusambo, 2016). Using the formula: $n = \frac{z^2 p(1-p)}{e^2}$;where 'z' = 1.96 for 95% CI, 'p' is expected true proportion (55%) and 'e' is the desired precision (0.05), the minimum sample size was estimated to be 380 participants to achieve the desired statistical power. However, in order to increase statistical power and precision, 65% of the calculated minimum sample was added to the minimum sample, hence 627 women were included in the study

The study population was women of reproductive age that is between 15 and 49 years as defined by the Tanzania Demographic and Health Survey report (Macro, 2011). The study participants were those who were residents in the study villages, with at least two children and willing to take part in the study. The units of analysis were both households and individual women.

In consultation with local leaders,using availablevillage registers, purposive sampling was used to list down women with the required age from each of the study villages. From the lists, all women who were heads of household were included in the study and

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those from male-headed households were randomly sampled. All women from female-headed households were included in the study because they are usually fewer (Macro, 2011). Three hundred and twenty three (59.6%) of the sampled women came from male-headed households while 219 (40.4%) came from female-headed households. After data cleaning, 542 participants qualified for analysis.

Definition of study variables

Outcome variables

The dependent variable for this study was household SES (wealth index) computed from housing characteristics and asset possession using the Polychoric Principle Component Analysis (PCA). PCA can be defined as a linear combination of optimally weighted observed variables. PCA is used to create a single index variable from a set of correlated variables(Vyas and Kumaranayake, 2006). The main idea of PCA is to reduce the dimensionality of a data set consisting of many variables correlated with each other, either heavily or lightly, while retaining the variation present in the dataset, up to the maximum extent.

Household characteristics that is ownership of the house and material used to build the house and the toilet facility were also used to determine the outcome variable household SES as previously described (Macro, 2011). Another indicator was possession of any of the following assets: motorbike, radio, bicycle, generator, and solar power equipment as recommended by other studies (Filmer and Pritchett, 2001; Sahn and Stifel, 2003; Rutstein and Johnson, 2004; Azzarri*et al.*, 2006). The first component of polychoric PCA was used to generate wealth scores and the scores were then classified using cluster analysis as described in previous studies (Vyas and Kumaranayake, 2006). Cluster analysis attempts to group the most similar cases in one group while maximizing difference between groups. By using this technique, it was possible to create the dependent variable household SES by categorizing wealth scores. The resulting two categories were low and medium-high. The ultimate units of analysis were individual women.

Data collection methods

Assorted methods were employed in collecting information concerning the study participants and corresponding households. Focus Group Discussions (FGDs) and observations were used to collect primary data. Documentary review was used to collect secondary data. Primary data included demographic information, reproductive factors (number of children, birth interval, unplanned pregnancy and age at first pregnancy), as well as household SES (housing characteristics, toilet facility and assets owned by the household). Secondary data from the national, regional, district and village statistics included poverty distribution in Tanzania, population size per participating village and socio-economic characteristics of the study population.

Explanatory variables and their definitions

The explanatory variables were the selected reproductive factors. They included number of biological children of the study participants, birth interval, and number of

unplanned pregnancy (s) a participant had experienced as well as the age when a participant conceived for the first time. For this study, birth interval refers to the interval between the last two consecutive live births (Koenig *et al*., 1990; Macro, 2011). On the other hand, unplanned or unintended pregnancies are terms used interchangeably which refer to pregnancies that are reported to have been either unwanted (i.e., they occurred when no more children were desired) or mistimed (i.e. they occurred earlier or later than desired) (Santelli*et al.,* 2003).

Data collection tool

Data on all study participants were obtained using a structured questionnaire through face to face interview. The questionnaire used in this study was developed by the PhD candidate. Validity and reliability of the questionnaire were determined. It was first piloted on ten respondents before the actual study and these respondents were excluded during actual data collection and analysis. After the pre-test, necessary adjustments in phrasing were made. While the questionnaire was used to collect quantitative data, a separate checklist was used to collect qualitative data though FGDs. The questionnaire was organized into four sections to enable capturing information about demographic, household and reproductive factors as well as household SES (Appendix 1). The checklist was designed to capture information about issues that either needed supplementary explanation, or was not known to normal respondents. Such issues include reasons for low level of education among women, instability of marriages, teenage pregnancy and occurrence of unplanned pregnancies among women in the study area.

Statistical analysis

Quantitative data

After data entry, data cleaning was done. Data were compiled and analyzed using SPSS v20.0 software Quantitative analysis involves computations of measures of central tendency (means and/or medians with SD and IQR), frequencies and percentages. Ordinal logistic regression models were applied to test associations and the effect of each explanatory (independent) variable on the outcome variable Odds ratio (ORs) with 95% Confidence Interval (95%CI) for reproductive factors associated with household SES were estimated. A p-value' of <0.05 was considered to be the cut-off for statistical significance.

Qualitative data

Analyzing qualitative data involved the use of content analysis as recommended by Krueger (Krueger *et al.,* 2001). Field notes were reviewed and the information from individual focus groups was summarized. Themes were aligned based on guiding questions to indicate different opinions about research issues. Important points were illustrated by quotes.

Results

Descriptive statistics of household and demographic characteristics of respondents

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Analysis of data on demographic and household characteristics of the participants was performed. Results for this analysis are presented in Table 1. The age range of participants was between 18 and 49 years, with a mean age of 33.6 (SD= 7.9). Majority (60.5%) of the participants were either married or co-habiting while about a third (29.2%) of participants was widowed, separated, or divorced. The rest of the interviewed women were never married. Majority (65.9%) of households involved in the survey consisted of between 4-6 persons with the median of 5 persons, whereas one-fifth (20.3% had more than 6 members. Most of the households (72.9%) consisted of at least one child aged below 5 years; and another big proportion of interviewed women came from households consisting of 1 to 2 children aged 5-14 years. Other characteristics concerning household composition are shown in Table 1.

Table 1: Household and demographic characteristics of respondents (N=542)

Characteristics		Frequency (n)	(%)
Age category (years)			
	18 – 24	62	11.4
	25 – 35	275	50.7
	36 – 49	205	37.9
	Mean (SD*, Range) Age (years)	33.6 (7.9, 18-49)	
Education level			
	No formal education	220	40.6
	Primary	306	56.4
	Secondary or higher	16	3.0
Marital status			
	Never married (Single)	56	10.3
	Married/cohabiting	328	60.5
	Divorced, widow, separated	158	29.2
Household size(No of persons)			
	Less than 4	75	13.8
	4 – 6	257	65.9
	More than 6	110	20.3
	Median (IQR**) number of HH members	5 (4 – 6)	
HH*** composition by age (years)			
	No. of HHs with <5yrs (n=314):		
	Number of children		
	1 child	229	72.9
	2 or more	85	27.1
	No HHs with 5 – 14 yrs (n=480):		
	Number of children		
	1 – 2	343	71.5
	3 or more	137	28.5
	No. of HHs with ≥15 yrs (n=542):		
	Number of persons		
	1 – 3	425	78.4
	4 or more	117	21.6

*SD=Standard deviation); **IQR=Interquartile range; ***HH=Household

Descriptive statistics of reproductive factors of study participants

This section presents reproductive factors of study participants. Results are presented in Table 2. More than half of respondents (52.6%) had 2-3 children. The median (IQR)

number of children per woman participating in the study was 3 (2-5). Almost one fifth of them (19%) desired to have more than 6 children. About a third (27.5%) of participants had experienced unplanned pregnancy. The mean age at first pregnancy was 18.5 (SD=3.2; Range=12-35), with 56.5% and 43.5% of participants becoming pregnant for the first time at age below18 and above 19 years, respectively.

Table 2: Reproductive factors of respondents (N=542)

Reproductive Characteristic	Frequency (n)	(%)
Median (IQR*) number of children	3 (2-5)	
Number of children		
2 – 3	285	52.6
4 – 5	230	42.4
6 – 10	27	5.0
Median number of children desired (n=524)	6 (5 – 6)	
Number of children desired		
2 – 3	29	5.4
4 – 5	410	75.6
≥ 6	103	19.0
Interval of last two births (in years) (n = 498)		
< 2	137	27.5
2 – 3	268	53.8
≥ 4	93	18.7
Unplanned pregnancy		
Not experienced	393	72.5
Experienced	149	27.5
Mean (SD**, Range) age at first pregnancy (years)	18.5 (3.2, 12-35)	
Age at first pregnancy (Years)		
≤ 18	306	56.5
≥ 19	236	43.5
Consent for first pregnancy (n = 535)		
Not consented	126	23.6
Consented	409	76.4
No consent 1st pregnancy, reason (n = 126)		
Got married	52	41.3
Ignorance of contraceptives	38	30.2
Economic problems (being idle)	34	27.0
Raped	2	1.6

*Interquartile range (IQR);**Standard deviation (SD)

FGDs results showed that reasons for conceiving at young age included getting marriage at that age, poverty, family instability resulting to separation of couples as well as culture associated with matrilineal system. About one third (27.5%) of the study women had experienced unplanned pregnancies. The contributing factors for unplanned pregnancies included lack of family planning education particularly for male partners hence not supporting their wives in birth control and poor family planning services in the study area (FGDs). Majority of participants (76.4%) consented for first pregnancy while the rest of the women did not consent for first pregnancy. Reasons for conception included getting married (41.3%), ignorance of birth-control methods (30.2%), being idle (27.0%) and being raped (1.6%).

