DETERMINANTS OF ADOPTION OF INTEGRATED SOIL FERTILITY MANAGEMENT STRATEGIES FOR MAIZE PRODUCTION INTENSIFICATION IN EMBU COUNTY, KENYA

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DECLARATION

Candidate's Declaration

This thesis is my original work and has not been presented for a degree in any other university or any other award.

Signature ___________________________ Date ___________________________

Declaration by Supervisors

We confirm that the work reported in this thesis was carried out by the student under our supervision.

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DEDICATION

To my beloved parents Mr. Joash Lago and Mrs. Rose Ajwang for their sacrifices in ensuring that we had a decent education; to my siblings for their encouragement, unending love and support.

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ACRONYMS AND ABBREVIATIONS

CIMMYT – International Maize and Wheat Improvement Centre

CRS – Creative Research Systems survey software

DAP – Di ammonium phosphate

HH – Household

HHH – Household head

IITA – International Institute of Tropical Agriculture

IPNI – International Plant Nutrition Institute

ISFM – Integrated Soil Fertility Management

KALRO– Kenya Agricultural and Livestock Research Organization

MNLR – Multinomial Logistic regression

MoA – Ministry of Agriculture

OLS – Ordinal Least Squares regression

SPSS– Statistical Package for Social Sciences

SSA – Sub-Saharan Africa

LR- Long rains

SR- Short rains

ABSTRACT

The continuous mining of soil nutrients with inadequate replenishment and improper soil management has resulted in poor fertility levels leading to poor harvests. Even so, researchers have come up with information and new technologies that can reverse the status of poor soils but the concern is that information on the uptake and use of these technologies is inadequate in Embu County. The objectives of this study were therefore to: (i) determine how household demographic and socioeconomic factors influence use of integrated soil fertility management strategies for maize production (ii) assess smallholder farmers' knowledge levels on the use of ISFM strategies for maize production, (iii) determine factors affecting knowledge levels of ISFM strategies for maize production and (iv) determine the influence of farmer management practices on the level of phosphorus in their farms in Embu County. A pilot study was conducted to ensure the appropriateness of the data collection tools. During the actual survey, 100 farm households were randomly selected and included in the study. A detailed questionnaire with both closed and open-ended questions was used to collect data on the levels of farmer knowledge on ISFM strategies, household demographic and socio-economic factors affecting farmers' use of ISFM strategies. Soil samples were also collected from fields of each farmer interviewed thus a total of 100 soil samples for analysis of phosphorus levels. Three soil cores were collected according to variability and farm size then composited to produce one sample for analysis. Soil was analysed for available P using Bray's method. The study considered five ISFM strategies; use of inorganic fertilizer, use of organic fertilizer, combined use of inorganic and organic fertilizer, use of improved seeds and combined use of inorganic and organic fertilizer with improved seeds. Data was analysed using descriptive statistic, ordinary least squares regression, binary logistic regression, multinomial logistic regression using SPSS version 20 software. Comparisons and associations were done using t-test and Chi-square. Ordinary least square regression showed that household size, off-farm income, size of land under maize, maize yield, occupation of household head and training were the socio-demographic factors significant in predicting phosphorus fertilizer use and animal manure use at $p<0.05$. Binary logistic regression showed size of land under maize, enough household labour, off-farm income and tropical livestock unit as significant factors in predicting combined use of inorganic fertilizer and organic fertilizer with improved maize seeds. Multinomial logistic regression showed that gender, age, household size, size of land under maize, off-farm earnings, maize yield, household members farming, farming experience, education level, total land owned, household labour as significant factors affecting levels of knowledge of farmers in the use of the ISFM strategies at $p<0.05$. Ordinary least squares regression also showed liming of soil, soil testing, size of maize land and total land owned as significant factors in predicting amounts of phosphorus at $p<0.05$. Factors affecting use and knowledge level of ISFM should be taken into consideration during training and extension work to increase use of ISFM strategies that would ultimately result in an increase in maize yield.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Soil capital is a major resource that smallholder-farming households rely on for food and income resources (Marenya and Barrett, 2007). This means that land has to produce enough to support a farmer and his family. In Sub-Saharan Africa (SSA), smallholder farmers have been experiencing dwindling agricultural produce which has been attributed to soil fertility depletion, which is resulting in food insecurity (Ngetich *et al*., 2012). The food supply and demand gap and even chronic food insecurity persist in East Africa (Adekele *et al*., 2010). Maize crop being the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America (Iken and Amusa, 2004); its production intensification must be emphasised to ensure food security. In 2010, it was estimated by CIMMYT and IITA that by 2025, maize will have become the crop with the greatest production globally and in developing countries (CIMMYT and IITA, 2010). Maize yields on most smallholder farms in SSA has remained less than one tonne per hectare threatening households' food security for over 70% of the rural populations as they primarily draw their livelihoods from agriculture (Muzari *et al*., 2012; Tauro *et al.*, 2011; Adekele *et al*., 2010).

To sustainably increase crop production, improvement of research on investment in nutrient additions to the soil is essential and globally agreed upon (Mapila *et al*., 2012). Integrated soil fertility management (ISFM) offers a promise to farmers in improvement and maximization of production. One of the greatest strengths of ISFM is its ability to integrate local sustainability, economic profitability, adoptability, and sustainability in developing improved land management recommendations (Sanginga and Woomer, 2009). But how far have researchers really come to assure that small-scale farmers have the knowledge, technologies and products to engage with ISFM and what must be done to move forward more effectively in the future (Woomer, 2012). Mugwe *et al.* (2009a), Akinola *et al*. (2010), Macharia *et al*. (2012), Adolwa *et al.* (2010) and Adolwa *et al.*

(2012) have all acknowledged that gaps exist on the level of knowledge, adoption and utilization of ISFM technologies, therefore research must be promoted to try and reduce these gaps.

