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INTEGRATION OF MANURE AND MINERAL FERTILIZERS AMONG SMALLHOLDER FARMERS IN KENYA: A PATHWAY TO SUSTAINABLE SOIL FERTILITY MANAGEMENT AND AGRICULTURAL INTENSIFICATION

Amos W. Wawire [1,2], Ádám Csorba[1], József A. Tóth[1], Erika Michéli[1],
[1] Szent István University, Hungary
[2] Karatina University, Kenya,

Correspondence: Amos Wawire, School of Agricultural and Environmental Sciences, Szent István University, H-2100 Gödöllő, Páter Károly utca 1, Hungary. Tel: +36301924166, Email: wanjamos@gmail.com

ABSTRACT: *Combination of mineral fertilizers and manure has been proposed as the sustainable approach of soil fertility management. This study evaluates the use of these two soil fertility practices. Data for this study was obtained through a survey conducted between January-March 2019 with 106 farmers. Results show that the proportion of farmers who used manure and inorganic fertilizer was 93.4% in each case. About 90% of the farmers used both fertilizer and manure. Farmers accessed fertilizers mostly through direct purchase from the local market (73.9%). Most of the manure is obtained on-farm (84.8%). About 67% of farmers used fertilizer both for planting and top dressing. However, only 20% of the farmers used fertilizer every season. Low income, low literacy, lack of soil fertility management skills, small land sizes, low livestock units, limited and declining capacity of agricultural extension explain the low investment in soil fertility management. Timely delivery of low-cost, high quality fertilizer is of paramount concern. Glaring loopholes undermining the efficiency of the government subsidy program have to be addressed. Farmers' capacity building is necessary to ensure high quality manure. Policy and institutional support are necessary to reverse the declining capacity of soil science research and agricultural extension.*

KEYWORDS: soil fertility, sustainable agricultural intensification, declining soil fertility, fertilizer, manure, subsidy, agricultural extension, integrated soil fertility management

INTRODUCTION

Agriculture in sub-Saharan Africa (SSA) constitutes the primary economic activity and contributes averagely 15-30% of GDP (Kamara et al., 2019; World Bank, 2008). It is largely considered as the major pathway to eradicate hunger, poverty and a platform for both rural and economic growth (FAO, 2018). It is estimated that every 10% increase in yields in Africa reduces poverty rates by 7% (Pretty et al., 2011). There is unanimous consensus on the need to significantly increase global food production to match the demand of the increasing population (Pretty et al., 2011; World Bank, 2008).

However, characterized by failure of the millions of smallholder farmers to realize sustained productivity growth, African agriculture has been termed as stagnant (Pretty et al., 2011). Agricultural productivity in Africa has steadily lagged behind the rest of the world for a very long time (Mason-D'Croz et al., 2019). The region is dominated by traditional farming practices which are considered as the major reasons for the severe soil fertility decline and low agricultural productivity The farming systems in the continent are constrained by limited nutrient supply due to low use of mineral fertilizers (Pretty et al., 2011) and organic resources (Vanlauwe, et al., 2014). Negative nutrient imbalances is thus a common phenomenon (Chianu et al., 2012). The region has the lowest fertilizer use globally (Chianu et al., 2012), with an average application rate estimated at 12 kg per hectare per year (CABI, 2017).

The low fertilizer use has been attributed to a number of factors including high importation cost, poor infrastructure, high tariffs and small, weak and fragmented markets. Other constraints include farmers' lack of knowledge on the use of fertilizers, low literacy levels and poor cultural practices. Inappropriate fertilizer packaging sizes, poor quality of supplied fertilizers, untimely availability, poorly managed or lack (or removal in some cases) of input subsidy programs, weak agricultural extension and soil science capacity have equally contributed to low intake (Chianu et al., 2012). Some of the government's subsidy programs, in Kenyan case for example, remain regressive and distortionary (Birch, 2018). However, the launch of the digital e-voucher system expected to take off in 2020 is likely to improve the sub-sector's efficiency (Xinhua, 2019). Manure use on the other hand, is constrained by limited availability and poor quality. Poor quality and lack or limited availability of organic resources are the major constraints to the use of organic inputs. The scarcity of organic resources is attributed to smallholder farmers low resource endowment. The farmers own a small number of livestock with different livestock management practices such as stall feeding and free grazing system. In some cases, free grazing happens on communal fields which does not support accumulation of enough manure on household's farm.

Combination of mineral fertilizer and manure which constitutes one of the strategies promoted under the concept of integrated soil fertility management (ISFM), provides a practical solution to soil fertility challenges and a pathway to sustainable agricultural intensification. The ISFM framework is built on the realization that no single soil fertility strategy can be regarded as a one-size-fits-all solution, and that some practices are site- or even field-specific (Adolwa et al., 2019).Targeted fertilizers are strategically used alongside manure to ensure fertility input efficiency and crop productivity (Tittonell et al., 2008). It is not surprising therefore that one of the major focus of the Abuja Fertilizer Summit was on maximizing efficiency and profitability of external inputs (Vanlauwe et al., 2014).

This approach also challenges a long-held belief that mineral fertilizer is the cure to all fertility issues (Vanlauwe et al., 2014). The attractiveness of a given set of ISFM technologies is highly depended on the nature of the field (responsiveness to fertility techniques). Poorly responsive and severely degraded fields for instance, would require long-term rehabilitation with gradual application of manure to restore soil fertility and enhance efficient uptake of nutrients by crops. This, however, implies a longer period required for SOC build-up, the waiting which most farmers cannot afford considering their conditions. Farmers are largely driven by short-term benefits. Nevertheless, mixed crop-livestock farming systems which are common among smallholder farmers provide good opportunity for application of ISFM principles. The framework's tenets provide for the strategic application of manure and mineral fertilizer within

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smallholder farms based on the responsiveness patterns of different fields to ensure maximum marginal returns to investment(Tittonell et al., 2008).