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Association between explanatory reproductive factors and household SES

Five explanatory variables that were contemplated to influence the outcome variable (household SES) were subjected to ordinal logistic regression models to analyze the association between the study variables. The explanatory variables were namely: number of children per woman, maximum number of children a women desired to have, interval of last two births, number of unplanned pregnancies and the age of a woman at first pregnancy. Out of these variables, three variables did not show significant relationships with the outcome variable (Table 3). Two variables, i.e. maximum number of children a woman desired to have and the age at first pregnancy showed significant association with the outcome variable. While the number of children a woman desired to have showed negative relationship with SES, the age of a woman at first pregnancy showed a positive significant association with the outcome variable. Women who wished to have more than 5 children were significantly less likely to be in the higher (medium-high) SES category compared to those who wished to have fewer children (≤5 children) [OR 0.68; 95% CI: (0.46-0.99), p<0.05].

Women who conceived while older than 18 years of age, were almost fifty percent (48%) more likely to be in the higher (medium-high) SES category compared to those conceiving for the first time while they were 18 years or younger [OR 1.48; 95% CI: (1.02-2.14), p<0.05]. A birth interval of 2 or more years between the last two births showed to have a weak association with SES. Women who spaced their children for 2 years or more showed to be 32% more likely to attain medium-high SES compared to their counterparts who spaced their last two births for less than 2 years apart. However, this relationship was not statistically significant neither in bivariate or multivariate logistic regression analysis.

Table 3: Reproductive factors associated with household SES (N=542)

Variable	Household SES		cOR	95% CI	P value	aOR	95% CI	P value
	Low n (%)	Medium-high n (%)						
Number of children:								
3 or less	121 (42.5)	164 (57.5)						
More than 3	121 (47.1)	136 (52.9)	0.83	0.59-1.16	0.543	1.00	0.68-1.46	0.321
Maximum number of children desired (n=524):								
5 or less	97 (38.3)	156 (61.7)						
More than 5	136 (50.2)	135 (49.8)	0.62	0.44-0.87	0.048	0.68	0.46-0.99	0.0134 *
Interval of last two births (years) (n=500):								
Less than 2	18 (52.9)	16 (47.1)						

2 or more	214 (45.9)	252 (54.1)	1.33	0.66-2.66	0.115	1.32	0.64-2.75	0.078
Unplanned pregnancy (ies):								
Yes	67 (45.0)	82 (55.0)						
No	175 (44.5)	218 (55.5)	1.02	0.70-1.49		1.02	0.68-1.53	0.056
Age at first pregnancy (years):								
18 or younger	150 (49.0)	156 (51.0)						
Older than 18	92 (39.0)	144 (61.0)	1.51	1.07-2.12	0.035	1.48	1.02-2.14	0.0118 *

*Significant at $p<0.05$; SES = Socio-economic status; cOR=Bivariate analysis odds ratio; aOR=Multivariate analysis odds ratio

Discussion

The mean age of respondents was 33.6 years, ranging from 18 to 49 years, with the age category of between 25 and 35 years forming the majority of participants. This implies that most of the women who participated in the survey bear children within this age range. In this study, 40.6% of women had not attained formal education. This proportion shows a considerable rate of illiteracy among women in the study area. The observed illiteracy rate was high compared to the average national illiteracy rate of 22% and 18% in 2010 and in 2012, respectively (Macro, 2011). The level of education has been reported as an important factor with impact on reproductive and SES issues. Education empowers women by increasing their autonomy and understanding of family planning issues, which often results into bearing fewer children (Levine *et al.,* 2001). Concerning the number of children per woman, our findings show that majority of women had 2-5 children, though about one fifth (19%) of them desired to have more than 6 children. The desired number of children for each woman is in line with findings from the Tanzania Demographic and Health Survey 2012 (URT, 2012), which reported a Total Fertility Rate (TFR) in rural Tanzanian women aged 15-49 years to be 6.1 compared to 3.7 in urban areas (Macro, 2011).

In this study, the number of children a woman desired to have was negatively associated with SES. This negative relationship has previously been proposed to operate through early pregnancy hence early parenthood and close spacing of children, which compromise economic productivity (Peterson, 1987; Budig and England, 2001; Cawthorne, 2008). Findings from this study therefore underscore the importance of family planning education among women that will enable them to effectively plan for appropriate number and spacing of their children. The World Health Organization recommends the spacing between consecutive children to be at least 2 years (World Health Organization, 2005). Appropriate planning of the number and spacing of children will enhance economic and development plans, including planning for costs of child education.

More than a half of study participants had their first conception below the age of 18 years, reflecting the predominance of early (teenage) pregnancies and motherhood in the study area. The age at first pregnancy showed a significant positive association with household SES. Participants who had their first pregnancy at or above 18 years were more likely to be in the higher (medium-high) household SES category. Teenage pregnancies and motherhood have been reported to be interlocked with poverty through discontinued education, reduced employment opportunities, un-stable marriages, low incomes and heightened health and developmental risks (Rindfuss*et al.*, 1984).

Findings from this study therefore explain the high degree of vulnerability of the study community, especially women, to poverty through childhood pregnancies and motherhood as previously suggested elsewhere (Varga, 2003; Jaiyeoba, 2009; Hofferth*et al.*, 2001). FGDs attributed teenage pregnancies to early marriages as well as poverty and family instability that forces girls to take responsibility of caring families.Cultural believes associated with matrilineal societies, to which the study community belongs, was reported to encourage early pregnancies by believing that getting children for a girl was important in ensuring perpetuation of the clan.

Through FGDs, participants explained their experience of schoolgirls becoming pregnant and fail to complete secondary education. As expressed by participants during FGDs, community members had the opinion that the education system in the country is likely contributing to the early pregnancies. A woman in Kibwayavillage made the following remark; *'…Lack of accommodation (hostels) in secondary schools forces students to stay in private residential apartments with no proper care, which tend to subject the girls to risks of engaging in unsafe sex, with consequences of unplanned pregnancies...'*. The findings underscore the need to conduct studies to establish empirical evidence on incidence of pregnancies in schools in the study area to suggest entry points for intervention considering that only 3% of participants showed to have attained post-primary school education. Participants expressed their views that the teaching on reproductive health in schools makes youths to ignore traditional training about reproductive matters, while it drives the youth to engage in sexual activities without knowing the consequences.

A woman from Maseyu village had this comment to make '... "Current education system exposes girls to sexuality prematurely and thus accelerates their involvement in sexual activities. While the school syllabus for reproductive health is incomplete, it makes girls lose interest of what their parents teach them..". The study findings from the current study were in line with the report of the WHO (McIntyre and World Health Organization, 2006), that a quarter of all women in Tanzania begin childbearing as adolescents before reaching the age of 20 years (Ngallaba*et al.*, 1993).

We observed a handful of un-consented pregnancies among participating women. The most common reasons were 'getting married', 'ignorance on contraception' and 'being idle'. All of the mentioned reasons are linked to family poverty. Poor households tend to force their teenage children into marriages as a means of economic gain (Varga, 2003). Ignorance of contraception and being jobless are both results of failure to access

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education and secure an income generating activity. Most of the study women had their last two births spaced at most 36 months apart. This birth interval is in accordance with the WHO recommendation of 2-3 years (World Health Organization, 2005). The health benefits of longer birth intervals of at least 2 years apart have been reported by several studies (Morley, 1977; Setty-Venugopal and Upadhyay, 2002; Marston, 2006; Macro, 2011).

Conclusions and recommendations

This study has found that the number of children has negative relationship with household SES such that women who wished to have relatively many children, more than five, were less likely to belong to higher (Medium – High) SES. The desire for many children (>5)constrain the attainment of higher SES.Women who conceived while older than 18 years of age, were more likely to attain higher SES compared to those who conceived while they were younger; but majority of women in the study area conceived for at the age of 18 years or younger. Early pregnancy and motherhood restrict the households from attaining higher SES. Factors promoting early pregnancies and motherhood are many with different nature including but not limited to economic and cultural factors.Based on the above conclusions, thegovernment through the Ministry of Health is urged to promote reproductive health education in Morogoro district.Early pregnancies and motherhood should be strongly discouraged as part of reproductive health interventions specially tailored to suitlow literacy group so that the intended messages are delivered effectively.

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Impact of habitat degradation on the assemblage of riparian ground beetles (Coleoptera: Carabidae) in the Morogoro Municipality, Tanzania

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Abstract

This study assessed the impact of habitat degradation on the assemblage of riparian ground beetles in the Morogoro Municipality, Tanzania. The beetles were collected from three degraded (Ngerengere, Morogoro and Kikundi) and three relatively pristine streams (Bigwa, Vituli and Lukuyu) during the rainy season between January and April 2013. The beetles were collected by active searching on the ground, in leaf litters, under logs and stones. The abundance, species richness and diversity of the beetles were analyzed using Diversity and Richness ver. 2.65, PRIMER ver. 6.1 and SYSTAT ver. 10. The abundance of beetles was significantly high in relatively pristine streams (n=143) compared to the degraded streams (n=75; 34.4%) (Mann-Whitney U=4396.500; p<0.05). Metagonum sp.2, Peryphus sp.3, Boeomimetes ephippium, Abacetus sp.2 were the most abundant in relatively pristine streams while Diatypus uluguruanus, Metagonum mboko, Peryphus sp.3 were the most abundant in degraded streams. The highest species richness (S=21) was recorded in relatively pristine streams (s=21) while the lowest species richness (S=13) was recorded in the degraded streams. Furthermore, relatively pristine streams showed the highest average diversity (H' = 2.5359) compared to the degraded streams (H' = 2.0662). Based on the findings, ground beetles are good indicators of habitat quality. These results call for strengthened measures to control degradation of the riparian areas in the Morogoro municipality.

