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Soil Fertility Management and Impact on Sweet Potatoes - Soybeans Growing in Makunga (Kakamega) and (Kibargoi) Elgeiyo Marakwet Counties

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Authors' contributions

This work was carried out in collaboration between all authors. Authors CJ and PK designed the study, performed the statistical analysis and wrote the protocol. Author CJ wrote the first draft of the manuscript. Author JK managed the analyses of the study. Author SK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Sweet potato is a perennial storage tuber crop grown as a food and/or cash crop. Soybean is a multipurpose crop grown for human food, livestock feed, soil fertility improvement, income generation and oil production among the smallholder farmers. Production of sweet potatoes in Kenya is however low due to various factors and constrains low soil fertility inclusive. This paper addressed soil fertility management and its effect on rotational cropping and the use of inorganic fertilizers on soybean - sweet potatoes production. The study was carried out in two regions of Kenya; Kakamega County (Makunga sub County) and Elgeiyo Marakwet County (Kibargoi sub County). The study incorporated 147 respondents from the two regions with 42 in Kibargoi and 107 in Makunga. Sweet potato growing was important to 85.2% of respondents as food crop and 79.8% as a cash crop. The sweet potatoes varieties grown in the areas were dominated by Yellow

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fleshed, Purple fleshed, Vita and Kabode. Soybeans were grown by 7.1% in Kibargoi and 48.6% in Makunga. The common varieties included local, SP3, SP24 and SP25. The soybeans was consumed by 30.9% and grains used as alternatives to milk. The results indicated that farms where sweet potatoes were grown and organic fertilizers used, the relationship was relatively significant (r=0.158). Soybeans had a negative correlation with organic fertilizers with an r=-0.223, this interprets that the application of inorganic fertilizers to soybeans does not affect its output or yield. The fertility of soils were rated moderate by 81.2% while 8.7% rated fertility high (Kibargoi only). The loss of fertility is attributed to soil erosion 45.6% and previous growing of sugarcane in Makunga was cited as a challenge. Application of fertilizer on crops for fertility management was done by 65.1% (97) of the total respondents with 89.7% (96) from Makunga applying fertilizers and 2.4% (1) applying fertilizers to farms in Kibargoi, a pearsons correlation was conducted and an. r=0.216 in Makunga was obtained (significant positive impact of fertilizers on soil fertility), in the use of organic fertilizers was insignificant and not attached to land fertility and a Pearson correlation r=-0.087 was attained. This indicates that farming in Kibargoi is not dependent of organic fertilizers as opposed to farming in Makunga where fertilizers dictate land fertility. It was therefore observed that the use of organic fertilizers do have an impact on land fertility as compared to the use of inorganic fertilizers.

Keywords: Soil fertility management; food security; soybeans; sweet potatoes; extension services.

1. INTRODUCTION

Sweet potato is a perennial storage tuber crop grown in Kenya both as a food and cash crop [1] mostly under small scale. Currently, there are many varieties under cultivation by farmers in Kenya with skin and flesh colors ranging from orange, deep purple and white to yellow. The orange fleshed sweet potato varieties are gaining popularity due to their higher contents of B-carotene which is a precursor of vitamin A. In Kenya, sweet potato production averages between 5.5-7.4 t ha^{-1} [1] comparing poorly to an optimal of 20-40 t/ha for the improved varieties [2].

Soybean is a multipurpose crop grown for human food, livestock feed, soil fertility improvement, income generation among the smallholder farmers and oil production [3]. It is ranked as the number two oil crop in Kenya [4]. High protein content of over 40% and capacity to improve soil fertility makes soybean the best alternative crop in rotational and mixed cropping systems.

The low sweet potato production in Kenya has been attributed to various constrains such as pests, diseases, lack of clean planting materials, drought, high cost of inputs and most importantly low soil fertility [1]. Although they tolerate low soil fertility [2] their production is greatly affected by deficiencies of nitrogen, phosphorus, magnesium, iron, boron, potassium and toxicity of aluminum [5]. Sweet potato has been shown to be a heavy feeder of potassium [6,7]. In addition, sulphur has been found to limit its production in Papua New Guinea [8]. However, high doses of phosphorus and nitrogen suppress tuber yields [7,8]. According to [9], it reported low available phosphorus and potassium in most soils of Kakamega and low available phosphorus in Elgeiyo Marakwet, which would contribute to low sweet potato production in these regions. Sweet potatoes thrive best on soil pH ranging from 5.5-6.5 [10]. Although they tolerate low pH, [11] their yields are greatly reduced under pH 5.5 probably due to the high aluminum saturation and low available phosphorus common in such pH [12].