Limited access to timely and accurate information has been identified as a major compromise to the improvement of rural agriculture in Kenya (Adolwa *et al.*, 2010), rendering the development of ISFM strategies not viable especially because the end users are not very knowledgeable. The kind of knowledge that smallholder farmers have is also not fully documented (Obala, 2013). Information has for some time been disseminated by researchers and extension workers but adoption breakthroughs are yet to be fully realized. The specific knowledge that farmers have on integrated soil fertility management needs also to be explored. Factors affecting these knowledge levels have also to be determined. Thus the need to carry out this study to determine factors affecting adoption and use, assess the kind of knowledge smallholder farmers have and determine factors affecting knowledge levels of integrated soil fertility management.

1.2 Problem statement and justification

Embu County is one of the most populated regions in Kenya with a total population of 543,221persons (GoK, 2010) and this population sets pressure on food production. Farmlands have drastically reduced in fertility due to soil erosion, leaching and repeated agricultural activities (FAO, 2005). In addition to these, inadequate replenishment and improper soil management has resulted in poor fertility levels that have resulted in poor harvests (Bot and Benites, 2005). The methods used to restore the soil fertility levels and to increase agricultural productivity under traditional shifting agriculture have become ineffective and even disappeared in most cases (Ajayi *et al.*, 2007). Integrated soil fertility management offers a solution but adoption breakthroughs and adoption challenges have not been fully documented at smallholder farmer level in the study area.

ISFM strategies have been proved to reverse soil nutrient depletion and improve crop yields but the adoption breakthroughs documentation is still wanting (Macharia *et al.*, 2012; Mugwe *et al.*, 2008) and, patterns of adoption and factors influencing the adoption process are not clearly understood (Odendo *et al*., 2009). The challenge thus remains in the promotion of increased efforts in the use of combined inorganic fertilizer and organic fertilizer with improved seeds and to research and document on factors affecting use and adoption of these ISFM strategies at household levels of smallholder farmer in SSA. All this is possible with the consideration that investments and research in soil management options need to be accompanied by farmer capacity and willingness to use integrated soil fertility management to improve agricultural productivity (Njuki *et al*., 2008).

1.3 Research questions

The study sought to answer the following questions:

(i) How do households' demographic and socioeconomic factors influence the use of ISFM strategies for maize production in Embu County?

(ii) How knowledgeable are smallholder farmers on the use of ISFM strategies for maize intensification in Embu County?

(iii) What factors affect knowledge levels of ISFM strategies among farmers in Embu County?

(iv) How do farmers' management practices influence phosphorus levels in their farms in Embu County?

1.4 Objectives

The **main objective** of the study was to determine the factors influencing adoption of ISFM strategies for maize production intensification in Embu County.

Specific objectives

(i) To determine the household demographic and socioeconomic factors influencing use of ISFM strategies for maize production in Embu County

(ii) To assess smallholder farmers' knowledge levels on the use of ISFM strategies for maize production in Embu County

(iii) To determine factors affecting knowledge levels of ISFM strategies among farmers in Embu County

(iv) To determine the influence of farmer management practices on the level of phosphorus in their farms in Embu County

1.5 Research Hypotheses

The study was guided by the following hypotheses:

(i) Household socioeconomic factors have a significant influence on farmers' use of ISFM strategies for maize production in Embu County

(ii) There is a positive relationship between farmers' knowledge level on ISFM strategies and its use for maize production in Embu County

(iii) Farmer's management practices significantly influence the amount of soil phosphorus in their farms in Embu County

1.6 Significance of the study

The findings of this study will lead to the streamlining of development policies and programmes to take full account of the socioeconomic status of farmers, to work to reverse nutrient depletion more effectively, to increase food security, reduce poverty and improve rural livelihoods. The determination and explanation of factors affecting adoption of ISFM strategies will also ensure that researchers and extension workers incorporate farmers' needs during communication and dissemination of ideas in a way that is more practical to resource constraint farmers. Farmers will also be encouraged to test their soils to ensure that they only apply the recommended amount and thus fertilizer use efficiency and economic viability.

1.7 Conceptual framework

There are various factors that may affect a farmer's level of knowledge on ISFM technologies after introduction (arrow 1); these include demographic and socio-economic factors (arrow 2). Knowledge of phosphorus management (arrow 3) combined with farm characteristics (arrow 4) allow farmers to improve phosphorus levels with external inputs resulting in the adoption of ISFM strategies for maize production intensification (arrows 5 and 6) (Figure 1.1). When a farmer uses ISFM, there is an increase in maize yield (arrow 7); increased maize yield also results in an increase in adoption of ISFM strategies (arrow 8). All these factors result in a farmer forming positive or negative perceptions and attitudes towards ISFM strategies and thus either end up using or not using ISFM in maize cultivation (Figure 1.1).