Key words: Ground beetles, Carabidae, habitat degradation, Tanzania

1.0 Introduction

Morogoro Municipality is located in Morogoro region on the eastern side of Tanzania at latitude 5 º - 6ºS and longitude 36 º - 37ºE. It is found on the lower slopes of the Uluguru Mountains at an altitude of about 500 m a.s.l and 190 Km west of Dar es Salaam. Morogoro Municipality receives several streams from the mountains, which supply water to Morogoro Municipality and other nearby regions such as the Coast and Dar es Salaam. The streams also create riparian habitats, which play a key role in water and biodiversity conservation. The riparian habitat often has high species diversity and is critical for wildlife. The habitat is important for insects, birds and other groups of organisms (Hafeez, Khan, & Inayatullah, 2000). Despite the benefits riparian habitat provide, they face an increasing pressure from both natural and anthropogenic activities.

The knowledge of biodiversity changes as a result of natural or anthropogenic mediated activities requires a baseline record (Maveety, Browne, & Erwin, 2011). Biodiversity inventories are important and can serve as studies of climate change and other expected environmental transformations (Chen *et al*., 2009; Maveety *et al*., 2011). This is useful

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particularly in planning to protect habitats in order to yield the greatest gains for wildlife (Knutson & Naef, 1997). As in other parts of the world, a wide range of anthropogenic activities such as domestic and industrial waste discharge, quarry mining, tree clear-cutting, farming activities and settlement establishment threaten riparian habitats in Morogoro Municipality.

Ground beetles have been widely used as bioindicators of environmental change and health of habitats because they are diverse and highly sensitive to habitat changes (Alexander et al., 2011; Rainio & Niemelä, 2003). Whereas ground beetle fauna of the Uluguru Mountains has been documented in a few surveys made by Basilewsky (1962; 1976) and Maganira and Nyundo (2015), there has been no any survey in the lowlands next to the mountains. It is feared that many species including some ground beetle species may be lost before they are described, as riparian forest clearing and other forms of habitat degradation continue to rise. The objective of the present study was to investigate the assemblage of riparian ground beetles in relation to anthropogenic activities taking place along stream banks in Morogoro Municipality, Tanzania.

3.0 Material and methods

3.1 *Sampling*

Baseline data of riparian ground beetles were collected from riparian habitat (stream banks) in Morogoro Municipality, Tanzania in the wet season between January and April, 2013 using active searching method. Six study sites were set at the riparian habitat of streams with two different habitat conditions (Figure 1). The sampled area for all the study sites measured 4 m wide and 10 m long. The relatively pristine streams (Vituli, Bigwa and Lukuyu) were located in the least urbanized zone (Bigwa area) with many large trees, ferns, herbs and received minimum domestic effluents. On the other hand, the degraded streams (Kikundi, Morogoro, and Ngerengere) were located in the highly urbanized zone (Morogoro Town area) with few large trees, ferns, herbs and received more effluents from homes, markets, and small industries than the relatively pristine streams and had pronounced tree clear-cutting, farming activities, and quarry mining. Generally, the vegetation cover was much more pronounced in relatively pristine streams compared to degraded streams.

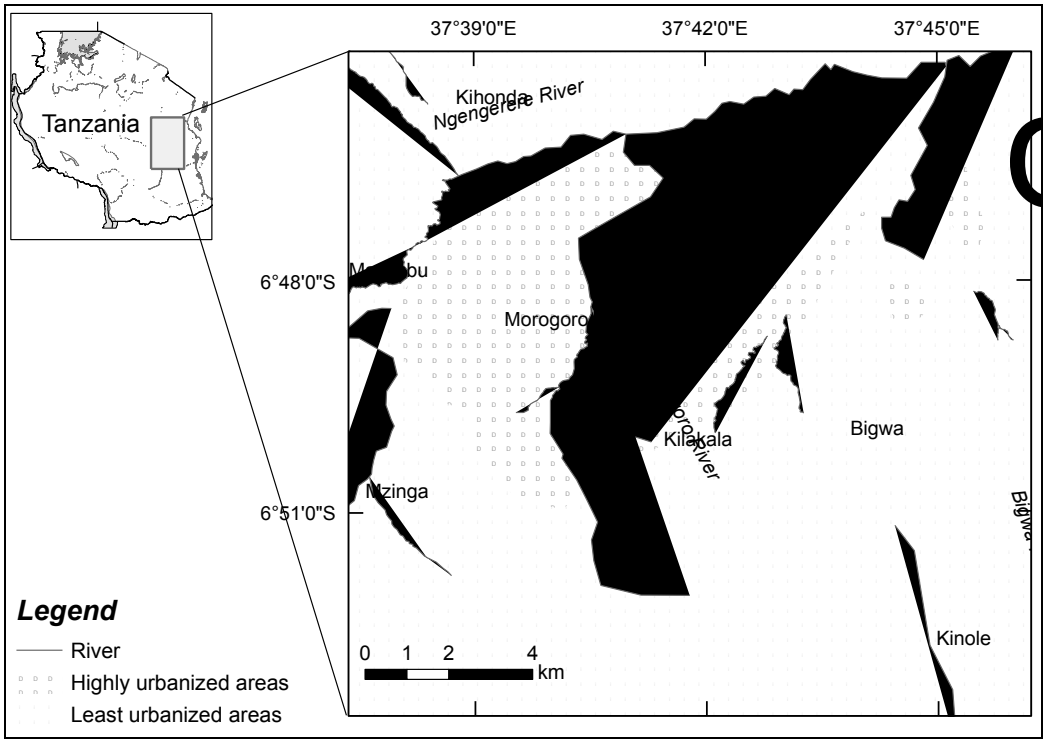

Figure 1: Map of the Morogoro municipality showing the studied streams

Active searching was done by searching for riparian ground beetles, at each site during the day, on the ground, in leaf litters, under logs and stones. The ground beetles collected by each of the collectors involved for a period of one hour constituted one "sample". A total of 216 samples were collected. Each sample was placed into one plastic bag containing 75% ethanol and then placed into plastic buckets before they were transferred to the laboratory for analysis.

3.2 Identification of the sampled beetles

In the laboratory, all the collected riparian ground beetles in each sample were counted and identified according to Basilewsky (1953), CSIRO-DE (1991), White (1983) and Picker, Griffiths, & Weaving (2004). In case where it was impossible to identify the specimens to species level, numbers were used for every mophospecies and were left to be identified later when experts and resources are available. Morphospecies is here used for Recognizable Taxonomic Unit (RTU) (CSIRO-DE, 1991), meaning a morphologically recognizable entity, to which all morphologically similar specimens are assigned. Some of the identified species were mounted and pinned (for relatively larger specimens) and carding was done for smaller specimens. The rest of the specimens were deposited in the Zoology laboratory in the Department of Biosciences of the Sokoine University of Agriculture for reference.

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3.4 Data analysis

The diversity of the riparian ground beetles was calculated using Shannon-Wiener index (Shannon, 1948).The species diversity between the two stream habitats was compared using Student's t-test(Barnett, Shapley, Benjamin, Henry, & McGarrell, 2002; Zar, 1984).Mann-Whitney test was used to compare the abundance of riparian ground beetles among sites. Species Diversity and Richness ver. 2.65 (Henderson & Seaby, 2001) and SYSTAT ver. 10 (Kroeger *et al*., 2000) were used for univariate analysis. Multivariate analysis of the assemblage of ground beetles was performed using PRIMERver. 6.1 (Clarke and Warwick, 2001). Constrained ordination analysis of the community structure of ground beetles was performed based on non-metric multidimensional scaling (n-MDS). Prior to this, abundance data were square root transformed to reduce the contribution of most abundant species. The Bray-Curtis similarity matrix was then generated. To test for differences in the assemblage of beetles between degraded and relatively pristine streams, one way analysis of similarities (ANOSIM) was performed. Furthermore, one way similarity percentage (SIMPER) routine was performed to identify beetles accounting for most of the dissimilarity between degraded and relatively pristine streams.