The only available fertilizer use recommendations of 90 Kg N and 100 Kg P/ha for sweet potato production in Western Kenya [11] is too high for resource poor farmers and may suppress tuber yields as reported by [9,10]. In addition, it does not contain essential nutrients such as potassium and sulphur.

This paper addresses the issue of sweet potatoes and soybeans growing in Makunga (Kakamega County) and Kibargoi (Elgeiyo Marakwet County) in relation with application of inorganic manures and farm rotational systems. The study also covered the use of organic manures by farmers and the quantity applied per farms.

2. MATERIALS AND METHODS

2.1 Description of Study Areas

The study was carried out in two zones of Kenyan western and Rift valley Regions. The sections were from two counties; Makunga (Kakamega County) and (Kibargoi) Elgeiyo Marakwet County.

2.2 East Wanga/Makunga, Kakamega County

Makunga is located in Mumias East Sub County, Kakamega County. The county is located at longitude 35°04' and 34 22' East and latitude 0° 26' and 1°09' N. Makunga is West of the Sub County and found under lower midland 3 agro-ecological zone (cotton zone). The average annual rainfall range for Kakamega County is 1200 – 1800 mm while for Mumias East Sub County is 1200-1400 mm with bimodal distribution. Long rain season occurs in the months of March to mid-July while short rain season occurs between Mid - July to February. It has annual mean temperature range of 22.4-21.6°C. The altitude of the area ranges from 1200-1400 m. The main soil type in Makunga area is Orthic Acrisols [2] Makunga has a household population of 2,325, 3,056 and 2,039 respectively making a total of 7,420 households in the divisions within the sub-County [13,14].

2.3 Cheptebo (Kibargoi), Elgeiyo Marakwet County

Cheptebo is located in Soy Division Elgeiyo Marakwet County. It is found under lower midland 5 agro-ecological zone (cotton zone). The county is located at longitude 35°42' and 35°09' East and latitude 1°18' and 0°10'N. The average annual rainfall range for Elgeiyo Marakwet County is 700 – 1400 mm while that of Soy division is 1000 – 1300 mm with bimodal distribution. Long rain occurs in the months of March to June while short rain season occurs between June to January. The main soil type in the Cheptebo area is Calcic Cambisols [2]. Soy Division has 3,496 total households [13,14].

2.4 Methodology

To determining the prevailing farmers' practices on soil fertility management in Kakamega and Elgeiyo Marakwet Counties, data was collected by carrying out a cross-sectional survey among the sweet potato smallholder farmers in the two counties. Structured interviews and observations were used to collect the following sets of data;

a) Demographic factors influencing sweet potato – soybean growing in the study sites.
b) Crop production and their significance as rated by smallholder farmers in the study sites.
c) Integrated sweet potato – soybean and animal production among the respondents