Sustainable agricultural intensification and soil health

Intensification of African agricultural systems has largely been touted as a major prerequisite for poverty alleviation among rural households (Vanlauwe, et al., 2014). Headey and Jayne (2014) observed that agricultural intensification is a critical mitigation mechanism against declining farm land sizes in Asia and Africa. However, this approach poses environmental degradation threats unless it is practiced sustainably (Kurgat et al., 2018; Vanlauwe et al., 2011).

Sustainable agricultural intensification (SAI) involves producing more on a given area of land while keeping the negative environmental impacts at minimum and contributing to the restoration or build-up of natural capital (Pretty, 2008; Warwick, 2008). SAI system is characterized by judicious use of external inputs, while minimizing the use technologies with drastic environmental impact. Unlike the conventional farming systems, sustainable systems ensure healthy soils which are less prone to shocks and stress. However, the adoption of sustainable intensification agriculture in most of African countries is reportedly low (Kurgat et al., 2018).

Soil fertility management

The soil fertility question is a complex one, requiring a precise approach. Some soils suffer from low nitrogen and phosphorus levels, thus there is a need for increased use of inorganic fertilizers and organic resources to boost land productivity (Makokha et al., 2001). Kenyan soils suffer from major macronutrients (N and P) as well as micronutrients such as K and S (Kibunja et al., 2017).

The use of fertilizers has been shown to sustainably increase crop yields by 50-100%, thus significantly bridging the gap between the actual farmers' yields and the potential possible yields based on on-station research trials (Chianu et al., 2012). However, appropriate application of inputs is critical in realizing increased productivity and profitability (Vanlauwe, et al., 2011). 'Appropriate' implies applying the right type of input, at the right time, at the right rate and place (Vanlauwe, et al., 2014). it also means avoiding non-responsive soils (Rusinamhodzi et al., 2013).

Combination of minimal amount of mineral fertilizers while capitalizing on organic resources, is necessary. This approach is equally critical owing to the fact that the manure used (raw or compost) is of low quality and scarce (Vanlauwe, et al., 2011). The nutrient composition of the organic inputs and the rate of release of these nutrients to plants are largely determined by the quality of organic resources based on their chemical characteristics. Compared to fertilizers, relatively large amount of organic inputs is required to release a given amount of nutrients. Realistically, however, the organic resources applied hardly release sufficient nutrients to match the nutrient required for optimum crop yield (Makokha et al., 2001). Affordability of fertilizers in this scenario, is vital. In fact, intensive use of fertilizer is required in the initial take-off of this approach to generate enough residue to be used as animal feed, translating into more manure.

Many soil fertility studies have focused on either the use of mineral fertilizers or organic resources. However, the complementarity of the two practices cannot be overemphasized and the application of either, with the exclusion of the other, would be unsustainable in the long run. Whereas, mineral fertilizers provide higher nutrients to the soil, manure and other organic resources are critical in raising soil organic matter, giving the soil the desired firm structure and ensuring sustainable productivity. For most farmers, manure is the first source of farm fertility. It thus follows that addressing soil fertility management requires taking into consideration the overall land management issues (Corbeels et al., 2000) to facilitate tailored solutions based on local needs and resources. This study examines the use of fertilizer and organic inputs among smallholder farmers.

The study area is located in the Central Kenya highlands, which is considered as one of the high agricultural productivity zone due to favourable agro-ecological conditions and fertile soils. The area is one of the regions with high rates of uptake of soil fertility management practices (Ariga & Jayne, 2011). However, the area is increasingly witnessing decline in productivity, which has largely been attributed to the deteriorating soil fertility. The decreasing agricultural land, encroachment of water catchment areas and environmental degradation continue to increasingly undermine the livelihood of the community (Meru County Government, 2014; MoALF, 2016) thus the need for this study.

METHODOLOGY

Study Area

The study was conducted in Meru (0°02'60.00" N 37°37'59.99" E) and Tharaka Nithi (0°17'60.00" N 38°00'0.00" E) Counties of Kenya’s central highlands (Figure 1). Farming in the region is generally rainfed agriculture.

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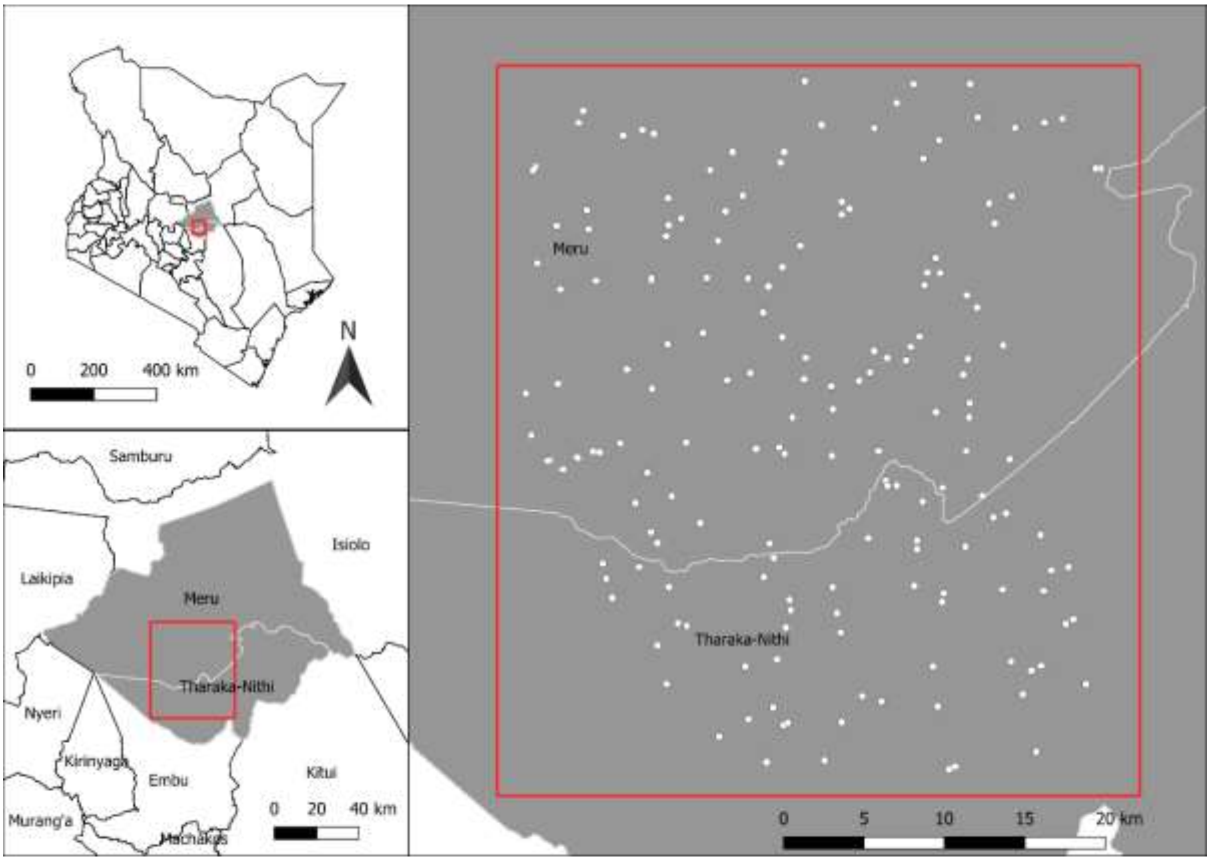