4.0 Results

4.1*Univariate analysis of community structure*

A total of 218 specimens of riparian ground beetles belonging to 25 species were recorded. The relatively pristine streams had the highest abundance of ground beetles (average density=0.033) while the degraded streams gave the lowest abundance (average density=0.017). The difference in abundance between these streams was statistically significant (Mann-Whitney U=4396.500; $p<0.05$). *Metagonum sp.2, Peryphus sp.3, Boeomimetes ephippium, Abacetus sp.2* were the most abundant species in relatively pristine streams while *Diatypus uluguruanus, Metagonum mboko, Peryphus sp.3* were the most abundant species in degraded streams (Table 1). The total number of species collected varied significantly with habitat type, with the highest species richness (S=21) found at the relatively pristine streams while the lowest species richness (S=13) were recorded at the degraded streams. There was a high level of site specificity for species in which among the 25 collected species, 12 species (*Metagonum* sp.1, *Acanthoscelis ruficornis, Peryphus meruanus, Trechodes* sp.1, *Tachys* sp.1, *Peryphus* sp.1, *Trechodes babaulti, Peryphus* sp.2, *Craspedophorus* sp.1, *Cymindis* sp.1, *Caminara* sp.1 and *Chlaenius cambodiensis*) occurred only in relatively pristine streams while only 4 species (*Odacantha* sp.1, *Tefflus* sp.1, *Abacetus* sp.1 and *Abacetus straneoi*) occurred in degraded streams only. The number of rare species was estimated using a taxonomic index (Coddington *et al*., 1991). Among the 25 collected species, 8 species were singletons and 3 species were doubletons. The number of rare species was higher in relatively pristine streams than in degraded streams (Table 1). Furthermore, relatively pristine streams showed the highest average diversity of beetles ($H' = 2.5359$) compared to the degraded streams ($H' = 2.0662$). The difference in diversity was significant ($p<0.05$).

Table 1: List of riparian ground beetle species collected in the Morogoro municipality

Species	Relatively pristine streams	Degraded streams
Metagonum sp.1	1	0
Crepidogaster pauliani	2	4
Odacantha sp.1	0	1
Clivina fossor	9	1
Tefflus sp.1	0	6
Acanthoscelis ruficornis	1	0
Abacetus sp.1	0	1
Abacetus sp.2	12	2
Peryphus meruanus	4	0
Trechodes sp.1	1	0
Peryphus sp.1	14	0
Tachys sp.1	10	0
Trechodes babaulti	5	0
Peryphus sp.2	6	0
Diatypus uluguruanus	4	22
Scarites linearis	1	1
Craspedophorus sp.1	2	0
Metagonum mboko	4	14
Peryphus sp.3	25	12
Abacetus straneoi	0	2
Metagonum sp.2	27	7
Boeomimetes ephippium	12	2
Cymindis sp.1	1	0
Chlaenius cambodiensis	1	0
Caminara sp.1	1	0
Total	**143**	**75**

4.2 Multivariate analysis of the community structure

Results of multidimensional scaling (MDS) are shown in Figure 2. The analysis separated samples from degraded and relatively pristine streams though the separation was not very clear. At 17% similarity level, MDS formed four clusters. Cluster I contained samples from Site 1 (Bingwa stream), while cluster III contained most samples from the streams of Vituli and Lukuyu (Sites 2 and 3) and few samples from the degraded streams (5b, 5c and 6C). Clusters II and IV were largely composed of samples from the degraded streams of Ngerengere, Kikundi, and Morogoro (4, 5, and 6 respectively).

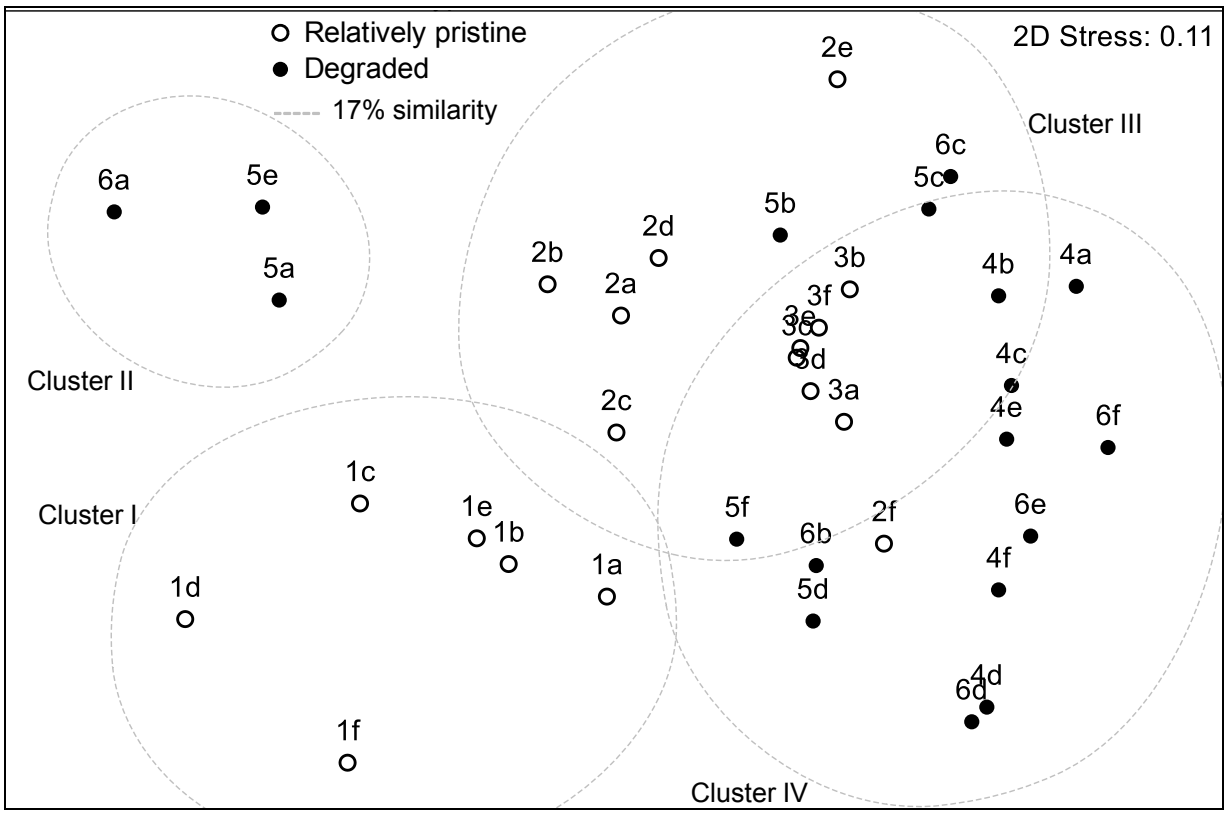

Figure 2: Two dimensional n-MDS of carabid beetle samples from riparian areas in Morogoro, Tanzania in 2015. Numeric values represent site number and letters represent sample number.

Although some clusters contained a mixture of samples from degraded and relatively pristine streams, ANOSIM indicated significant differences in assemblages between degraded and relatively pristine streams (Global R = 0.151, p = 0.3%). SIMPER indicated an average dissimilarity of 87.21% between degraded and relatively pristine streams (Table 2).*Peryphus sp.3, Metagonum sp.2,* and *Diatypus uluguruanus* contributed most of the dissimilarity, each contributing 13.49, 12.72 and 10.70% of the dissimilarity respectively. Other species which contributed at least 5% of the dissimilarity included *Metagonum mboko, Tachys sp.1, Abacetus sp.2, Clivina fossor* and *Boeomimetes ephippium*. SIMPER also identified an average similarity of 19.16 and 21.96 between degraded and relatively pristine streams respectively. *Diatypus uluguruanus, Peryphus sp.3* and *Metagonum mboko* contributed at least 20% of the similarity among degraded streams while *Metagonum sp.2, Peryphus sp.3, Clivina fossor, Abacetus sp.2* and *Tachys sp.1* contributed at least 10% of the similarity among relatively pristine streams.

Table 2. Average dissimilarity of carabid beetles from degraded and relatively pristine streams. Av.Abund = average abundance.

Species	Relatively pristine Av.Abund	Degraded Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
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Peryphus sp.3	0.74	0.5	11.76	0.94	13.49	13.49
Metagonum sp.2	0.84	0.25	11.1	0.93	12.72	26.21
Diatypus uluguruanus	0.19	0.7	9.33	0.79	10.7	36.92
Metagonum mboko	0.19	0.53	7.26	0.8	8.32	45.24
Tachys sp.1	0.41	0	6.16	0.59	7.06	52.3
Abacetus sp.2	0.49	0.08	6.12	0.75	7.01	59.32
Clivina fossor	0.43	0.06	5.55	0.77	6.36	65.68
Boeomimetes ephippium	0.33	0.11	4.77	0.55	5.47	71.15
Peryphus sp.1	0.38	0	3.94	0.46	4.52	75.67
Crepidogaster pauliani	0.08	0.19	3.42	0.47	3.92	79.59
Peryphus sp.2	0.27	0	3.39	0.49	3.88	83.47
Tefflus sp.1	0	0.23	2.47	0.42	2.83	86.3
Peryphus meruanus	0.19	0	1.95	0.42	2.24	88.53
Trechodes babaulti	0.17	0	1.82	0.34	2.08	90.62

5.0 Discussion

Degradation of natural riparian habitat through different land use systems have negative effect on ground beetle abundance, species richness and diversity in streams occurring in the Morogoro Municipality. The decline in ground beetle species richness and diversity due to habitat degradation have also been reported previously (Koivula, Kukkonen, & Niemelä, 2002; Niemelä *et al*., 2002; Niemelä, Langor, & Spence, 1993). A decrease in the abundance, richness and diversity following habitat degradation has also been recorded for other groups of insects (Beck, Schulze, Linsenmair, & Fiedler, 2002; Boonrotpong, Sotthibandhu, & Pholpunthin, 2004; Holloway, Kick-Spriggs, & Khen, 1992; Kwon, Lee, & Sung, 2014; Shahabuddin, Schulze, & Tscharntke, 2005). Ngerengere, Kikundi, and Morogoro streams are subjected to human activities including urbanization, pollution, and reduction of vegetation cover that might have contributed to alteration of habitats for the ground beetles. Degradation and loss of habitats may be among the prime factors for the observed decrease in abundance, richness and diversity of the ground beetle in this study.