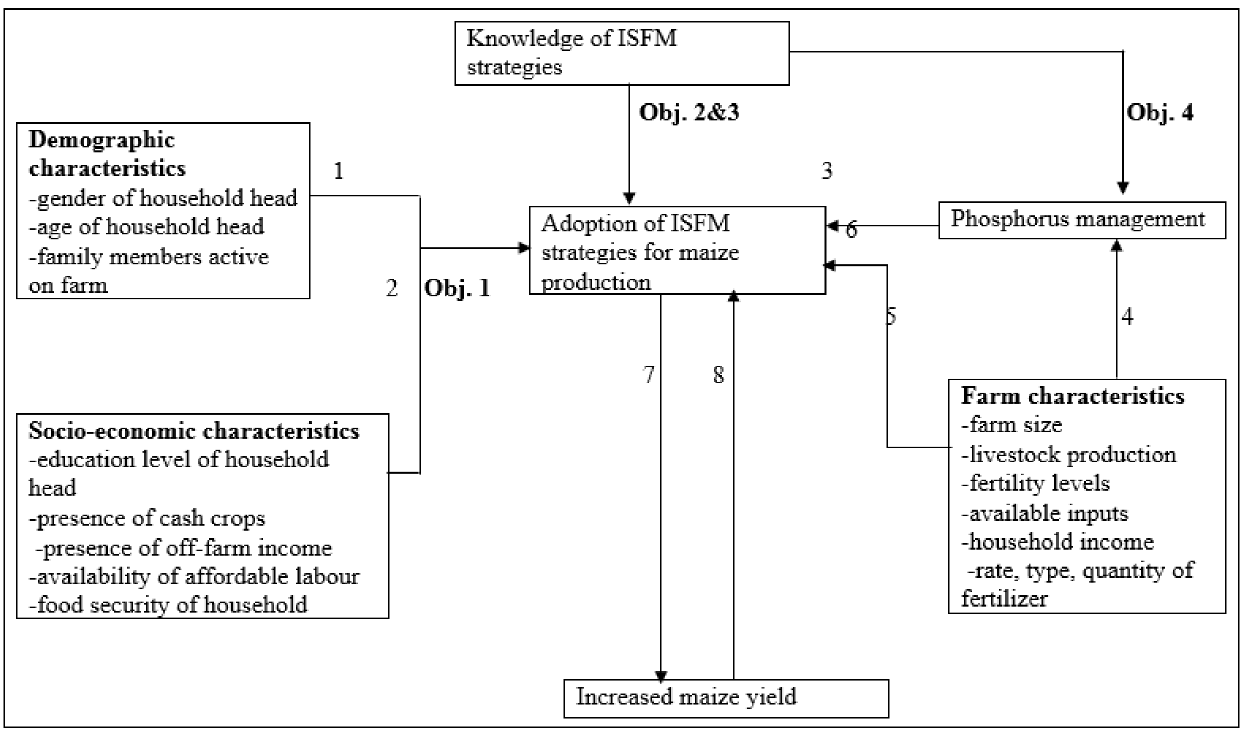

Figure 1.1: Conceptual framework of the factors affecting adoption of ISFM

1.8 Operational definition of terms

Adopters - people or farmers who uptake a technology and continue to use it

Adoption - the uptake and continuity of use of an introduced strategy

Disadoption - the abandonment of an introduced strategy

Strategy - A method or plan chosen to bring about a desired future, such as achievement of a goal or solution to a problem

Extension workers - An extension worker is usually a technically trained person with excellent people skills who communicate and disseminate technological information to farmers.

Integrated Soil Fertility Management (ISFM) – A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic principles.

Non-adopters - people or farmers who do not uptake a technology for use

Smallholder farmers - smallholder farmers are usually farmers with small pieces of land supporting a single family with a mixture of cash crops and subsistence farming.

Soil capital - the amount and quality of land one controls

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

There is no doubt that maize is one of the most important cereal crops in Kenya as it is consumed by if not all, almost all the communities. In many parts of Africa, traditional crops mainly the small grains such as finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*) are increasingly replaced by other staple foods such as maize (Zea mays) and cassava (Manihot esculenta) (Giller *et al*., 2011). This is often due to a change in preferences, the extra labour required to process small grains and damage by birds (Giller *et al*., 2011). The concern is why maize yield has remained less than one tonne per hectare (Tauro *et al*., 2012) in the rural parts of Kenya which is the agricultural backbone of the country. A major yield constraint besides unpredictable rainfall is soil nutrient depletion. Soil nutrient depletion is a subject of major concern and debate in Africa because, in many countries in sub-Saharan Africa, the economic growth and quality of life depend on the agricultural sector (Mugwe *et al*., 2009b). Unless the nutrients are replenished through organic or mineral fertilizers, or partially returned through crop residues, or rebuilt more comprehensively through traditional fallow systems that allow restoration of nutrients and reconstruction of soil organic matter, soil nutrient levels decline continuously (Mucheru-Muna *et al*., 2007).

Integrated soil fertility management (ISFM) has been proven to reverse nutrient depleted soils to productive ones (Vanlauwe *et al*., 2015; Macharia *et al*., 2014; Mucheru-Muna *et al*., 2014; Macharia *et al*., 2012; Akinola *et al*., 2010; Vanlauwe *et al*., 2010; Mugwe *et al*., 2009; Mugwe *et al*., 2008; Mucheru-Muna *et al*., 2007; Mowo *et al*., 2006). The overall goal of ISFM is to maximize the interactions that result from the potent combination of fertilizers, organic inputs, improved germplasm, and farmer knowledge (Vanlauwe *et al*., 2015). The ultimate outcome is improved productivity through wiser farm investments and field practices. The integration of mineral fertilizers with organics encompassing their judicious manipulation in achieving productive and sustainable agricultural systems, has been identified to improve the agronomic efficiency of the external inputs used, reduces the risks of acidification and provides a more balanced supply of nutrients (Mugwe *et al.,* 2009a). It has also been proven that effective use of organic soil amendment methods in combination with inorganic fertilizer could help reverse the nutrient depletion trend (Mucheru-Muna *et al.,* 2014; Akinola *et al*., 2010).

Besides the low fertilizer use in SSA, fertilizer use varies considerably among farmers in the same sites (Mapfumo *et al*., 2012). Availability of organic and mineral nutrient resources, their management under spatially variable soil fertility conditions has consequences on the soil resource base, cropping patterns and crop yields on smallholder farms (Zingore *et al*., 2007). The low adoption is also associated with negative economic externalities, low returns to agricultural investments, and general high food prices during months when farmers purchase food for their households which consequently threaten food security in the region (Macharia *et al.,* 2010). According to Misiko and Ramisch (2007), ISFM strategies have been met with major challenges mainly because ISFM technologies are knowledge-intensive and their adaptations and applications are diverse. Research therefore, has to focus and examine the type and level of knowledge smallholder farmers have on ISFM strategies. Research also has to take into account the variability of smallholder farms and the demographic and socioeconomic status of smallholder farmers.