Figure 1.Study area and distribution of household farms in Meru and Tharaka Nithi Counties

The altitude of Meru County ranges from 300m to 5,199 above sea level. This wide variations have resulted in a broad range of microclimates and agro-ecological zones which range from upper highlands, upper and lower midlands, and lower highlands. Tharaka Nithi's altitude range between 600m and 5,200m above sea level. Rainfall in the region varies considerably, increasing from east to west, with the annual average ranging from 300 mm to 2,500 mm. The area experiences a bi-modal rainfall pattern. longer rains occur between March-May, and the shorter rains between October-December.. Temperatures range between 8°C and 32°C. The high climatic variation and ecological zones explains the region's diverse agricultural production (County Government of Tharaka-Nithi, 2013; Meru County Government, 2014).

Meru's total land area is estimated at 6,936 km^2, with a population of 1,545,714 and 426,360 households. Tharaka Nithi, on the other hand, has a population of 393,177 and 109,860 households, with a land area of 2,662 km^2 (CIDP, 2018; KNBS, 2019). The population density for the two counties according to Kenya's 2019 census is about 221 and 153 for Meru and Tharaka Nithi respectively. In both counties, agriculture is the major economic activity accounting for 80% of the economy, with farming, directly or indirectly, supporting more than 90% of the population. Farming is largely dominated by smallholders, accounting for about 98.6% of farms. The average farm size is about 2 and 2.9 acres for Meru and Tharaka Nithi respectively. (County Government of Tharaka-Nithi, 2013; Meru County Government, 2014).

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Most farmers in the region practice mixed farming. A wide variety of crops are cultivated including coffee, tea, maize, beans, vegetables, bananas, potatoes and fruit crops. Livestock enterprises include dairy cattle, beef cattle, sheep, goats and poultry. (CIDP, 2018; County Government of Tharaka-Nithi, 2013). The two enterprises are mutual beneficial to each other. Part of the crop residue is used to as animal feed, while manure produced is used on the farm to replenish soil nutrients.

Nitisols, Ferrasols, Regosols, Vertisols and Phaeozems are the most dominant Reference soil groups (IUSS Working Group WRB, 2015) (Dijkshoorn, 2007). Humic topsoils dominate the Western part due to low rate of mineralization of organic matter, heavy leaching (especially in the middle elevation zone because of moderate rainfall and temperature) and eluviation. These soils are largely acidic with low base saturation including Andosols, Umbrisols and Alisols (Mutuma, 2017).

Tharaka-Nithi soils are predominantly sandy loam and shallow a situation that renders the March-May long rains insufficient to buffer crops from agricultural drought, necessitating the need for moisture conservation remedies (Muriu-Ng'ang'a et al., 2017).

Sampling and Data collection

Data for this study was obtained through a farm household survey conducted between January-March 2019 using questionnaires. Three sub-counties were purposively sampled from each of the two counties. A sample size of 106 farmers chosen for questionnaire survey was determined using Cochran's' (1963) sampling formula. Of the 106 surveyed farmers, 26 were drawn from Tharaka Nithi County while 80 were drawn from Meru County. The sample size for each county was based on proportionate sampling technique guided by the respective Counties' population (KNBS, 2019).

A total of 19 County wards selected for sampling were determined using multi-stage sampling. Farm households were then selected through systematic random sampling. Both the questionnaires were administered face-to-face. Data collected include socioeconomic variables (such as education, household farm size), type of cultivated crops, types and quantity of each livestock, contact and access to agricultural extension service providers, fertilizer and manure use, type of fertilizer and manure used, source of fertilizer and manure, and frequency of application. Data on farmers' perceived constraints to soil fertility were also captured.