We recorded species of beetles which showed high level of site specificity as many of them were found to reside only in relatively pristine streams. Some studies have also indicated species site specificity in ground beetles (Maganira & Nyundo, 2015; Niemelä, 2001). It has been reported that some beetles preferred to colonize less suitable habitats when density increases in the preferred sites otherwise they prefer to select suitable habitats (Binckley & Jr, 2005). The preference of relatively pristine streams by many species of beetle in this study can be demonstrated by suitability of the microhabitats in these streams which may favour their survival and reproduction. The beetles in relatively pristine streams may be benefiting from the soil moisture, microclimate stability and the vegetation cover. Pristine sites offer greater diversity of food, more stable microclimate, higher humidity and greater quantity of refuges against predators

while in degraded habitats there is low availability of food resources and decreased soil moisture content (Fagundes, 2011).

The impact of degradation of the streams were observed to have less influence on *Peryphus sp.3, Metagonum sp.2,* and *Diatypus uluguruanus* as they were the most species observed to exist in both relative pristine and degraded streams and therefore contributed to most of the average abundance dissimilarities observed between relative pristine and degraded streams. The reason for this observation may be due to the fact that some species of beetles including *Trechodes babaulti* have ability to tolerate the disturbance (Maganira & Nyundo, 2015; Skłodowski & Garbalińska, 2011) and therefore can attain high abundance in both degraded and relatively pristine habitats.

In general the difference in riparian ground beetle assemblage recorded in degraded and relatively pristine streams is an indication of the significance of habitat quality on the preference or assemblage of riparian ground beetles. The reasons to the observed difference in riparian ground beetle assemblage may be due to differences in disturbance levels since the level differed significantly between degraded and relatively pristine streams.

In conclusion, riparian ground beetle communities of the Uluguru Mountains lowlands appear to be relatively susceptible to anthropogenic degradation activities. High abundance, richness and diversity were recorded in relatively pristine than degraded streams explaining the influence of riparian habitat quality on the assemblage preference of ground beetle species. The majority of riparian ground beetles preferred relatively pristine streams while only four species occurred exclusively in the degraded streams indicating adaptation to degraded environment. Based on the findings, ground beetles are good indicators of habitat quality. These results call for strengthened measures to control degradation of the riparian areas in the Morogoro municipality. For effective stream and riparian habitat management, further studies may focus on seasonal riparian ground beetle assemblage and quantification of the extent of pollutants in the streams in Morogoro Municipality.

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Cost-Benefit Analysis of Groundwater investment and Use for Irrigation by Smallholder Farmers in the Usangu Plains, Tanzania

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Abstract

Groundwater (GW) use for irrigation by smallholder farmers has been proposed as a solution to increasing water scarcity in the Usangu Plains, Tanzania. This study evaluated the financial viability of utilising GW for irrigation by smallholder farmers in the plains. Specifically, the study analysed the costs and benefits of using GW for small scale irrigation and examined the socio-economic factors influencing the use of GW for irigation. Primary data were collected using a semi-structured questionnaire which was administered to a random sample of 97 households in three villages, while data from key informants were gathered using a checklist. Secondary data from various sources were used to supplement the primary data. Discounted cash flow, descriptive statistics, and logistic regression were used to analyse data. Key findings show that, investment in GW for irrigation is economically viable at a discounting rate of 12% and had a Net Present Value of TZS 38 636 794, Cost Benefit Ratio of 6.55, and Internal Rate of Return was 81%. Socio-economic factors namely household size was statistical significance (P<0.05) while gender, income and membership in socio networks although were not significant had a positive association with GWI. High initial investment cost relative to farmer's income level was revealed. Conclusively, investment in GWI by smallholder farmer is financially viable and household income level was found to be a constraint to GWI development. The study suggest that, government and development agencies should participate in GWI investment such as through subsidisation and tax exemption of GWI devices. Further, market for agricultural goods should be improvedand enhancesupport to increase productivity of smallholder farmers that will lead to increased incomes enabling affordability of GWIs.

Keywords: Cost Benefit Analysis, Groundwater, Internal rate of return, Net present value, Smallholder farmer, UsanguPlains

2.0 Introduction

Africa has a population of more than 650 million people who depend on rain-fed agriculture in an environment which is already affected by water scarcity and land degradation (FAO, 2010). In particular,agricultural sector in Africa mainlySub Saharan Africa (SSA) is said to employ more than 80% of its rural community who are predominantly smallholderfarmers. Thus, development inagriculture sectorisseen as an important measure of securing smallholder farmers from extremepoverty, food insecurity and at the same time safeguarding the environment (Allaire, 2009). Given the semi-arid condition of SSA with unpredictable nature of the rainfall, irrigation agricultureis among the strategies available for increasing agricultural production.Conversely, surface water resources in SSA are under increasing pressure as a result ofincreasingdemandand alsorapid environmental change (Calow*et al.*, 2010). Thus consideration of groundwater (GW) use for irrigation has been advocated as one of the strategy to drought mitigation,

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adaptation to climate change impacts, livelihood enhancement, and food security to smallholder farmers in SSA (Villholth*et al.*, 2013 andTuinhof*et al.*, 2011).

Groundwater use for irrigation by smallholder farmers is reported to benefit thousands of households in many part of the world through income generation, employment creation and also food security assurance. Namara*et al.*(2011); ECA, (2011) and Villholth*et al.*(2013)advocateGW use for irrigation by smallholder farmers as a strategy to reduce risks associated with environmental degradation,rainfall variability and also increased yields of food crops.Also, African Climate Policy Centre(ACPC),(2013) emphasizeson GW as an important renewable resource that can contribute significantly towards offsetting the impact of climate change, food insecurity and extreme poverty in the SSA.Akudugu*et al.* (2012); Dittoh*et al.(*2013); Shah*et al. (*2013) and Villholth (2013) reported GW as a solution to smallholder farmers since it responds to their demand for its reliable and flexible irrigation water supply due to itsmode of access, ownership and also investment.Tanzania is an agriculture based developing country whereby about 80% of its population are smallholder farmers engaged in a wide range of agricultural activities for their food and livelihoods enhancement. Like other SSA countries, agriculture development in the country is highly constrained by inadequate and unreliable water for irrigation.Usangu Plains found in Southern part of Tanzania is one of the areas facedwithachallenge of water scarcityas it was first detected in early 1990 as a result of significance change of river flows in dry season (Kajembe*et al.*,2009; Walsh, 2012).This challengemarked to have a multiple negative impacts inagricultural activities,livelihood option of the smallholder farmers, important biodiversity of the Ruaha National Park, Usangu Wetlandand andMtera, and Kidatu dams thatapproximately generate 50% of the nation hydroelectric power (i.e. 284MW out of the total capacity of hydropower generation in the countryof 567.7 MW) (TANESCO, 2019).As part of a strategy to address this problem to safeguard theenvironment, sustainable development of GW use for irrigation by smallholder farmers was proposed to supplement surface water(WWF, 2010; URT, 2008 and WB, 2006).However, implementation of existing plan is stillquestionable sincethe existing literature does not offer enough information on the financial viability ofinvesting in GW use for irrigation by smallholder farmers. Villholth *et al.* (2013) observed that,there is a potential profit gains for the farmers, by being able to grow a second crop in the dry season through irrigation with GW.According to the authors,economics of the farmers is a major constrainst to GW irrigation development in the Usangu Plains. Nevertheless,not much attention has been paid on the estimated costs and benefits that areassociated with investing on GW irrigation and also on determinant factors of the smallholder farmers to use GW for irrigation.It is important to know whether an investment is worthy or otherwise remains equally important as a guide for investment decisions.This paper presentsthecosts and benefits associated with the useofGW for irrigation as well as the socio-economic factors enhancing or constraining GW irrigation by smallholder farmers n the Usangu Plains, Mbarali District in Tanzania.

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3.0 Materials and Methods

3.1 Description of the study area

Usangu plains is located in the upper part of the Great Ruaha River Basin catchment (Figure 1)in the south-western highlands of Tanzania, between latitudes 7° 41' and 9° 25' south, and

longitudes 33° 40' and 35° 40' east. It falls in two administrative regions and eight districts with the larger part in Mbeya Region primarily in Mbarali District.The Usangu Plains represents almost (15,560 km^{2}) of the land of Mbarali District (URT, 2010). It encompasses an extensive wetland, comprising seasonally flooded grassland and a much smaller area of a permanent swamp commonly known as *Ihefu* which collects water from all the rivers in the Uporoto and Kipengere mountain ranges. This makes the area critical to Tanzania for livelihood options of the smallholder farmers and agro-pastoralists.The area is also home to majority of smallholder farmers producing irrigated paddy, maize, pulse, fruits, vegetables and also livestock keeping.Furthermore,Usangu plains provide the lifeblood of the Ruaha National Park and the Usangu wetlands that makes critical habitat for much of Tanzanian biodiversity including the population of endangered game animals like elephants and wild dogs. The flowing water through the Usangu plains and the park feed into the Mtera, and Kidatu hydropower reservoirs (Mwakalila, 2011), which produce about 50% of the country hydroelectric power, before joining the Rufiji River and emptying into the Indian Ocean (Kashaigili, 2006).The climate of the Usangu is mostlysemi-arid with seasonal temperature and rainfall variations. Temperatures range between 20 and 25°C, whereas annual rainfall varies between 500–700 mm/year. It receives the unimodal type of rainfall from November to May, normally scattered and varies across the Usangu plains. Rainfall is generally unreliable, and localized droughts are common (URT, 2010).