2.2 Influence of demographic and socioeconomic factors on ISFM use

Wiredu *et al*. (2014) insists that effective promotion of ISFM requires information on the factors that can stimulate or constrain uptake. The adoption of technologies by farmers is a process that begins with the acquisition of information, testing and eventual adoption (or continuous use) of a technology (Ajayi *et al*., 2007). Mugwe *et al.* (2009); Akinola *et al*. (2010) and Macharia *et al*.(2012) showed that a number of variables may affect a farmer’s decision to either adopt or not to adopt a strategy, this is because, a smallholder farmer has triple functions as entrepreneur, manager and craftsman. As an entrepreneur the farmer defines the mission and long-term objectives of the farm and devises strategies to realize set objectives (Mowo *et al*., 2006); as manager, the farmer allocates resources to achieve the objectives. In principle, he or she makes an analysis of all farm operations, decides what to do, and plans, executes and controls the things that have to be done. As a craftsman, the farmer needs the technical skills and capabilities to carry out required activities for optimal performance of the farm (Mowo *et al*., 2006). Given that adoption is a dynamic process, several factors (e.g. age, household size, wealth ranking, farm size, etc) presumed to be independent are, in fact, likely to influence one another, hence they should not be treated in isolation, ignoring their mutual interdependencies and reducing the adoption-decision to a zero-sum game (Ajayi *et al*., 2007).

In addition, farmers are heterogeneous in terms of their household and farm characteristics, which in turn influence their decision to adopt or not to adopt. This situation must be investigated as there is little evidence that farmers have benefited from researchers' efforts (Mugwe *et al*., 2009). Soil fertility and nutrient management are functions of socioeconomic processes associated with a household and its management (Mowo *et al*., 2006). Demographic and socioeconomic variables include the age of the household head, the household size, measure of social interaction resulting from membership in farmers' organization, off-farm income from non-farm activities, access to credit, and education of household head (Mugwe *et al*., 2009a; Odendo *et al*., 2009). Perception of the state of land degradation and depletion by the farmer, effective extension and researcher's contacts, farm size and asset, gender, experience, labor resources, credit, extension, training, management skills, location, livestock ownership, and expenditure have also been reported to influence ISFM adoption (Geta *et al*., 2013; Macharia *et al*., 2012; Mugwe *et al*., 2009b; Odendo *et al*., 2009).

Not all the factors have a positive or negative effect on adoption, for example, the age factor can have both a positive and a negative effect (Akinola *et al*., 2010; Woomer, 2012). For example, younger farmers have been found to be more knowledgeable about new practices and may be more willing to bear risk and adopt new technology because of their longer planning horizons as opposed to older farmers who are already accustomed to certain ways of doing things (Akinola *et al*., 2010). The older the farmers, the less likely they are to adopt new practices as they place confidence in their old ways and methods. On the other hand, older farmers may have more experience, resources, or authority that may give them more possibilities for trying a new technology (Macharia *et al*., 2014; Geta *et al*., 2013; Macharia *et al*., 2012; Akinola *et al*., 2010). Kimaru *et al*. (2012); Macharia *et al*. (2012) and Akinola *et al*. (2010) acknowledged that education also increases the ability of farmers to use their resources efficiently and enhances farmers' ability to obtain, analyze and interpret information and adapt it to his local conditions. (Mugwe *et al*. 2009a) established that labour also influenced adoption positively possibly because hired labour increases labour availability within a household, and this allows a household to implement new technologies. Thus, this study sought to establish the influence of demographic and socioeconomic factors on the adoption of ISFM strategies.

2.3 Smallholder farmers' knowledge of ISFM strategies

One of the main reasons advanced for low adoption is a lack of adequate knowledge of farmers' adoption behaviour towards new technologies (Mugwe *et al.,* 2009b).The integration of scientific systems and indigenous knowledge should be viewed as a logical development in soil knowledge systems (Mairura *et al*., 2008). Most farmers have little or no knowledge on the importance of integrating both organic and inorganic fertilizers to achieve good returns. They view inorganic fertilizers as being expensive and therefore do not incorporate it in their farming activities. They are not aware that combining inorganic and organic fertilizer has been proven to replenish soils and even achieve better yields than either sole application (Mucheru-Muna *et al*., 2007).

Some farmers only have the knowledge and capacity to use organic fertilizers not knowing that nutrient cycling through livestock is in principle not efficient for increasing food production (Giller *et al*., 2011) and inorganic fertilizer is as important in crop cultivation. Farmers also do not have the knowledge to practice judicious management of their soils, using nutrients available in their vicinity and adopting agricultural practices geared towards soil fertility improvement such as improved fallow, agroforestry and biomass transfer (Mowo *et al*., 2006). The major factors that positively influence the farmers' decision to use manure are; availability of manure, herd size, farmers' experience and knowledge in the use organic fertilizer (Ajayi *et al*., 2007). Smallholder farmers' knowledge in the proper use and management of organic fertilizer is important as poor treatment of manure results in low quality and this may limit its utilization (Ajayi *et al*., 2007).

Such experiences where investments in inputs do not give farmers viable return have continued to shift their attitudes negatively and towards ISFM strategies as experiences have an impact on knowledge. Closer examination has led to the identification of recognizable patterns between farming systems, between farmers, their aspirations and their resource allocation strategies across the farms (Giller *et al.,* 2011); this means that farmers might be having the same type of knowledge across a region. Knowledge gaps exist on the level of knowledge and utilization of the technologies; (Akinola, 2010; Macharia *et al*., 2012), and where it has been done, the information is not adequately utilized by farmers (Adolwa *et al*., 2010) and is also not easily available and in most cases outdated and unreliable (Sanginga and Woomer, 2009).

An adequate understanding of farmers' knowledge of integrated soil fertility strategies is important as it enables the current existing indigenous knowledge to be documented and be integrated with scientific knowledge to facilitate the development of appropriate and effective technology development and dissemination programmes (Odendo *et al*., 2010). In addition, there is evidence of lack of suitable mechanisms for transferring available empirical knowledge on concepts and principles of integrated soil fertility management (ISFM), from researchers to farmers in ways that promote innovation and sustainable adoption (Mapfumo *et al.,* 2012). Therefore, the study sought to assess smallholder farmers' knowledge levels on the use of ISFM strategies in maize production and to find out what factors affect farmer knowledge in the use of ISFM for maize production intensification.