For the analysis 6 fertilizer and manure application regimes were used as dependent variables, namely, 1) fertilizer use 2) manure use 3) fertilizer use for planting only, 4) fertilizer use for top dressing only, 5) fertilizer used for both planting and top dressing 6) fertilizer use every season. To enrich data questionnaire data,

Table 1. Definition of variables used in the study

Variables	**Definition**
Independent variables	
Education	Household head education level (1= below high school, 2=above high school
Maize crop	Whether farmer cultivates maize (0=No, 1= Yes)
Tea crop	Whether farmer cultivates Tea (0=No, 1= Yes)
Coffee	Whether farmer cultivates coffee (0=No, 1= Yes)
Contact with extension in the last 5 years	0=no, 1=yes
Farm size	Total size of landholding cultivated by household (in acres)
Household income	Annual household income (on-farm and off-farm)
Tropical livestock units (TLU)	Aggregated livestock assets
Perceived challenges to soil fertility (as independent variables)	
Expensive fertilizer	perceived as a challenge? (0=No, 1=Yes)
Limited soil analysis	perceived as a challenge? (0=No, 1=Yes)
Limited manure	perceived as a challenge? (0=No, 1=Yes)
Limited knowledge on soil fertility	perceived as a challenge? (0=No, 1=Yes)
Limited access to subsidized fertilizer	perceived as a challenge? (0=No, 1=Yes)
Poor quality fertilizer	perceived as a challenge? (0=No, 1=Yes)
Limited fertilizer	perceived as a challenge? (0=No, 1=Yes)
Dependent variables	
Fertilizer use	0= not applied, 1=applied)
Fertilizer application pattern	0= None, 1= Planting only, 2= Topdressing only, 3=Planting + topdressing
Fertilizer applied every season	0=No, 1=yes
Manure	0=not applied, 1=applied

Data analysis

SPSS software was used to generate descriptive statistics. Frequency distributions were used to display statistics on the use of mineral fertilizer and manure, their sources and types. Results on frequency of use of fertilizers were also generated. Fisher's exact test and Welch's t-test were used to test for the significant associations between selected explanatory variables and variables under investigation. Some of the variables selected for use in the model were based on extensive literature review. Considering that the binary nature of the decision for use or non-use, binary choice models come in handy. Possible outcome is associated with a set of explanatory variables (Muriu-Ng'ang'a et al., 2017; Noltze et al., 2012) and include farmers' socioeconomic variables (including education, household income, farm size and livestock ownership), institutional factors (such as access to subsidy fertilizers, contact with extension, access to soil testing facilities), farmers' perception on hindrances to soil fertility (including expensive fertilizer, poor fertilizer quality, lack of soil fertility management skills). The independent variables used in the model were the various fertilizer and manure application regimes including questions on whether the farmer: 1) uses fertilizer, 2) uses manure, 3) applies

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fertilizer only during planting, 4) applies fertilizer only during top dressing 5) applies fertilizers during both planting and top dressing and 6) uses fertilizer every planting season.

RESULTS

Farm household demographic and socio-economic characteristics

The mean age of the household heads was 47 years, with an average family size of five people. An average of 3 household members provide labour on the farm. The mean household farm size was three acres. The average total household income is estimated at KES 271,668 ($ 2,700) per year. The mean livestock holding unit was 2.5 TLU.

Table 1. Socioeconomic characteristics of the households in the study area

Variable	Frequency	Percent
Gender		
Female	49	46.2
Male	57	53.8
Age		
<40	42	39.6
>40	64	60.4
Education		
Primary and below	51	48.1
High school	45	42.5
Higher education	10	9.4
Location (County)		
Meru	80	75.5
Tharaka Nithi	26	7.5
Farming as primary occupation	97	91.5
Number of years in farming		
<20	54	50.9
>20	52	49.1
Contact with Extension	46	43.4
Access to soil information	11	10.4

Access to Fertilizer and manure

The use of fertilizer and mineral fertilizers was 93.4% in each case. Approximately 85% of the farmers used both manure and inorganic fertilizer. Farmers access to fertilizer is largely through direct purchase from the market, mostly from agro-dealers (Table 2). In addition, tea factories constitute an important source of mineral fertilizers for tea growers. Only a handful of farmers have benefitted from the government subsidized fertilizers. Other sources of fertilizers available to farmers were input credit from coffee factories, NGOs and other private investors (exporters).

Table 2. Sources of fertilizers and manure and their proportional contribution to the total amount of fertilizer used on the farm

Manure Source	% share	Fertilizer Source	% Share
On-farm	84.8	Market purchase	73.9
Market purchase	6.7	GoK subsidized	6.3
Free from neighbour	4.3	Tea Factory	19.4
Buy from neighbour	3.0	Others	0.5
Buy from next village	1.2		
TOTAL	**100.0**		**100.0**

Most of the manure used on the farm (84.8%) is on-farm generated (Table 2). This manure is however, in small amount and inadequate to meet the farm needs, and thus is supplemented from other sources including purchase from the local market and from neighbouring households. Acquisitions from neighbours can be at a cost or free, often in cases of relatives. Supplies of goat manure from neighbouring towns, especially Isiolo town, were common.