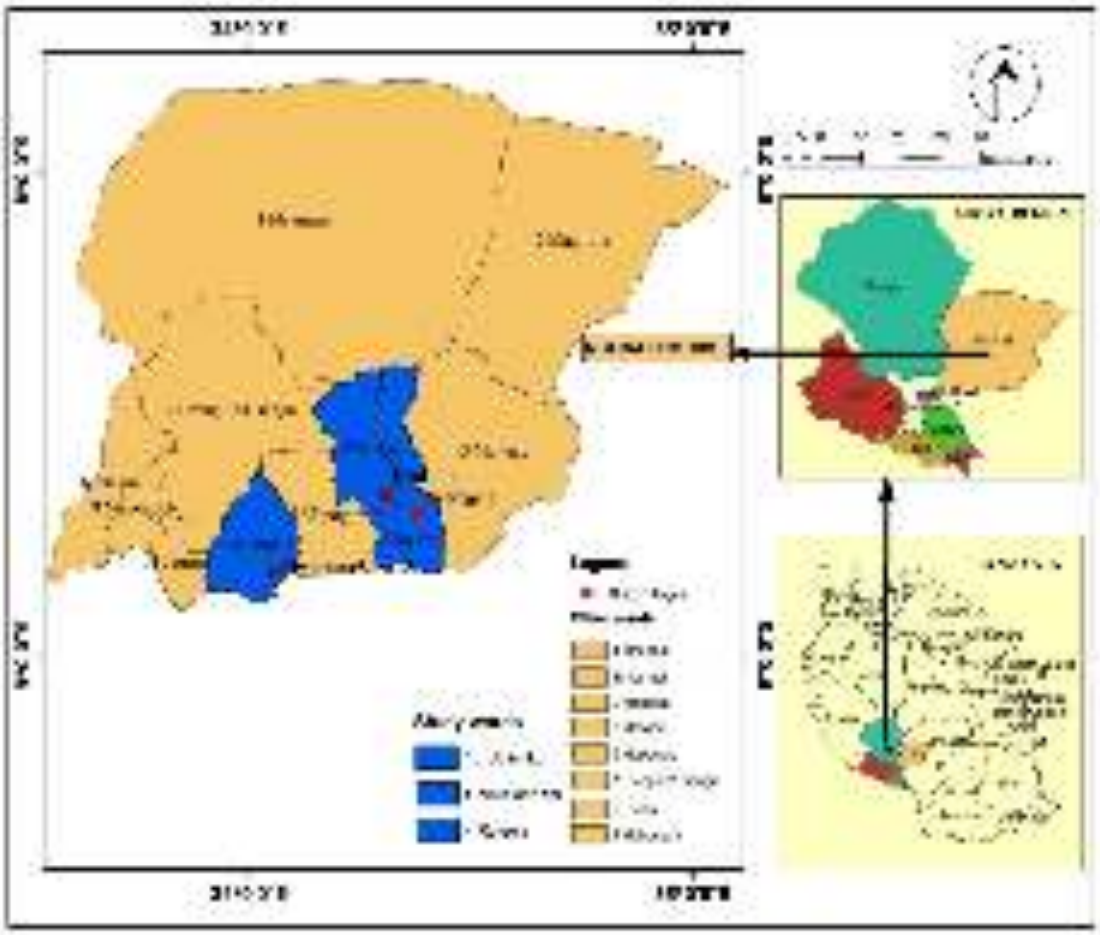

Figure 1: Map of the study area showing the studied villages.

Land use and land cover in the area include settlements, scattered croplands, grassland with scattered croplands, open bushland, seasonally inundated grassland and perennial swamp (Kashaigili, 2006; Mwita, 2016).Communities around in the Usangu Plains are smallholder farmers who depend mainly on small scale agriculture. About 90% of the population rely on agriculture, while livestock keeping, petty businesses are also important economic activities. Irrigated paddy is the dominant crop produced in the plains during wet season and it is produced mainly for subsistence to smallholder farmers and in a little extent for commercial purpose.

The human population in the Usangu plains was estimated to be more than 300,517 people as per 2012 national census data with an annual growth rate of 2.7 (URT, 2013). The population is multi-ethnic and multi-cultural in which Sangu are the indigenous ethnic group and other ethnic groups include, Bena, Hehe, Maasai, Sukuma and Nyakyusa. There has been a huge change in ethnic composition with increasing competition in land-use systems (Ngailo, 2011).

3.2 Research design, Sampling and Data collection techniques

The study employed two designs, a case study and exploratory cross-sectional research designs. Case study design was crucial for the present study because, currently the use of GW in the Usangu Plains is mainly for domestic purposes and to a very small extent for irrigation. Among the studied villages, only one village Nyeregete was found using GW for irrigation from dug wells at a very small extent. Apart from the studied villages, Mont Fort Secondary School is one of the places in the Mbarali District where GW investment and its use for irrigation is highly practised to supplement surface water irrigation. Thus, Mont Fort Secondary School was used as a case study, where detailed information which is associated with functioning of GWI and investment was studied. Also, the study employed a exploratory cross-sectional research design. Under this design, data from households were collected once examined and the relationship between variables was determined. The study design was advantageous as it was compatible with the available time and resources (Bryman and Bell, 2015).

The sampling procedures involved purposive selection of three out of 99 villages in the district. The villages were Nyeregete, Ubaruku and Mwaluma. These were selected based on the evidence that there were groundwater uses. The households were randomly selected using a random number table technique from the population of smallholder farmers in the study villages.According to Bailey (1994), a sample size of at least 30 households is statistically adequate. Accordingly, a total sample of 97 households was interviewed (Nyeregete village, 33 households; Ubaruku village, 34 households; and Mwaluma village, 30).

Both qualitative and quantitative data were collected. Quantitative data were collected using a semi-structured questionnaire containing both open-ended and closed questions. The questionnaire was administered to households. The information collected includes households' socioeconomic and demographic information, economic activities, groundwater information, information on previous crop production season and the existing price for inputs and outputs. Qualitative data were collected through Focus Group Discussion, Key informant interviews using probing questions and checklist. Furthermore, direct observation, transect walk and informal discussion were also carried out to counter check some of the responses from farmers and to get an insight on the actual field conditions. In addition, an in-depth interview was carried out with wells drillers, Rufiji Basin Water Board and the MbaraliDistric Water Engineer to gather more information associated with cost and benefit of GW use for irrigation in the case study.

Data analysis

Descriptive statisticsand financialanalysis were used for data analysis. Gross margin and Net Present Value (NPV), Internal Rate of Return (IRR) and Cost Benefit Ration (CBR) decision criteria were employed to analyse data oncosts and benefits associated with the use of GW for irrigation and its investment. NPV, IRR and CBR were applied to evaluate the long-term financial viability of using groundwater for small scale irrigation, while gross margin was used to evaluate the profitability of using GW irrigation against

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SW for irrigation as an alternative scenario in a short run period of time. Theinformation on surface water irrigation was included in this analysis in order to compare the profitability with and without groundwater irrigation, while other factors such as climate change notwithstanding. Sensitivity analysis was carried out to study the effect of a change in fluctuating factors such as prices of inputs and outputs scale of production and discount rate on NPV and CBR.

NPV, IRR and CBR was obtained using the following formula (Lin *et al.*, 2000):

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} \quad \text{.....} \quad (1)$$

$$CBR = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}} \quad \text{.....} \quad (2)$$

IRR was obtained by using the following formula

$$IRR = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} = 0 \quad \text{.....} \quad (3)$$

Where for all equation 1, 2 and 3

Σ = is the sum of the discounted cost and benefits

B = benefits at year at year 2016 (market value of yield at year 2016)

C = Cost at year 2016 (market value of inputs, fees and other production costs)

t = the time in years i.e. 30 years (t=30)

r = discount rate 12%, 18% and 20%

$(1 + r)^t$ = discount factor

The cost component included the initial capital cost of the borehole, operation and maintenance cost, water fee, market prices of inputs, the cost of ploughing, planting weeding, and harvesting.

In line with the CBA framework, the analysis was carried out on the basis of the following assumptions:

Discounting reflects the time value of money. Benefits and costs are worth more if they are experienced sooner such that all future benefits and costs should be discounted to its present value for the investments with long life span. The higher the discount rate, the lower the present value of future benefits and costs. For projects with the costs concentrated in early periods and benefits following later, raising the discount rate tends to reduce the net present value. The discounting rate of 12% was used in this analysis as per the Bank of Tanzania (BOT), and as indicated in the Monthly Economic Review of February, 2017. Apart from constant discounting rate from the Central Bank in Tanzania (BOT), the study also considered 16% and 20% of interest rates that are used by different microfinance banks of Tanzania as they are the main credit sources for smallholder farmers. However, there is considerable uncertainty over the correct discount rate and also high uncertainties are expected in agricultural production and which include an increase in the production costs and a decrease in returns that can affect

investment financial viability. Different scenarios were assumed to check the investment sensitivity.