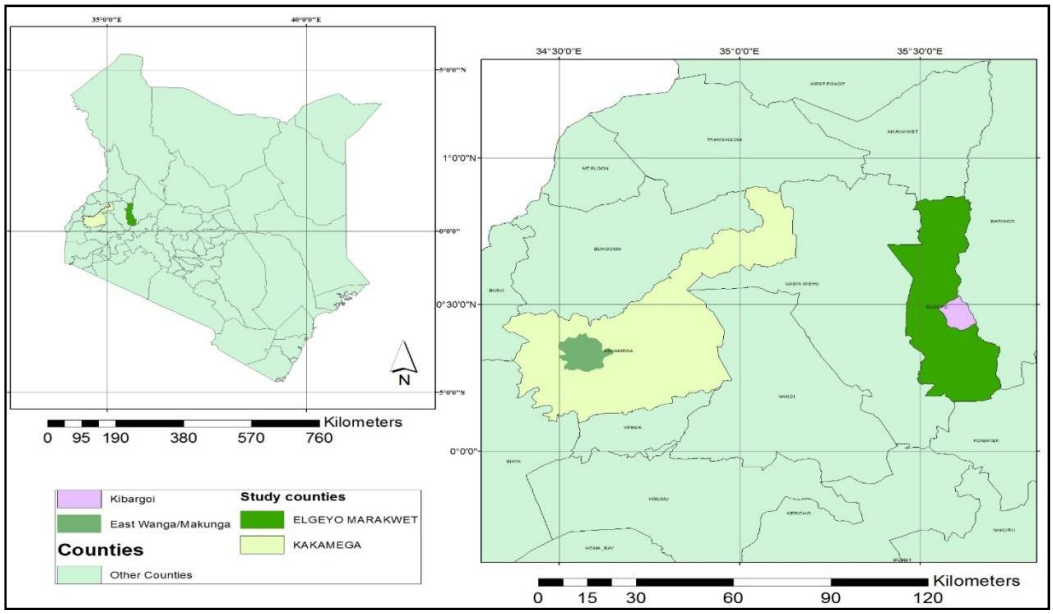

Fig. 1. Geographical locations of the sub-Counties where the study was carried out

d) Soil fertility management options practiced by the farmers in the study sites and
e) Agricultural extension service delivery in the areas of study

Purposeful sampling design was used to collect 10% of the total household population per Sub County growing sweet potatoes. This data was obtained from the selected sub county agricultural office. One Sub County per County and one location per each sub County were selected with the help of extension staff from the respective county governments based on agro-ecological zones and land use. The area chiefs together with the extension staff helped in mobilizing the community and partially in data collection.

The sample in each location was computed based on the population proportion using the following formula according to [15];

The size of the sample will be determined using the mathematical formula; $n_o = \{ z^2 * p * q \} / d^2$.

Where:

n_0 is the desired sample size
z is the standard normal deviate at the required confidence level;
p is the proportion of the respondents
q = 1-p and
d is the level of statistical significance set.

2.5 Data Analysis

Data from the cross sectional survey was coded and analyzed using statistical package for social sciences (SPSS) version 23.0 [16].

3. RESULTS AND DISCUSSION

3.1 Demographic Factors Influencing Sweet Potato – Soybean Growing in the Study Sites

The gender representation was dominated by female with 54.4% (81) while males were 45.6% (68). However, in cross tabulation per regions there was observed shift of women respondents in Kibargoi with men represented by 66.7% (28) and in Makunga females dominated as respondents with 62.6% (Fig. 2), this could be attributed to the social setting of the two societies where most females work at the home farms in Makunga as opposed to the Kibargoi location. The results gathered from Kibargoi are in agreement with finding by [17] who pointed out male dominated households in their study in Ethiopia while [18] reported female dominance in agricultural activities in western Kenya.

Formal education was one of demographics parameters and it was found out that 133 respondents had acquired either primary or secondary education. Primary education had been acquired by 55.7% (83) while 33.6 (50) had acquired secondary education; those with college education were 7.4% (11) of the total respondents while 3.4% had not acquired any form of formal education. The authors [17,18] revealed in their findings that education level is significant in understanding and adopting new agricultural activities and corroborates the results of this study.

The distribution by location indicated that Makunga had 71.1% (59) respondents who had acquired primary education while 28.9% (24) had acquired the same level of education in Kibargoi. The highest numbers of secondary schooled

Table 1. Location and education cross tabulation

			Education level				Total
			Primary	Secondary	College	None	
Location	**Kibargoi**	Count	24	11	6	1	42
		% within Location	57.1%	26.2%	14.3%	2.4%	100.0%
		% within Education Level	28.9%	22.0%	54.5%	20.0%	28.2%
		% of Total	16.1%	7.4%	4.0%	0.7%	28.2%
	Makunga	Count	59	39	5	4	107
		% within Location	55.1%	36.4%	4.7%	3.7%	100.0%
		% within Education Level	71.1%	78.0%	45.5%	80.0%	71.8%
		% of Total	39.6%	26.2%	3.4%	2.7%	71.8%