2.4 Phosphorus fertilization and management

Developing soil fertility management options for increasing productivity of staple food crops is a challenge in most parts of Sub-Saharan Africa, where soils are constrained by nitrogen (N) and phosphorus (P) deficiencies (Tauro *et al*., 2011). Phosphorus is one of the most important fertility components for maize as it is the second largest consumed nutrient in global agriculture production, being surpassed only by nitrogen (Batten, 1992). Low effectiveness of phosphorus fertilization occurs because plants do not use most of the added phosphorus. This happens after adsorption reaction of P with soil colloids and conversion into organic form (Verde *et al*., 2014).Where sometimes nitrogen can be fixed into the soil by rotations of maize with beans having nitrogen-fixing nodules (Ngetich *et al*., 2012), phosphorus deficiencies have to be supplemented from external inputs. Consequently, most of the N required for agricultural productivity in the continent comes largely from a judicious management of biological N fixation mostly through cereal-legume intercropping systems (Ngetich *et al*., 2012; Mucheru-Muna *et al*., 2010; Giller, 2001; Jerenyama *et al*., 2000; Giller *et al*., 1994) but P deficiencies have to be supplemented from external outputs.

The nonrenewable phosphate reserves in the world, which can be economically exploited at values of 40 dollars per ton, will be exhausted during the second half of this century (Murrel and Fixen, 2006). This means that phosphate reserves must be exploited in a sustainable manner for the present and future generations. On another note, phosphorus has one of the lowest use efficiency among the plant macronutrients and a 50% yield reduction has been observed from P deficient conditions relative to the well fertilized production fields (Fageria and Baligar, 1997). Available P is also a good indicator for predicting previous land management that is also invariably linked to farmer resource endowment (Chikowo *et al*., 2014). Therefore, this study sought to establish how the management practices of farmers affect the level of phosphorus in the soil.

2.5 Summary of reviewed literature and research gaps

Soil fertility depletion is one of the major constraints to food security and income generation in sub-Saharan Africa. Intensification and diversification of agricultural production is required to meet the food, feed, and income needs of the poor and this cannot happen without sustainable investment in soil fertility management. Emerging evidence indicates that ISFM, involving the judicious use of combinations of organic with inorganic resources is a feasible approach to overcome soil fertility constraints within the smallholder farms. The ultimate outcome is improved productivity through wiser farm investments and field practices. Soil-related constraints can therefore be overcome by recycling more, biological processes and by using adapted germplasm to adverse soil conditions, enhancing soil biological activity and optimizing nutrient cycling with adequate external inputs to maximize their use efficiency. Integrated soil fertility management has been proven to improve soil chemical and physical properties as well as improve yields of targeted crops. Rural farmers have limited resources and research is now directed at incorporating farmer situations when developing strategies as they are the targeted end users of this information. Researchers have realized that (ISFM) is knowledge intensive and its application is uniquely specific to each farmer as individuals have been found to have different rates of understanding and disintegrating information received. However, few studies have looked into the adoption and knowledge levels of ISFM strategies at farm level in the study area. Information gaps also exist on the factors affecting adoption and utilization of ISFM strategies, the kind of knowledge and the level of knowledge of ISFM strategies by smallholder farmers in Kenya.

CHAPTER THREE

METHODOLOGY

3.1 Study area

The study was carried out in Runyenjes sub-County, Embu County. Embu County is located approximately 120 kms NorthEastern of Nairobi, towards Mt Kenya. Embu County's population is 516,212 people (GoK, 2010). It covers an area of 2,818 km^2 and has 4 constituencies namely Embu, Runyenjes, Gachoka and Siakago. It borders Tharaka Nithi County to the North, Kitui to the East, Machakos to the South, Murang'a to the South West, Kirinyaga to the West, and Meru to the North West.Geographical coordinates of Embu County: 0°32′S 37°27′E (Figure 3.1).