Types of fertilizers and manure used

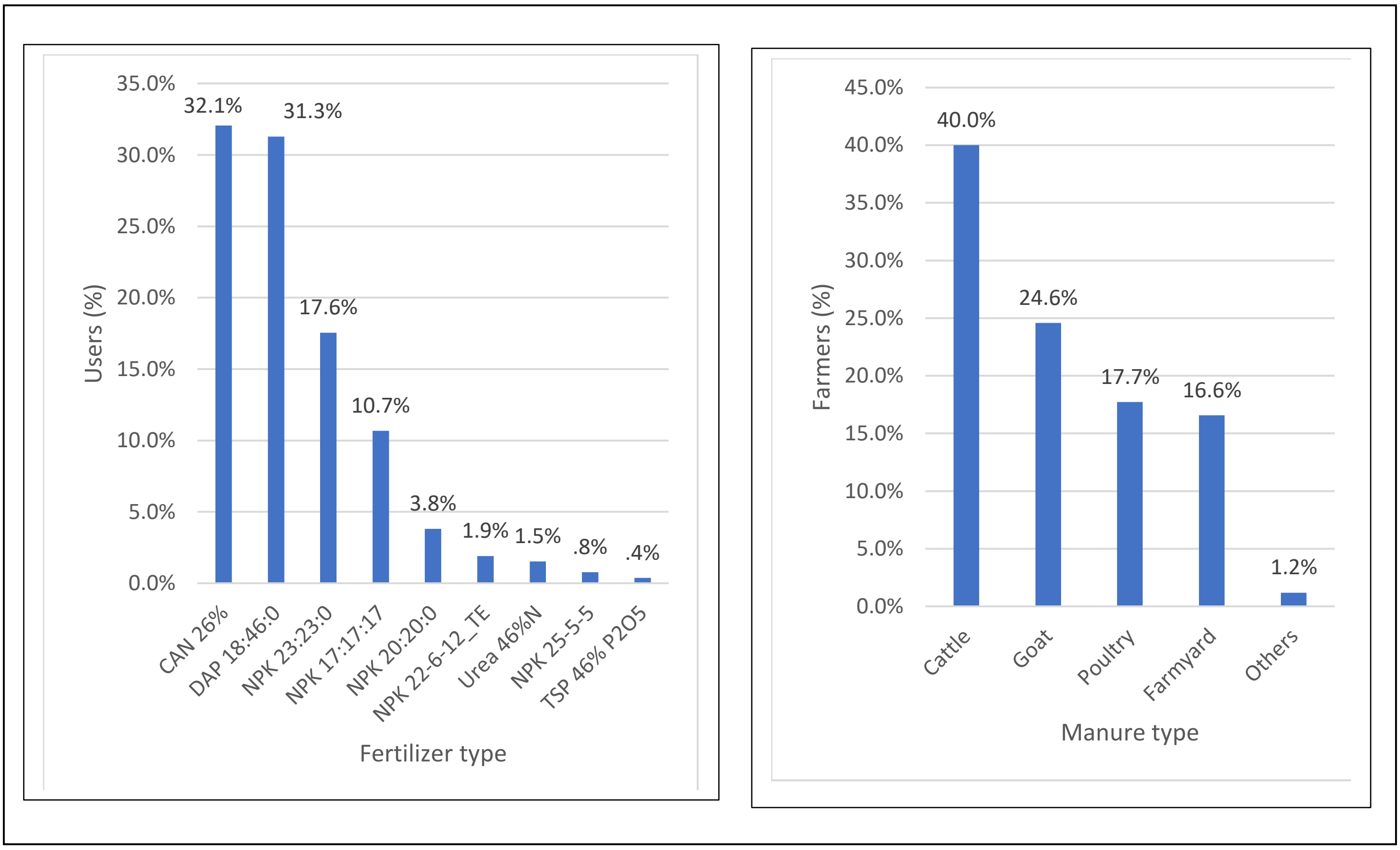

Figure 1. The different types of fertilizer and manure used by farmers

Diammonium phosphate (DAP 18:46:0) and Calcium ammonium nitrate (CAN 26%) are the most commonly used fertilizers during planting and top dressing, respectively (Fig 1). Almost half of the manure used by farmers is unprocessed cattle dung (Fig. 1). Nearly all the farmers (94.3%) practice crop-livestock mixed farming, with majority of them (76.4%) owning cattle.

Inorganic fertilizer application patterns

Majority of the farmers used fertilizer for both planting and topdressing (Table 3.). The rest of the farmers either only used mineral fertilizer for planting or top dressing due to inadequate resources.

Table 3. Fertilizer use patterns during planting, top dressing and planting + top dressing

Fertilizer treatment	**Response (%)**
Planting + top-dressing	66.7%
Top-dressing	17.2%
Planting	16.1%

The average fertilizer application rate was 76 and 61 kg ha^{-1} for planting and top dressing, respectively.

About 71% of farmers use inorganic fertilizers every farming season for planting and 61% for top-dressing (Fig. 2). The rest of the farmers apply fertilizers only during the main season. The use of mineral fertilizers is reported to be unpredictable for nearly 30% of the farmers, as their action is largely determined by availability of resources at any given time. Of the farmers, who use mineral fertilizers, only 20% use the input in both cases (during planting and top dressing) every season.

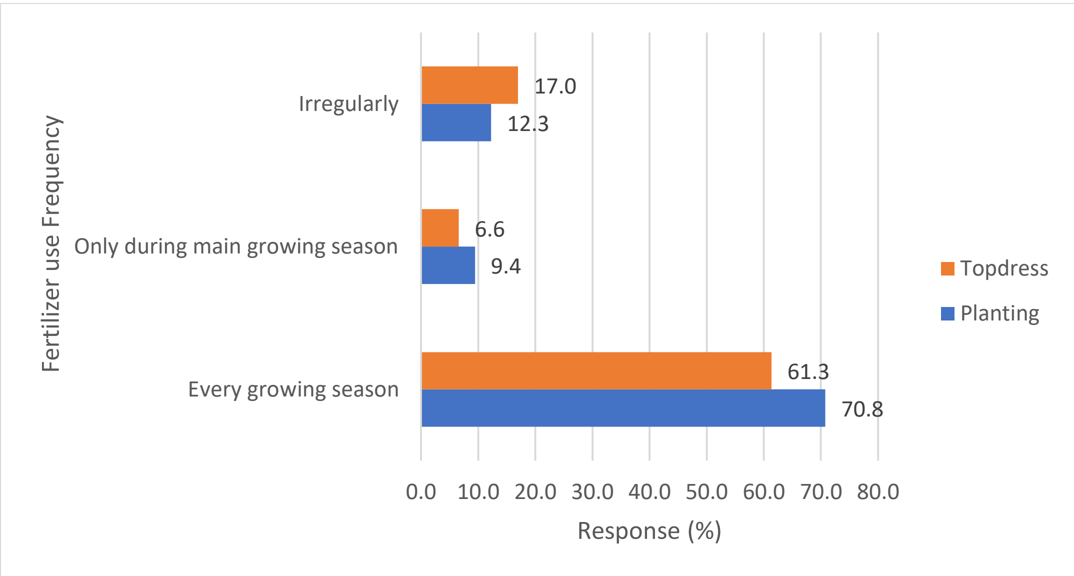

Figure 2. The frequency of fertilizer application by farmers

Constraints to Manure and inorganic fertilizer use

High cost of fertilizer was reported as the major reason for limited access to inorganic resources (Table 4). Low use of manure was attributed to its scarcity.