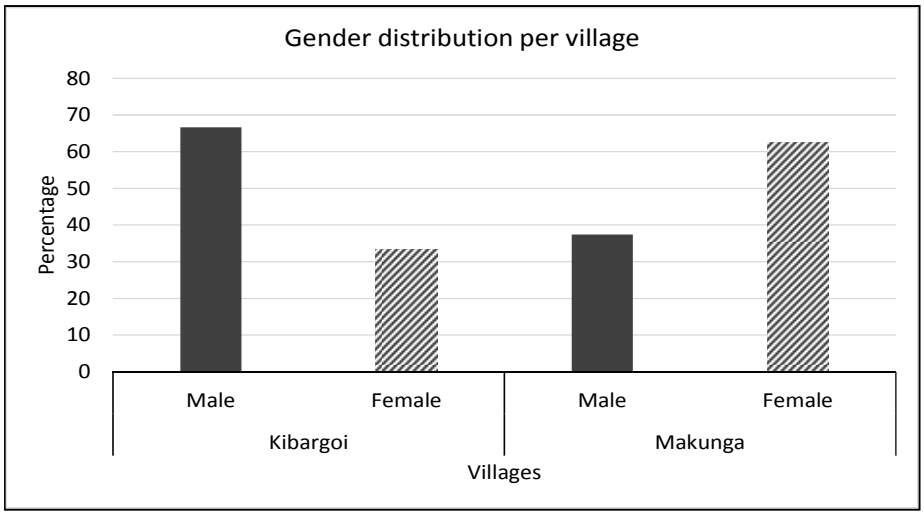

Fig. 2. Gender distribution per location

respondents were in Makunga with 78% while Kibargoi had 22% as shown in Table 1.

The occupation of the respondents indicated that the most dominant activities in that zones were farming with 86% (128) of them were engaged in farming fulltime. Although the 85.95% of the respondents indicated farming as a key activity 14.1% (21) respondents also indicated that farming was an essential activity and they practice it alongside their other duties. This could be attributed to the zones richness in agricultural activities with land being considered as a basic mode of production. The other occupations engaged by the respondents (6.7%) included business in food stuffs and shop keeping as represented by Fig. 3.

Farming was dominant in Makunga 91.6% (98) and 71.4% (30) in Kibargoi. In Kibargoi 57.1% (4) female respondents did business compared to 42.9% (3) of male, while 66.7% (2) female engaged in business in Makunga. There were more male respondents who did farming in Makunga 90% (36) than there were in Kibargoi 70% (21) respondents. It was also noted that women did varied activities than males in the two regions.

The mean number of dependents per household of respondents as shown in Fig. 4 was 7 children per homestead, the mean average dependents per homestead in Makunga was 7 children while Kibargoi was 6 children. This average number of dependents per household is higher than the National average of 5 children per household in 2009 [14]. In addition, it agrees with [19] that labour availability among smallholder farmers is paramount and eases farming labour requirement.