Scenario one anticipates the increase of production cost and reduced income while scenario two assumed an increase in production cost and increased income. Therefore, scenario one assumed a 25% increase in the production costs and 10% decrease in income while scenario two assumed 100% increase in the production costs and 25% increase in income. However, Gebrehewaria*et al*. (2016) also revealed that the size of land for production affects the investment financial viability. This is due to the economies of scale, whereby, the cost per unit of an output generally decreases with an increase in the scale of production. The sensitivity of the investment was measured at a 0.4 ha of land. Based on these scenarios, sensitivity of investing in GW for small scale irrigation was tested at 12%, 16% and 20% discounting rates.

It is widely acknowledged that estimating the life of a project or program is difficult, subjective and widely debated. It depends on the assessments of the program's physical life, technological changes, shifts in demand or fashion, competing products that emerge and the general state of the world many years in advance. However, since GWI involves fixed cost which is capital intensive, lifespan is one of the important variables of determining the viability of an investment. This takes into account the entire income stream for the whole lifespan of the investment. For example, the available evidence shows that boreholes are drilled and function for a lifespan of 20 to 50 years (Carter *et al.*, 2014). This study opted for 30 years investment lifespan. However, the life span of wells can last less or more than the opted lifespan. Such lifespan was selected so as to avoid underestimation or overestimation of the financial viability of such investment.

Cost-benefit analysis (CBA) was applied to estimate the direct costs and benefits accrued from investing in GW irrigation by smallholder farmers. In-line with the CBA framework, the analysis was carried out on the basis of the following considerations:

i. All costs and benefits are estimated in incremental terms as opposed to surface water irrigation as a business as usual alternative.
ii. The analysis starts at (year 0) when the initial investment costs of the GWI facilities occurred while the maintenance and operation cost were assumed to start from the second year after the investment.
iii. All production costs and benefits from using groundwater for irrigation were regarded with the crude assumption that, since it was difficult to forecast the cash flows for the entire lifespan of the investment, constant value was used in measuring project viability throughout the lifespan of the project. Costs and benefits have been quantified and valued in TZS using the Nov – Dec 2016 market prices.
iv. Two production seasons in a year for groundwater irrigation were assumed where paddy could be produced during the wet season and during the dry season the same field would be used to cultivate any other crop. This is due to the argument that through GW, the farmer has an added advantage of irrigating his/her farm during the dry season. Empirical evidence was observed during data collection, whereby some households that owned wells (mostly dug wells) had irrigated backyard gardens during the dry season. Vegetables and tree fruits were grown in

these gardens for their own consumption and for sale in the local market. At Mont Fort Secondary School paddy seedlings, vegetables, onions and orchard crops were found grown on school gardens using GWI in the dry season.

v. This analysis used onion as the second crop during the dry season. This was due to the argument that paddy was reported as both a cash and food crop grown during wet season, while onions, water melon and vegetables were reported as cash crops grown in the dry season. Thus, paddy and onion were selected in estimating the viability of investing in GW irrigation by smallholder farmers. By considering such scenarios, a relative profitability of using GW for small scale irrigation was established.

vi. Operation and maintenance were estimated to take 10% of the investment cost per year. This was estimated from the communal deep well supplying water to the villages of Ubaruku and Mpakani, where hydroelectric power is used as a source of energy.

Gross Margin Analysis

Gross margin was used to analyse profitability of using groundwater for small scale irrigation. As performance from agriculture varies from season to season and crop to crop, gross margin analysis is useful for production cycles of less than a year as this enables costs and returns to be directly linked to a particular activity. It also allows establishing profitability of the enterprise (Makombe*et al.*, 2007). The Model for gross margin analysis is presented as follows:

$GMI=\sum TR-\sum TVC$……..……..……..... (4)

$TR= P_y.Y_i$……..... (5)

$TVC = P_x.Xi$ ……..……..... (6)

Where GMI = Gross Margin Income

TR = Total Revenue

TVC = Total Variable Cost

Py = Unit Price of Output Produced

Y = Quantity of Output (Kg)

Pxi = Unit Price of Variable input used

Xi = Quantity of Input.

3.0 Results

3.1 Short term economic analysis of GW use for irrigation

Table 1 presents the estimated profitability of surface water and GW use for irrigation. The production cost for the first and second seasons was TZS 1,586,250 for surface water and 4,860,000 for groundwater use. Average net profit of first and second seasonswas TZS630,415 and 4,820,415 respectively (Table 1). The relative profitability of using surface water for irrigation was also evaluated and the findingsshowed that GW

use for irrigation by smallholder farmers is more worthwhile. Themainreason of that difference could be an opportunity that a farmer can get by having more than one production season in a year through GW irrigation. Also to ensure financial viability of using GW water use for irrigation need to be combined with high valued crops that have high demand both in local and international markets.

Table 1: Profitability of using GW for irrigation

Operation	Parameter	Surface water (TZS/ ha)	Groundwater (TZS/ ha)
Production Cost [a]	(Wet season) **Paddy**		
	Nursery management	40 000	40 000
	Ploughing	162 500	162 500
	Furrowing	162 500	162 500
	Inputs (fertiliser, seeds, and pesticides per acre	296 250	296 500
	Planting	210 000	210 000
	Weeding	165 000	165 000
	Bird scaring	50 000	50 000
	Harvesting	500 000	500 000
	Total cost of production (paddy)	**1 586 250**	**1 586 250**
	Dry season (Onion)		
	Nursery management	NA	60 000
	Ploughing and basin preparation	NA	212 500
	Inputs (fertiliser seeds and pesticides)	NA	1 775 000
	Planting	NA	150 000
	Harvesting	NA	212 500
	Total cost of production (onion)		2 410 000
	Water use fee per year	50 000	150 000
Other cost	O and M [b]	0	2 300 000
	Others total cost	50 000	2 450 000
	Total Production cost	1 636 250	6 446 250
Benefits			
Crop yield (ton/ha/year)	Paddy	4.25	4.25
	Onion	NA	20
Output price (TZS/ton)		533 333	533 333
		NA	450 000
Total revenue (TZS/ton/year)	Paddy 4.25 Onion 20	2 266 665	11 266 665
Gross Margin [c]		630 415	4 820 415

Data represent farm statistics from the harvest of the cropping season 2016
Production cost [a]: Production cost per hectare per season
O and M cost [b]: Operation and Maintenance Cost per year

3.2 Financial viability of GWI

The depth of the wells used in CBA was adopted from the dug wells and also from motorised wells found in the study area; as per report from the Mbarali District council and from the Rufiji Basin Water Board and also well labels. About 25 dug wells and 5 functioning machinery drilled wells were observed during the survey. Their depth ranged from 9 to 23 for dug wells with an average of 15 meters and 14 to100 meters for machine drilled wells. This study focused on three different types of well depths namely, 40, 50, and 100 meters. This is due to the reason that, the GWI demands for initial capital increases as the well depths increases. Also shallow wells (both dug and machinery drilled wells) were reported to have low recharge capacity and sometimes they dry up completely during the off rain season. As a result a 40 meters well depth was chosen as a yardstick in the analysis of well depth to support small scale GW irrigation due to the empirical evidence observed during case study survey at Mont Fort secondary School where by their 40 meters well depth supports water to the compound for domestics, livestock, fish pond and also small-scale irrigation.

Table 2 shows a summary of NPV, IRR and CBR calculations for 1 hectare of paddy and one hectare of onion. As shown in Table 2, the highest NPV was observed while investing in 40 meters depth with the value of TZS 38 636 794, 23 032 915, and 19 807 103 at the discounting rate of 12% 18% and 20% respectively. Likewise, investing in 50 and 100 meter depth had positive NPVs at the same discounting rate although less than that observed when investing in 40 meters deep well. The possible reason for this was due to the increasing cost of drilling as the well depth increases. The business as usual scenario gives the NPV of TZS 4 534 025, 2 947 353 and 2 615 663 which was lower than when investing in GW use for irrigation.

Investing in GWI had positive NPVs at a discounting rate of 12% 18% and 20% per hectare in all adopted well depth; this implies that the present value of benefits stream was greater than the present value of the cost stream. Therefore according to the NPV criterion, investing in GWI by smallholder farmer is financially viable since the NPVs are above zero. Thus, upon decision making process, smallholder farmers' investment in GWI is economically viable. This implies financial viability of GWI by smallholder farmers tend to decrease with the increasing cost of investment.
The BCR was also greater than one and according to decision criteria, projects with BCR which is positive and greater than one are financially viable because the discounted benefits are higher than the discounted costs. The IRR was greater than all the discount rate which was used to compute NPV and BCR, and as a general rule the project with an IRR higher than the discount rate is deemed to be acceptable. The maximum interest

rates (IRR) for the investment projects were to recover its investment and operating expenses in its lifetime and to break even.