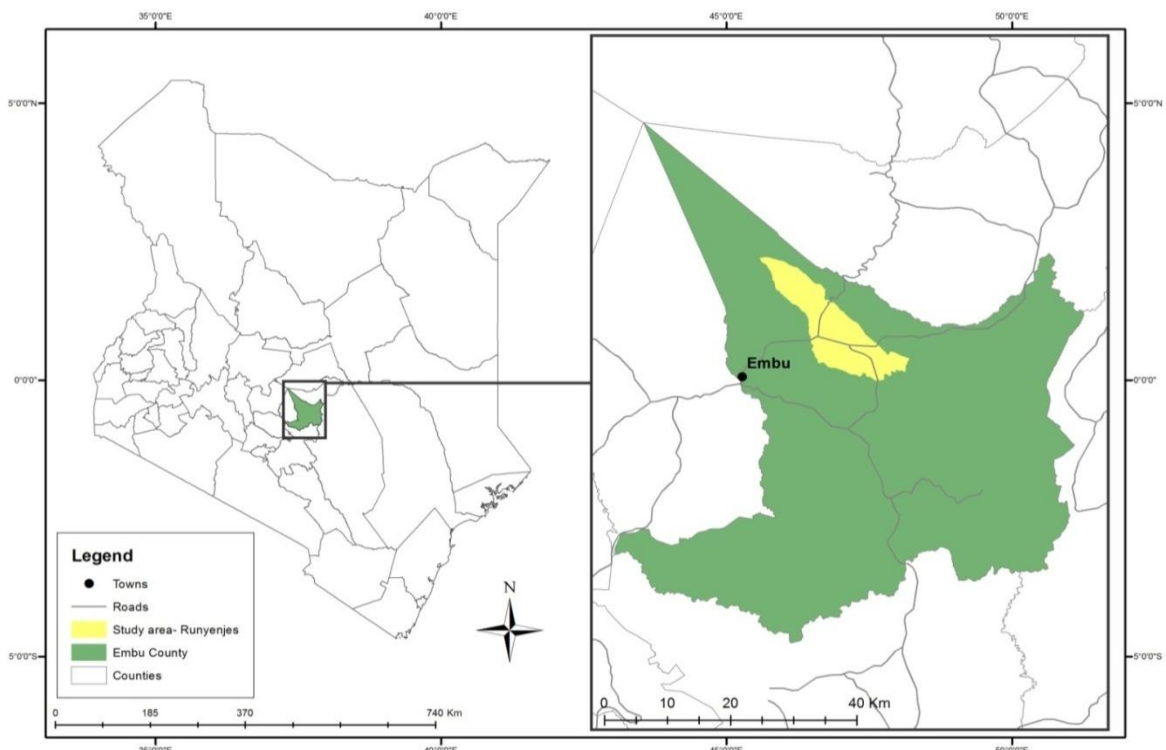

Figure 3.1: Map of Embu County

Runyenjes sub-County lies in the Upper Midland 2 and 3 (UM 2, UM3) at an altitude of approximately 1,200-2,070 meters above sea level. It covers 149 km^2, out of which 96.26

km^2 is arable land. The estimated population is 64,111(GoK, 2010) with a population density of 561 persons per Km^{-2}. The average farmholding is 0.4-0.8 ha. The annual mean temperature ranges from 12 °C to 27 °C. The average annual rainfall is 1495mm and the range is between 1,000-2,000 mm. Rainfall distribution is bimodal with LR from mid-March to May and SR from October to December allowing for two planting seasons per year. The soils are well drained and mostly Nitisols. Farmers in Embu County practice mixed farming where farmers plant crops and keep livestock. The main subsistence agricultural products include: maize *(Zea mays*), beans (*Phaseolus vulgaris)*, yams (*Dioscorea spp*.), cassava (*Manihot esculenta*), millet (*Eleusine coracana*), sorghum (*Sorghum* spp.), and bananas (*Musa spp*.). The main cash crops include tea (*Camellia sinensis*), coffee (*Coffea spp*.), cotton (*Gossypium spp*.) and macadamia nuts (*Macadamia spp. ternifolia*). The main livestock in the region include cattle, goats, sheep and poultry.

3.2 Research design

The study design was a survey. Both quantitative and qualitative research frameworks were used. The study employed two sources of data. **Primary sources;**that included interviews, direct observation and photography. **Secondary sources;** these sources included information from published work, relevant books, relevant seminars and conference meetings reports, and mostly the internet.

3.2.1 Sampling strategy

Runyenjes sub-County was targeted for this study; Runyenjes was purposefully selected as it is characterized by smallholder farmers who grow both subsistence and cash crops that include maize. Stratified random sampling was used as the sub-County is divided into villages with households. The estimated population being 64,111 in Runyenjes sub-County (GoK, 2010), a total of 100 households was obtained using sample size calculator software (CRS, 2007) at a confidence level of 95% and confidence interval of 9.8% formed the sample.

$$S = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Where: S=Sample size

Z=Z value (e.g. 1.96 for 95% confidence level)

p=percentage picking a choice, expressed as decimal (0.5)

c=confidence interval, expressed as decimal (0.098)

3.2.2 Soil Sampling and testing

Soil samples were collected from fields of each of the 100 farmers interviewed. The soil was collected at 20 cm depth. Three (3) soil cores were collected according to variability and size of land and then composited to produce one sample for analysis. Soil samples were air-dried prior to analysis and soil was analyzed for available phosphorus using standard methods (Bray's method, 1945). Phosphorus was extracted from the soil using Bray No 1 solution as extractant. The extracted P was measured colour metrically based on the reaction with ammonium molybdate and development of the 'Molybdenum Blue' colour. The absorbance of the compound was them measured using a spectrophotometer in and is directly proportional to the amount of phosphorus available and extractable from the soil**.** The pH was also determined using a pH meter.

3.3 Data collection

3.3.1 Pilot study

The pilot study was used to test the suitability of the farmer interview schedule. Three farmers from each ward were picked randomly constituting 18 farmers to participate in the pilot study. Farmer interview schedule was then adjusted appropriately according to the findings of the pilot study. Farmers that participated in the pilot study were excluded from the actual survey.

3.3.2 Farmer interview schedule

The 100 households were interviewed using a farmer interview schedule. The farmer interview schedule employed both closed and open-ended questions to collect both qualitative and quantitative data (Appendix 1). Data collected included demographic, socioeconomic, type and level of ISFM knowledge, and management practices of smallholder farmers in the study area.

Reliability and validity of the farmer interview schedule was determined during the pilot study before the actual data collection exercise. Reliability ensured that farmer interview schedule would produce stable and constant data. Validity was also ensured by analysing pre-test data and ensuring that the data targeted for collection was actually what the farmer interview schedule collected (Cesur and Fer, 2009).

3.4 Data Analysis

The questionnaires were first examined to ensure that they were properly and consistently filled. A code sheet was prepared in the SPSS version 20 after which data was entered. Data was cleaned and summarized using descriptive statistics. Comparisons and associations were done using t-test and Chi square. The ordinary least squares regression was used to determine socio-demographic factors affecting use of ISFM strategies for maize production (Table 3.1).

This model: $y = X\beta + \varepsilon$

Where: y and ε are $n \times 1$ vectors; X is an $n \times p$ matrix of regressors and the coefficient β_1 is the intercept.

Due to the binary nature of the data on the use of combined inorganic fertilizer and animal manure, binary logistic regression was used. Several studies have used logit model in the analysis of adoption of different technologies (Mugi-Ngenga *et al*., 2016; Macharia *et al*., 2014; Macharia *et al*., 2012; Mugwe *et al*., 2009a; Mugwe *et al*., 2008 and Njuki *et al*., 2008). This model was picked as it can include a large number of explanatory variables and because of the binary nature of the dependent variable (Table 3.1).