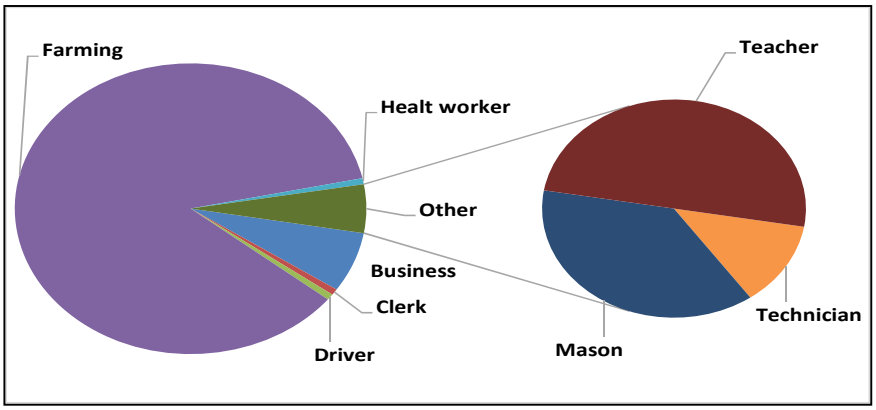

Fig. 3. Respondents' occupation

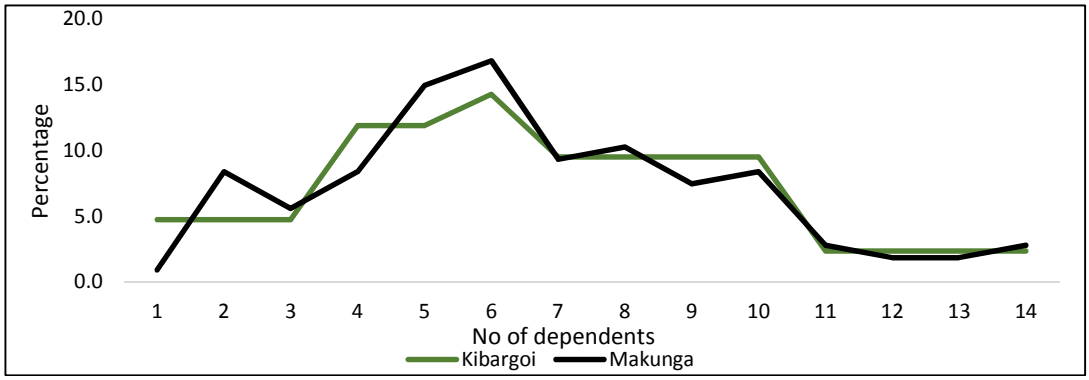

Fig. 4. Comparison of number of dependents per location

The mean size of land in the study areas was 2.35 acres per respondents and the maximum size of land owned by a respondent was 25 acres while minimum was 0.25 acres. However, there was a disparity between the two regions with Makunga having a mean of 2.7 and Kibargoi 2.2 the range was huge with Kibargoi 9.75 acres and Makunga 24 acres. The land holding in the areas is above the National mean average of 2.4 acres per household in medium populated areas [13].

3.2 Crop Production and Their Significance as Rated by Smallholder Farmers in the Study Sites

Most farmers in sub-Saharan Africa (SSA) face urgent problems of food security for their families for the whole year as well as earning sufficient income [20]. The study sorted to get respondents ranking of crops based on their importance in food security and income generation activities.

As shown in Tables 2 and 3, the major crops included maize, beans and sweet potatoes which were grown as food and cash crops with maize being an outstanding food security crop.

The results agree with other findings that maize is the principal cereal crop for millions of people in mixed crop-livestock farming systems in eastern and southern Africa [21].

3.2.1 Sweet potatoes growing

Sweet potatoes was rated most important food crop and cash crop by respondents in Makunga, Kakamega County as shown in Tables 2 and 3.

Table 2. Importance attached to crops

Importance		Sorghum	Millet	Maize	Soybean	Beans	Sweet potatoes	Irish potatoes	Disodium
Food crop	Yes	67.79	64.43	98.66	57.05	96.64	85.23	44.97	41.61
	No	32.21	35.57	1.34	42.95	3.36	14.77	55.03	58.39
Cash crop	Yes	54.36	59.06	85.91	51.68	77.85	79.87	44.97	37.58
	No	45.64	40.94	14.09	48.32	22.15	20.13	55.03	62.42

Table 3. Crop production rating on food security

Location		Sorghum	Millet	Maize	Soybean	Beans	Sweet potatoes	Irish potatoes	Disodium
Kibargoi	Grow	33	39	41	23	41	36	23	17
	Don't grow	9	3	1	19	1	6	19	25
	Mean	1.72	1.33	1.02	2.91	1.219	1.55	2.34	2.82
Makunga	Grow	68	57	106	62	103	91	44	45
	Don't grow	39	50	1	45	4	16	63	62
	Mean	2.41	2.21	1.10	2.14	1.50	1.56	2.77	2.8

These findings corroborates with other authors [1] who pointed out the significance of sweet potatoes as both a cash crop and food crop.

The sweet potatoes varieties were grown due to various attributes (Table 4) and the most outstanding was high yielding varieties. Rated second was improved varieties by Makunga respondents.

The yield of sweet potatoes produced by farmers was on an average of 18.4 bags (calibrated as 50 kg bag) per farmer in the study sites as indicated in Fig. 5.

The findings indicate a need to great awareness among smallholder farmers on available improved varieties by establishing corporation with higher institutions of learning and research centres as pointed out by [17] with focus on improved yields and family nutrition.

3.2.2 Soybean growing

The percentage of respondents growing soybeans is indicated in Table 5.

Soybeans are grown by 36.9% of the total respondents in the study area and it is least grown in Kibargoi by only 7.1% of the respondents whereas in Makunga it is grown by 48.6% of the respondents.

Soybean grains were used for human consumption by 30.9%, and the residents cited that the grains are used for human consumption as an alternative to milk.

3.2.3 Crop production and fertilizer use

The use of organic fertilizers to grow sweet potatoes were used by 11.4% of those who grew sweet potatoes and 74.5% did not use.