Table 2: Summary of the results of Cost Benefit Analysis

Parameter	40 meters deep (TZS/ha)	50 meters deep (TZS/ha	100 metres deep (TZS/ha)	Surface water irrigation (TZS/ha)
Investment	7 800 000	9 437 500	23 000 000	_
Production cost				
Maintenance cost and Operation	780 000	943 750	2 300 000	_
Inputs cost	3 996 250	3 996 250	3 996 250	1 586 250
Water use fee	150 000	150 000	150 000	50 000
Total Production cost	4 926 250	5 090 000	6 446 250	1 636 250
Crop Value	11 266 665	11 266 665	11 266 665	2 266 665
Net Benefit	6 340 415	6 176 665	4 820 415	630 415
NPV at 12%	38 636 794	35 997 029	14 133 330	4 534 025
NPV at 18%	23 032 915	20 879 629	3 045 165	2 947 353
NPV at 20%	19 807 103	17 763 101	833 783	2 615 663
CBR at 12%	6.55	5.27	1.69	-
CBR at 18%	4.48	3.61	1.16	-
CBR at 20%	4.05	3.26	1.04	-
1RR	81%	66%	21%	

3.3 Sensitivity analysis

Sensitivity analysis was carried out to test the changes in NPV, CBR and IRR as a result of changes in market prices of variable inputs, price of outputs, and the scale of production. Sensitivity analysis was made for the increase in the production cost, decrease income and reduction in land size. The NPVs at all the discount rates in all developed scenarios were positive when 40 meters deep well was used. Investing in 50 meters well depth, gives a negative NPV at the discounting rate of 20% and in one acre piece of land which was used in production contrary to the NPVs of 100 meters well depth, which were consistently negative at all the discounted rate (Table 3). The CBRs were also greater than one when investment was to made in 40 -50 well depth for scenario one and two with the exception of 50 meters whereby at a discounting rate of 20% meters and reduced area of cultivation to one acre the CBR is less than one. This reflects that the financial viability of GWI by smallholder farmer tend to decrease with an increase capital cost and reduced area of cultivation. The findings imply further that a

decrease in the scale of production leads to a decrease in the financial viability of GWI, at such investment in GWI by smallholder farmer should be made at not less than one acre. The maximum IRR was also observed in all the scenarios when the investment was to be made through 40 and CBR was greater than one.

Table 3: Sensitivity analysis GWI

Parameter estimated	40 meters well depth	50 meters well depth	100 meters depth
Scenario 1 :25% Increase in production costs 10% decrease in income			
NPV at 12%	21 676 107.88	18 652 014. 89	-5 560 364.92
NPV at 18%	12 007 582.56	9 604 463. 82	-9 756 766
NP Vat 20%	10 022 542.35	7 756 823. 39	-10 527 440.28
CBR at 12%	4.11	3.21	0.73
CBR at 18%	2.28	2.2	0.50
CBR at 20%	2.54	1.99	0.45
IRR	51%	40%	8%
Scenario 2: 100% increase in production costs and 25 increase in income			
NPV at 12%	23 464 396.48	19 646 920. 81	-11 971 102.86
NPV at 18	13 170 063.57	10 251 204.30	-13 924 080.57
NPV at 20%	11 054 199.76	8 330 781.7	-14,225,772.5
CBR at 12%	4.37	3.33	0.42
CBR at 18%	2.99	2.28	0.29
CBR at 20%	2.7	2.06	0.26
IRR	54%	41%	3%
Scenario 3: Land size for production is one acre **(0.4 ha)**			
NPV at 12%	6 615 647 59	3 975 882.97	-17 887 816.37
NPV at 18%	2 217 496 59	64 211.02	-17 770 253.45
NPV at 20%	1 334 215 77	-709 784.93	-17 639 103.67
CBR at 12%	1.95	1.47	0.12
CBR at 18%	1.34	1.01	0.09
CBR at 20%	1.21	0.91	0.08
IRR	24%	18%	-4%

3.4Socio-economic Factors Determining the use of GWI by Smallholder Farmers

The analysis of socio-economic factors that influence the use of GWI by smallholder farmers was undertaken using the logit model. The model was statistically significant ($P < 0.001$) as suggested by Omnibus Tests of Model Coefficients (likelihood ratio test), which gives an overall indication of how well the model performs. The results of the logit model are presented in Table 4. This study found that all selected factors affect the decision of the household on the use of GW for irrigation. It further highlight the importance of household size in explaining the use of GWI by smallholder farmer. Households size was statistically

significant ($P < 0.05$) and positively related to the use of GWI by smallholder farmers. This implies that, when, the household size increases by one unit, there is an increase in the probability that the households will use GW for irrigation by 38.3% the coefficient estimates (Table 4). The plausable explanation for this situation is availability of adequate labour to be deployed in groundwater small scale irrigation. Furthermore, this finding indicates that an increase in the number of the households leads to an increase in the ability and desire to diversify the available resource for food security and livelihoods support.

Table 4: Logistic regression analysis result

Variable	B	S.E	Sig
Gender	1.181	0.979	0.228
Households size	0.383	0.190	0.043*
Age	0.020	0.30	0.501
Education level	16.224		0.777
Access to financial institution	19.235	10073.519	0.998
Social network membership	1.275	1.163	0.273
Households income level	0.000	0.000	0.777
Constant	-42.232	30063.844	0.999

The findings indicate that the model with descriptors performs better than the null hypothesis.

The results show further that the model performance is statistically significant (χ^2 (44.045) = 8, $p < 0.001$). The inferential test for goodness-of-fit, the HosmerandLeme show (H-L) statistic, indicates that the model fits the data well at $p > 0.05$. The descriptive measures of goodness-of-fit also supports that the model fits the data well (Cox and Snell R^2=0.189; andNagelkerke R^2=0.388). The descriptor which is statistically significant as the determinant of GW use is: *households size* ($P < 0.05$).

4.0 Discussions

4.1 Groundwater and small scale irrigation

Groundwater is the critical underlying resource for human survival and economic development in extensive drought-prone areas across Sub-Saharan Africa (SSA) (Foster *et al.*, 2012). Tuinhof *et al.* (2011) observed that many parts of SSA are prone to severe drought that is directly related to persistent poverty, hence there is a high demand for investment to focus on drought impacts. In SSA, dependence on groundwater in rural and urban water supply is undisputable, as evidenced by high presence of wells (boreholes and dug wells) for both domestic and livestock consumption. Currently, there is growing interest in the prospect
of accelerating groundwater use for agriculture irrigation both at small scale and commercial scale with high-value crop production, drought mitigation and climate

change adaptation (Foster *et al.*, 2012). Ngigi (2009) observed that smallholder farmers GWI in SSA are important development pathways to fight against poverty, food security, land and labour productivity, as well as rural employment and adaptation to the increasing impact of climate variability and climate change. Furthermore, Abric *et al.* (2011) ascertain such a pathway reflects the recognition of small scale irrigation benefits that is practised most by poor farmers while Villholth (2013) reports that groundwater responds the demand of smallholder farmers for a reliable and flexible irrigation water supply. As compared to surface water irrigation (SWI) scheme which is often seen limited according to geographical location and highly capital intensive, ground water irrigation is observed to be more attractive to smallholder farmers due to its mode of access and ownership.

4.2 Investment in groundwaterirrigation

The decision that farmers make about investing in a particular technology are based on the cost and benefits that are associated with such a technology. This is highly influenced by the ability of the farmer to access such technology. Adegbola and Gardebroek (2007) revealed that farmer investment in a certain agricultural technology is influenced by the economic gain that is anticipated.Capital investment has been observed as the largest constraint facing poor farmers in SSA. Villholth (2013) observed that access to and demand for GWI in well construction and other facilities for an operationare seen as a limiting factor that hinders GWI development in SSA. The cost of well drilling including both manual drilling less than about 20 m and motorized drilling has been observed to increase from the simple to the more advanced technologies. Abric *et al.* (2011) show that the prices for low-cost shallow manual drilling in West Africa is approximately one-tenth of prices given for deep wells. Hence, manual drilling wells have been promoted and adopted widely in West Africa as a suitable approach for smallholder irrigation. In terms of operation and maintenance in most of the regions in SSA, farmers have been observed using manual lifting devices including bucket with rope and treadle pumps due to the high cost of motorized pumps operated by fossil fuel
and electricity. It is further noted that while the capital investment is financed by the government and transferred to smallholders, operational and maintenance costs are high, while beneficiaries' willingness and ability to pay these costs was very low, posing large risks for the financial feasibility and sustainability of such projects, such that manual drilling shallow wells are seen favourable to smallholder farmers due to its investment cost that can be affordable to smallholder farmers. However, economic viability of the groundwater use for irrigation could be the determinant factor whether to promote it or not.

5.0 Conclusion

From the findings, the use of GWI by smallholder farmers was found economically viable when investing in shallow wells. The CBA carried out between GW use for irrigation by smallholder farmers using both shallow wells and deep wells shows positive NPVs when investing in shallow wells. Such that according to NPV criterion investing in GW irrigationby smallholder is suggested to be worth through investing in shallow wells. The findings further revealed that financial viability of investing in GW irrigation by smallholder farmer decrease with increasing investment cost.

Because GWI requires high initial investment, it is recommended that different strategies such as co-investment or cost sharing mechanism to be used. Further community awareness in producing crops with high value and reliable markets for agriculture crops is recommended to ensure sustainable economic viability of GW irrigation by smallholder farmers.

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