$(p_i/(1-p_i) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots\ldots\ldots + \beta_{10} x_{10} + e$

Where: p_i (use of an ISFM strategy: 0 = don't use; 1 = use)

β_0 is the intercept

$\beta_1, \beta_2, \beta_3$……… parameter estimates

x_1, x_2, x_3…… independent variables

e error term

Table 3.1: Definition of study variables (demographic + socioeconomic) influencing use of ISFM strategies for maize production among farmers inRunyenjes sub-County

Variables	Definition
Dependent variables	
Amount of fertilizer used	Continuous variable
Use of ISFM strategies	0=Don't use/1=Use
Independent variables	
Age of the household head (years)	Continuous variable
Gender of the household head	0 Male
	1 Female
Marital status of the household head	1 Single
	2 Married
	3 Polygamous
	4 Widowed/Divorced
Education level	1 No education
	2 Primary level
	3 Secondary level
	4 Tertiary level
Years of farming experience	Continuous variable
Livestock (number)	Continuous variable
Household size (number)	Continuous variable
Household labour (number)	Continuous variable
Occupation of household head	1 Farming
	2 Business/ Employed
Total maize land (acres)	Continuous variable
Land acquisition	1 Inherited
	2 Purchased
	3 Rented
Labour supplementation	1 Yes
	2 No
Farm income (number)	Continuous
Off-farm income (number)	Continuous
Yield in t/ha	Continuous

To determine farmers' ISFM knowledge levels, a five Likert scale analysis of 50 items was used. Each set of ISFM questions was subjected to reliability test using Cronbach's alpha test. The internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test (Cronbach, 1951). All the sets of test questions having a coefficient greater than 0.7 showed that the sets were reliable for the knowledge research model.

In the quest to answer the research question on what knowledge farmers had on different ISFM strategies, data was transposed so that responses to each question within an ISFM strategy (knowledge of inorganic fertilizers, organic manure, combined organic manure + inorganic fertilizers, use of improved germplasm and combined organic manure + inorganic fertilizers + improved seeds) were grouped together to provide ease during acquisition of means. Transposing was used so that all cases became variables and selected variables became cases in a new data set.

1=strongly disagree, 2=disagree, 3=not sure, 4= agree, 5= strongly agree

Decision on knowledge level using Likert scale

$$\frac{\Sigma f}{f} = \frac{5+4+3+2+1}{5} = \frac{15}{5} = 3$$

To find out the mean level of knowledge, means were rounded to the nearest whole number where a mean <3 represented low knowledge level, mean =3 represented moderate knowledge level, mean >3 represented high knowledge level.

With knowledge levels having more than two levels, multinomial logistic regression was appropriate in search of predictors affecting knowledge levels of integrated soil fertility management (Table 3.2).

Multinomial regression was used to describe data and to explain the relationship between one dependent nominal variable and one or more continuous-level (interval or ratio scale) independent variables.

Equations developed were as below:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots\ldots\ldots \beta_n X_n + \varepsilon$$

-where ε is a random error with a mean of zero and a constant standard deviation σ

Table 3.2: Definition of study variables influencing farmers' levels of knowledge on the use of ISFM strategies for maize production among farmers in Runyenjes sub-County

Variables	Definition
Dependent variables	
Knowledge level	<3 Low levels
	3 Moderate level
	>3 High level
Independent variables	
Age of the household head (years)	Continuous variable
Gender of the household head	0 Male
	1 Female
Education level	1 No education
	2 Primary level
	3 Secondary level
	4 Tertiary level
Farming experience (yrs)	1 < 10 years
	2 10-20 years
	3 20-30 years
	4 > 30 years
Livestock (number)	Continuous variable
Household size (number)	Continuous variable
HH members farming	Continuous variable
Enough HH labour	0 No
	1 Yes
Total maize land (acres)	Continuous variable
Training in ISFM strategies	0 Not trained
	1 Trained
Off-farm earnings	Continuous
Total land owned (acres)	Continuous
Yield in t/ha	Continuous

Following the dependent variable being a continuous variable, ordinary least square regression (Table 3.3) was used to determine factors affecting levels of available phosphorus in smallholder farms in the study area.

Table 3.3: Definition of study variables (management practices) influencing phosphorus levels in the soils of farms in Runyenjes sub-County

Variables	Definition
Dependent variable	
Phosphorus levels (mg/kg)	Continuous
Independent variables	
Fertilizer application	1 Yes
	2 No
Fertilizer applied	1 Organic manure only
	2 Inorganic fertilizer only
	3 Organic + inorganic fertilizer
Type of inorganic fertilizer applied	1 DAP
	2 TSP
	3 NPK 23:23:0
	4 CAN
Amount of fertilizer applied/yr	1 < 50 kgs
	2 50-100 kgs
	3 100-150 kgs
	4 150-200 kgs
	5 >200kgs
Years of farming experience	1 < 10 years
	2 10-20 years
	3 20-30 years
	4 >30 years
Maize yields in (t/ha)	Continuous
Household income (Ksh)	Continuous
Training on fertilizer	0 Not trained
	1 Trained
Frequency of training	1 Monthly
	2 Quarterly
	3 Biannually
	4 Annually
Consistency of P fertilizer use	1 Yes
	2 No
Soil erosion management	1Yes
	2 No
Liming	1Yes
	2 No

CHAPTER FOUR:
RESULTS AND DISCUSSION

4.1 Socio-demographic characteristics of households in Runyenjes sub-County

Results indicated that 72% of household heads were male while 28% were female out of the 100 respondents interviewed in Runyenjes sub-county (Table 4.1). In a natural African setting, males usually head the households. In the Central highlands of Kenya, men are the landowners and take almost all decisions (Mugwe *et al*., 2008). Women, on the other hand, have user rights to the land and bear the bulk of the agricultural and domestic work (Mugwe *et al*., 2008). Documented research in Africa shows that women's lesser access to critical resources (land, cash and labor) often undermines their ability to mobilize labor (Barret and Marenya, 2007). But in labor-intensive practices, women fare better, perhaps due to superior social capacity to mobilize family or other reciprocal labor (Barret and Marenya, 2007). Despite this widely accepted notion, rural financial programmes have been largely designed, crafted and implemented with the male head of a household as the intended client, (Fletschner and Kenney, 2011). These programmes fail to recognize that women are active, productive and engaged economic agents with their own financial needs and constraints.