The use of inorganic fertilizers was also studied and it was observed that 81.9% (122) respondents did not use inorganic fertilizers. The common type of inorganic fertilizers were Di-ammonium phosphate (DAP) used by the 2% respondents. The results obtained agrees with [17] who pointed out the need to research on area specific fertilizer rates in order to improve crop production.

Table 4. Attributes for selecting the variety per location

Location	Variety	Frequency	Percent
Kibargoi	Improved variety	2	4.8
	High yield	26	61.9
	Diseases resistant	1	2.4
	Easily available	4	9.5
	Don't grow	9	21.4
	Total	42	100
Makunga	Orange fleshed	11	10.3
	Improved variety	17	15.9
	High yield	48	44.9
	Improve soil fertility	7	6.5
	Diseases resistant	9	8.4
	Easily available	11	10.3
	Don't grow	4	3.7
	Total	107	100

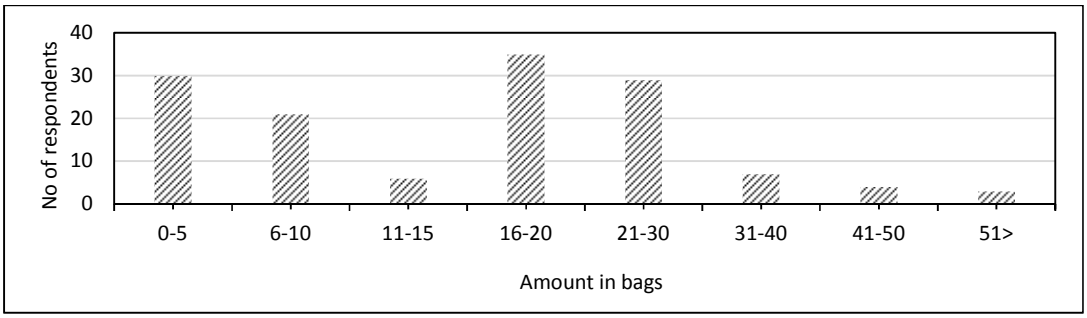

Fig. 5. Production of sweet potatoes in bags

Table 5. Soybeans growing per locations

Location	Grow soybeans	Frequency	Percent
Kibargoi	Yes	3	7.1
	No	39	92.9
	Total	42	100
Makunga	Yes	52	48.6
	No	55	51.4
	Total	107	100

3.3 Integrated Sweet Potato – Soybean and Animal Production

The animals kept by the respondents included cattle, sheep, goats, rabbits and poultry.

The ownership and care of rabbit; children (3.4%), father owned 2% and mother 3% is indicated in Fig. 6.

The rabbits were kept in wooden, mesh houses and cages raised above the ground to avoid attack by predators that farmers cited included wild and home dogs.

The sweet potato vines were also used for various uses which included feed to animals, planting material and to enhance soil fertility status agreeing with [22] who reported on significance of vines as rabbit feed.

3.4 Soil Fertility Management Options Practiced by the Farmers in the Study Sites

The degradation in soil fertility was observed to be the main challenge in the study sites and this was attributed to low inherent soil fertility, soil erosion and high cost of fertilizers as shown in Table 6.

Farmers have attempted to solve soil fertility problems in the degraded farms by a combination of farm management operations (Table 7) which included; rotational cropping system intercropping, use of inorganic fertilizers, use of animal manure and use of crop residues.