Table 4. Factors limiting the use of mineral fertilizers and manure by farmers in the study area

Fertilizer		Manure	
Constraint	Percent	Constraint	Percent
High cost	94.4	Lack of funds	14.3
Lack of resources	5.6	limited manure	85.7

Determinants of uptake of inorganic fertilizer and manure

Selected variables hypothesized to influence the decision by farmers to use mineral fertilizers and/or manure were used in Fisher's Exact test (Table 5) and Welch's t-test (Table 6) models. Fertilizer and manure application regimes were included in the models as the dependent variables. They include questions on whether the farmer: 1) uses fertilizer, 2) uses manure, 3) applies fertilizer only during planting, 4) applies fertilizer only during top dressing 5) applies fertilizers during both planting and top dressing and 6) uses fertilizer every planting season.

There was a significant positive correlation between maize crop and income and the decision to use fertilizer. Other outcomes that were significantly associated with maize crop include planting with fertilizer, top dressing with fertilizer, planting plus top dressing with fertilizer, and the use of manure. Meaning that maize had higher chances of receiving the mentioned treatments. Income was significantly correlated with the adoption as well as use of fertilizer for planting. Contact with extension providers was significantly associated with the use of fertilizer for planting and manure application. Education level of the household head and the perceptions about poor quality fertilizer had a significant association with the farmer's decision to top dress their crops. Lack of knowledge on better fertility practices and the size of livestock unit were significantly correlated to the use of manure.

Table 5. Fisher's Exact test of significance of determinants of inorganic fertilizer and manure use

	Use fertilizer		Fertilizer plant		Fertilizer top dress		Fertilizer Plant+topdress		Every season		Manure appl	
Variables	Coef	P>|z|	Coef	P>|z|	Coef	P>|z|	Coef	P>|z|	Coef	P>|z|	Coef	P>|z|
Education	-0.061	0.717	*0.062*	*0.717*	0.237	**0.051***	0.130	0.265	0.100	0.432	0.022	1.000
Maize	0.434	**0.000*****	0.434	**0.000*****	0.584	**0.000*****	0.889	**0.000*****	0.114	0.318	0.242	**0.021***
Tea	0.011	1.000	-0.011	1.000	0.067	0.688	0.141	0.289	-0.102	*0.452*	0.002	1.000
Coffee	0.049	1.000	0.049	1.000	-0.087	0.391	0.100	0.569	-0.075	1.000	0.052	1.000
Expensive fertilizer	0.095	0.441	0.095	0.441	0.022	1.000	0.019	0.530	0.062	*0.394*	0.117	0.253
soil testing	0.150	0.196	0.150	0.196	0.030	1.000	0.007	1.000	0.067	0.753	0.086	0.404
Limitetd Manure	*0.041*	*0.521*	*0.041*	*0.521*	*0.034*	*1.000*	*-0.055*	*0.690*	*0.137*	*0.195*	*0.093*	*1.000*
lack of fertility skills	0.156	0.133	0.156	0.133	0.090	0.467	-0.024	0.774	0.061	0.727	0.223	**0.043***
Limited subsidy	0.049	1.000	0.049	0.788	0.072	1.000	0.100	0.569	0.062	0.492	0.052	1.000
poor fertilizer quality	0.085	0.383	0.085	0.383	-0.239	**0.043***	0.044	0.643	0.093	1.000	0.075	1.000
extension contact	0.178	0.134	0.221	***0.047****	0.003	1.000	0.031	0.824	0.045	0.793	0.198	**0.040***

"*","**","***" significant at 0.5, 0.01 and 0.001 respectively

Table 6. Welch's t-test of significance of determinants of inorganic fertilizer and manure use

	Welch t-test p-values				
Variables	Manure app	Fertilizer use	Fertilizer for planting	Fertilizer top dress	Every season
Farm size	**0.037***	0.574	0.72	0.162	0.311
Household income	0.839	**0.013****	**0.013****	0.453	0.198
TLU[a]	0.011	0.143	0.254	0.399	0.953

"*","**","***" significant at 0.5, 0.01 and 0.001 respectively

[a]TLU= Tropical Livestock Units (livestock numbers converted to a common unit)

DISCUSSION

Fertilizer and manure use

The study shows that majority of farmers (93.4%) use manure and inorganic fertilizer. The first source of soil fertility management is on-farm manure and other organic resources and supplemented with inorganic fertilizers. Nevertheless, mineral fertilizers have been regarded as the key entry point (especially under integrated soil fertility management system) as they are a prerequisite for production of the required organic resources (Chianu et al., 2012). The interaction of nutrients from mineral fertilizers and organic resources significantly influence crop yields (Chianu et al., 2012; Marenya & Barrett, 2009; Mugwe et al., 2009). There is overwhelming consensus that combination of inorganic fertilizers and organic inputs produces the highest and most sustainable crop yields per unit nutrient as suggested by reviewed literature (Chianu et al., 2012). There is increasing adoption of inorganic and organic inputs as suggested by our results. This finding is consistent with previous studies on adoption of soil fertility management practices in Kenya. For instance a research by Ariga and Jayne (2011) established that the proportion of Kenyan farmers using fertilizer increased from 59% in 1997 to 72% in 2007. However, not every region across the country has experienced similar rise (Marenya & Barrett, 2009). The high potential areas such as Kenya's central highlands and Western Kenya have experienced higher proportion growth of fertilizer users, and are said to use nearly 6 kilograms more fertilizer per acre (Ariga & Jayne, 2011).