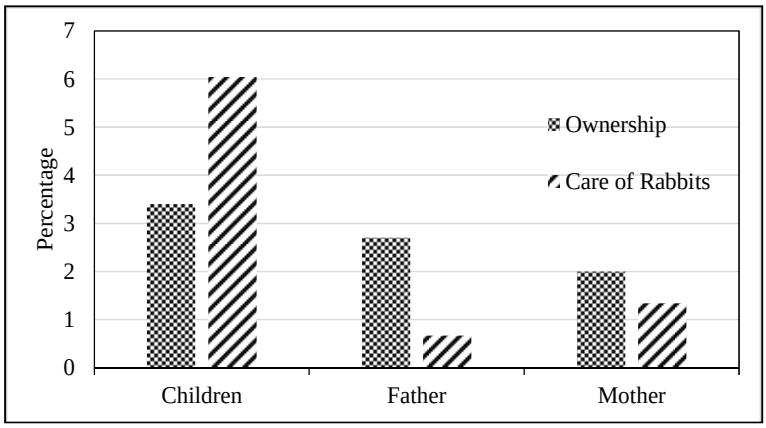

Fig. 6. Rabbit keeping and care

Table 6. Challenges in soil fertility management

Location	Challenge	Frequency	Percent
Kibargoi	Low soil fertility	8	19
	Soil erosion	23	54.8
	Drought	9	21.4
	High cost of fertilizers	2	4.8
	Total	42	100
Makunga	Low soil fertility	30	28
	Delayed supply of fertilizers	2	1.9
	Soil erosion	45	42.1
	Drought	1	0.9
	High cost of fertilizers	28	26.2
	None	1	0.9
	Total	107	100

Table 7. Methods of improving soil fertility in farms

Location	Method	Respondents	Percent
Kibargoi	Rotational cropping system	15	35.7
	Intercropping	8	19.0
	Use of animal manure	10	23.8
	Use of crop residues	4	9.5
	All above	5	11.9
	Total	42	100.0
Makunga	Rotational cropping system	2	1.9
	Intercropping	4	3.7
	Use of inorganic fertilizers	3	2.8
	Use of animal manure	6	5.6
	Use of crop residues	3	2.8
	All above	89	83.2
	Total	107	100.0

Table 8. Source of agricultural information

	Sweet potatoes growing		Soybeans growing		Rabbits rearing	
	Respondents	Percent	Respondents	Percent	Respondents	Percent
Own experience	32	21.5	10	6.7	5	3.4
NGOs	3	2	3	2	0	0
Church	4	2.7	2	1.3	0	0
Extension services	46	30.9	21	14.1	4	2.7
Friends/Relatives	36	24.2	17	11.4	5	3.4
All above	11	7.4	6	4	1	.7
Valid Total	132	88.6	59	39.6	15	10.1

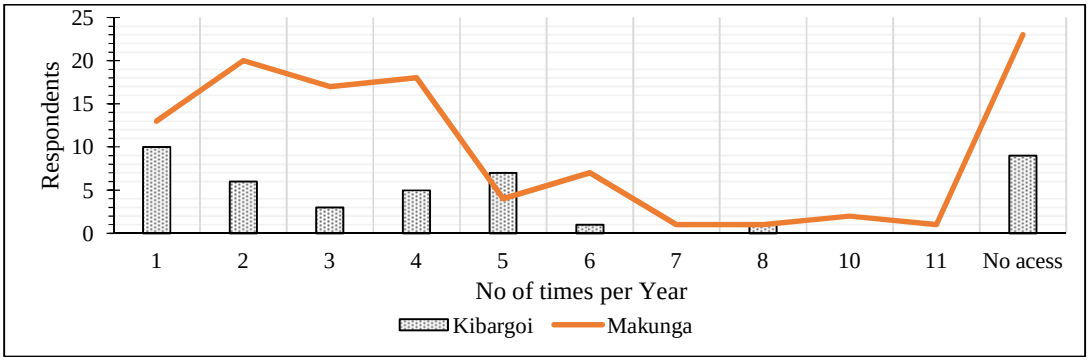

Fig. 7. Extension services' availability per year

The results indicate constraints highlighted by other authors [23,24] on the significance of close link with farmers training centres on promotion and adoption of technologies that enhance crop yields.

3.5 Agricultural Extension Service Delivery in the Study Area

The source of information for growing of sweet potatoes were obtained generally from extension services, friends and relatives as shown in Table 8.

While access to agricultural information is on a lower scale (Fig. 2) as reported by [18] implying the need to intensify the services among the small holder farmers in the areas of study.

4. CONCLUSION AND RECOMMENDATION

From the study, it can be concluded that there were more female respondents and education level influence understanding and practice of new agricultural technologies and that farm labour requirement plays a significant role in crop

production. It was also deduced that maize was the most important crop grown in the two zones as either food crop or cash crop while sweet potato and soybean growing were on a lower scale. The findings point out the need to promote sweet potato – soybean to enhance their production. It is also concluded that there is need for an integrated link between the farmers, higher institutions of learning as well as research in order to establish site specific fertilizer rates to enhance soil fertility improvement. It is recommended that agricultural service delivery be prioritized improved crop production.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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