However, caution should be exercised in drawing conclusions as the statistics only imply application of fertilizer at least on one plot on the farm and not necessarily on the entire agricultural farm. A study by Crowley and Carter (2000) found that 90% of farmers in Western Kenya used inorganic fertilizers. However, more than 80% of the fields received less than 50% of the recommended 120 kg per ha (Chianu et al., 2012). Both inorganic fertilizer and organic resources are inadequate among the smallholder farmers. A condition that has resulted to fertility gradients within farms. Farmers give preferential treatment to specific crops and plots on the farm (Chianu et al., 2012).

Accessibility of fertility resources

Most of the manure used by farmers (84.8%) are generated on the farm and as such it is influenced by aggregated livestock ownership (Tropical Livestock units or TLU). However, a little amount of manure is produced on the farm due to a relatively small amount of livestock (averaged at two TLU) owned by smallholder farmers. The deficiencies are partly filled by purchases from the local market and neighbouring household farms as well as borrowing from kinsmen. The nutrient quality of manure varies widely based on management practices including feed sources, decomposition rate and the handling (Makokha et al., 2001). Scarcity of manure is the major constraint undermining its application, a situation that could be attributed to a limited number of livestock owned by smallholder farmers. Limitation in resource endowment restrains most of the farmers from exploring the option of supplementing farm-produced manure with supplies from the market. The high cost of transporting purchased manure could also hinder farmers from buying organic resources. Unprocessed cattle dung is the most popular type of manure used by farmers. This could be alluded to the fact that technical skills and intensive labour are required in the processing manure resources as suggested earlier by literature.

High proportion of farmers acquire fertilizers by way of direct purchase from the market. This is largely attributed to the liberalization of the fertilizer subsector in the early 1990s which paved way for the entry of the private sector in importation, wholesaling local retailing and distribution of fertilizers (Ariga & Jayne, 2011; Wanzala et al., 2002). However, the fertilizer production-consumption chain has been increasingly been characterized by inefficiencies and high transaction costs leading to fertilizer shortage.

Other options for smallholder farmers access to fertilizers are through government subsidies and input credit schemes. Fertilizer subsidies are key stimulators of fertilizer uptake and agricultural productivity among low input-low output farming systems. However, only a few farmers accessed fertilizer through subsidized programs. Inefficient administrative processes have been blamed for the poor distribution of subsidized fertilizers, and this has undermined

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the achievement of the program's objective of increased uptake among the resource-poor farmers. This program has been characterized by a myriad of challenges including delay in availing fertilizers to farmers in time, low quality fertilizer and limiting in major nutrients for specific locations. The distribution process is characterized by misappropriation (KPA, 2017), long bureaucratic application process and long distance to the designated distribution centres, National Cereals Produce Board (NCPB) depots.

Input credit schemes have provided an opportunity for smallholder farmers to access fertilizer through the integrated input-output chains for major commercial crops including tea, coffee and sugar. These credits are however in most cases only available to farmers within out-grower schemes. Tea and coffee growers in the region received fertilizers from their respective cooperatives on integrated marketing arrangement. The implication of this arrangement, as argued by Makokha et al. (2001), is that more fertilizer is available for cash crops, and little for food crops. However, this has also been a means for farmers to obtain fertilizers for their food crops. The companies recoup their loans after buying the crops from the beneficiary farmers (Ariga & Jayne, 2011). However due to poverty, some farmers sell the acquired fertilizer to meet other household needs. "Sometimes when we are forced to sell some of the fertilizers to buy food or pay for the children's school fees,“ said one farmer.

The most widely used fertilizers are calcium ammonium nitrate (CAN 26%) and diammonium phosphate (DAP 18-46-0). Increased use of di-ammonium phosphate (DAP) is attributed to its high nutrient value. It should be noted that most of the African countries import their mineral fertilizers, and thus it is cost-effective to import fertilizer with high nutrient content (P and N). However, excessive phosphates can undermine absorption of equally important micronutrients such as iron and zinc thus slowing the growth of crops. Other common fertilizers include complex NPK, Urea and Triple Superphosphate. However, most of these fertilizers are characterized by very dismal quantities of secondary nutrients such as S, Ca and Mg (Bayite-Kasule, 2009; Sanginga & Woomer, 2009). This situation partly explains the negative nutrient imbalance and low productivity that define most of the African farming systems (Chianu et al., 2012). Some of these fertilizers have produced unsatisfactory results raising questions about formulation of the nutrient components and overall quality of these inputs, and agronomic knowledge of the manufacturers (Sanginga & Woomer, 2009). Lack of farmers guidance on the appropriate fertilizer or reliance on outdated recommendations are partly responsible for poor crop response. Poor fertilizer quality in Africa has also been attributed to adulteration by unscrupulous traders (Chianu et al., 2012)

Smallholder farmers have generally low income to invest in sufficient manure and mineral fertilizers (Makokha et al., 2001) thus have been compelled into adaptive strategies. Our survey findings indicate that less than a quarter of the farmers (20%) regularly use fertilizer every season. A section of farmers opts for use of fertilizers either only during planting or top dressing while others only during the main planting season. These findings confirm inconsistencies in fertilizer consumption that characterize African farming systems.

Determinants of fertilizer and manure use

Education, contact with extension and household income had a significant association with the decision to top dress crops with fertilizer. Low farmer literacy is one of the factors that have been linked to low fertilizer uptake by smallholder farmers (Breman et al., 2005). A study by Marenya and Barett (2009) investigating fertilizer use rates among smallholder farmers in Western Kenya established that younger and educated farmers were more likely to use fertilizers.

Farmers' decision to invest in soil fertility management is largely influenced by the household's income. Our findings corroborate previous studies that have investigated adoption of improved farming practices among smallholder farmers (Chianu et al., 2012; Makokha et al., 2001; Odhiambo Ochola & Fengying, 2015). Farmers with more disposable income are likely to invest in fertility management.

Contact with Agricultural extension influenced adoption of fertilizer and manure. Information on fertilizer recommendations, how to apply fertilizers during top dressing, suitable crops and timing of fertilizer application, is likely to influence farmers positively. These findings are consistent with a myriad of studies that have demonstrated a relationship between extension and adoption of sound agricultural practices (Jayne & Muyanga, 2012; Makokha et al., 2001). The impact of extension was evident in Malawi where Starter Pack and Target Input programs driven by extension led to significant benefits (Chianu et al., 2012). However, dwindling extension activities continues to hinder application of agricultural research innovations. In some cases, extension messages are not timely as when needed and in certain cases not clear (Makokha et al., 2001). Surveyed farmers during our study expressed that there was minimal visibility of extension workers. The increasing gap between the actual and potential agricultural production has partly been attributed to the deteriorating agricultural extension (Chianu et al., 2012). Although our findings failed to establish a significant association between access to subsidized fertilizer and the use of fertilizers, smart subsidies have been shown to inspire investment in inorganic fertilizers among smallholder farmers in Malawi resulting in food surpluses (Blackie & Mann, 2005; Denning et al., 2009).

Among the major crops, only maize had significant correlations with the various fertilizer treatment regimes. There was no significant association between tea and coffee and the various fertility treatment regimes. This finding however, contradicts the assertion that fertilizer and manure in African farming systems are largely dedicated to cash crops at the expense of cash crops (Makokha et al., 2001) due to anticipated income (Chianu et al., 2012; FAO, 2004) and availability of input credit schemes for the cash crops. However, resource-poor farmers divert some of the fertilizers from the input credit scheme to support the production of food crops and especially maize as it is the staple crop and usually equated to food security.

There was a significant correlation between the perception of lack of soil fertility skills (as a constraint to soil fertility management) and manure use. It is expected that farmers require skills in the preparation of manure. In fact, all factors held constant, individual farmers skills will influence the type of manure availed. A study by Makokha et al (2001) investigating the factors conditioning the use of manure and fertilizer in Kenya established lack of knowledge as one of the constraints to uptake of manure and fertilizers. Farmers' competence or technical skills in using agricultural inputs is critical in reaping the benefits of such inputs (Dorward & Chirwa, 2011).

The perception of poor fertilizers as a constraint to soil fertility was significantly associated with the use of fertilizer for top dressing. Indeed, poor quality fertilizers, believed to be as a result of adulteration (which is prevalent in African countries) discourages farmers from investing in fertilizers. As noted earlier, the vice is common in repackaged fertilizers, whose initial objective was to accommodate the needs of farmers who demand the inputs in small quantities (Chianu et al., 2012).

There is a significant association between the farm size and adoption of fertility management strategies (Ariga & Jayne, 2011). The average household farm size based on our survey was 3 acres. In our model, the decision to use manure was significantly associated with household farm size. A study by Chinangwa et al. (2006) investigating adoption of soil fertility improvement technologies in Malawi registered similar findings. Large farm size encourages farmers to keep more livestock (mostly cattle) which provide manure for farm use. Further, livestock holding size has a significant relationship with the decision to use manure. Farm size was also significantly correlated with the access to subsidized fertilizer (Table A2). This implies that farmers with larger land size are more likely to access benefit from the government subsidized fertilizer. contrary, to the reported perception by farmers that subsidized fertilizers are mostly accessed by the rich, our findings did not establish a correlation between income and access to subsidized fertilizer (Table 1A.)

CONCLUSION AND RECOMMENDATIONS

Manure and mineral fertilizers are critical in addressing the challenges of declining soil fertility and low agricultural productivity that characterize most farming systems in many parts in sub-Saharan Africa. This is not only for environmental sustainability, but also an appropriate strategy for smallholders with low income and limited access to fertilizer. Manure alone is not enough to satisfy nutrient requirements of the soil, as it is often available in low quantities and is of low quality (Makokha et al., 2001). thus, addressing the soil nutrient imbalance question that is common among farming systems in Kenya, a combination of manure and mineral fertilizers, is highly recommended.

While agriculture has steadily contributed a significant share to the GDP of most of the African countries, public spending on agriculture as a proportion of the overall expenditure in these very countries has remained substantially low (World Bank, 2008).This has resulted in poor investment in agricultural research, extension, irrigation technologies, mechanization and other production systems (DFID, 2009; Eicher, 2009; Haggblade & Hazell, 2009). .

African governments must fast-track the implementation of agricultural policies such as the Maputo declaration (Sers & Mughal, 2018) and Abuja Fertilizer summit declaration (Abuja Fertilizer Summit, 2006).

There is need to invest in farmers' capacity building programs such as training in agronomic practices, soil fertility, and efficient use of mineral fertilizer and manure , to raise crop responses. Policies to reverse the systematic decline in extension and soil science capacity are critical. Extension workers should partner with soil science experts and other agricultural researchers in developing packages with guidelines on the use of fertilizers and manure processing and adapting these solutions to farmers conditions. To achieve this, increased budgetary allocation to agriculture and research is vital. Enhancing rural financial systems is critical in promoting smallholder farmers' access to agricultural inputs. Regular reviews of outdated recommendations should be undertaken in light of the volatile agro-ecological conditions engineered largely by climate change. Integrated soil fertility management approach (ISFM) should be adopted as a matter of urgency.

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Conflict of interest

The authors declare no conflict of interest

Appendices

Table A1. Correlation between Farmer's income and access to Government subsidized fertilizer using ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.693	18	.038	.573	0.910
Within Groups	5.845	87	.067		
Total	6.538	105			

Table A2. Correlation between Household Farm size and access to Government subsidized fertilizer using ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.186	58	0.089	2.884	0.000
Within Groups	1.333	43	0.031		
Total	6.52	101			