Results also indicated that 70% of the households interviewed had married heads. This is important because having a spouse increases a household's access to labour that is essential in ISFM application. For example, Mugwe *et al*. (2008) found the farm management variable to positively influence adoption. The paper explains that spouses working on-farm full-time have a higher probability of adopting the ISFM technologies as they had more labour than those who had only one of the spouses working on-farm full-time.

The average household size was 5 members with the maximum members being 12 and minimum being 1 member. An average of 2 members per household, were fully involved in farming (Table 4.1). This implies that despite average household size being five, only two members were actively involved in farming thus increasing a household dependence on hired labor.

Table 4.1: Socio-demographic characteristics of farmer households in Runyenjes sub-County

Parameters	**Frequency**	**(n=100)**		
Gender of the HH head				
Male	72			
Female	28			
Marital status of the HH head				
Married	70			
Polygamous/Extended	4			
Widowed/Divorced/Single	26			
Education level				
No education	16			
Primary level	45			
Secondary level	33			
Tertiary level	6			
Occupation of household head				
Farming	79			
Business	9			
Employed	12			
Labour sufficiency				
Sufficient	21			
Supplement	79			
Land acquisition				
Inherited	81			
Purchased	12			
Rented	7			
Improved maize seeds				
Users	92			
Non users	8			
	Mean	**Minimum**	**Maximum**	**SD**
Age of the household head (years)	55.57	25	86	15.28
Years of farming experience	30.19	1	65	17.217
Total land owned (Ha)	1.17	0.1	16	1.70
Total land under maize (Ha)	0.55	0.05	1.6	0.39
Household size (number)	4.97	1	12	2.540
HH member involved in farming	2.36	0	7	1.404
(TLU) Total Livestock Unit	1.50	0.00	6.86	1.20
Maize Yield (t/ha)	1.17	0.055	4.44	0.881

As explained by Barret and Marenya, (2007), family labor assumes great importance given that low incomes constrain financial liquidity for hiring wage labourers, and given possible moral hazard problems associated with non-family labor calling for considerable supervision. This is very common especially in households with large maize farms. Results show that only 21% of the households interviewed had sufficient household labour (Table 4.1).

Results showed that over 80% of the household heads in Runyenjes sub-County had some basic education (Table 4.1). The results also indicate that only 39% of the farmers had achieved post-primary education (Table 4.1). Low literacy levels pose a challenge on a farmer's ability to access and understand information on newly introduced technologies. It is more likely that a farmer with a higher educational attainment (e.g., high school or college graduate) will access up-to-date agricultural information as opposed to a farmer who is illiterate or semi-illiterate and would normally be unable to decipher information in an agricultural brochure or even from a workshop organized by extension workers or researchers (Adolwa, 2012).

The average age of the household heads was 55 years. The oldest farmer was 86 years and the youngest was 25 years (Table 4.1). This shows that majority of the farmers are above their youthful age and this may pose a challenge to labour availability. As explained by Martey *et al*. (2014), a young population is more likely to have more labour as a younger population is more energetic than an older population. The age factor can have both a positive and a negative effect (Akinola *et al*., 2010; Woomer, 2012). For example, a younger population has been found to adopt ISFM technologies (Mugwe *et al*., 2008) and to be more knowledgeable. Younger farmers have the time to experiment with new strategies as opposed to the older farmers who are accustomed to their farming practices (Akinola *et al*., 2011).

Farming experience averaged at 30 years, the farmer with the most experience had 65 years of farming experience (Table 4.1). Young farmers have been found to reject new ideas due to lack of experience (Macharia *et al*., 2014). On the other hand, older farmers might have the experience and resources to try new strategies (Macharia *et al*., 2014; Geta *et al*., 2013; Akinola *et al*., 2010).

Most of the household heads (79%), practiced farming as their main source of livelihood, 12% were employed, while 9% owned businesses (Table 4.1).This means that most of the population relies on agriculture for their livelihood. Full-time farmers are more likely to use a strategy to increase yield compared to farmers with alternative activities and income sources. Mugi-Ngenga *et al*. (2016), Martey *et al*. (2014) and Geta *et al*. (2013) found that farmers who solely practiced farming are likely to invest in inputs to increase yields.

Most (81%) of the households had inherited their land, 12% had purchased while 7% had rented the land they cultivated (Table 4.1). The average land owned by farmers was 1.17 ha, while the average land under maize per season was 0.55 ha.The average yield was 1.17 t/ha (Table 4.1). Tropical livestock unit average per household was 1.50 (Table 4.1). This shows that there is some access to animal manure in the study area.Since the organic materials may often not be available in large amounts that are required for sole application, farmers are often encouraged to adopt the combination of organic and mineral fertilizers as they resulted in high maize grain yields (Mucheru-Muna *et al*., 2007).

Results indicated 92% of users of improved seeds among the smallholder farmers interviewed. The high percentage in the usage of improved seed within the study area can be attributed to the promotion of the same. Furthermore, the close proximity of research institution like Kenya Agricultural and Livestock Research Organization (KALRO) and the Ministry of Agriculture (MoA) could have led to the awareness of farmers on the importance of improved seeds in increasing maize yields. In addition, there is adequate availability of improved seeds in the study area as agro-vets and agro-dealers are strategically located. Improved seeds are also available at the shopping centers in smaller packages affordable to smallholder farmers.

4.2 Socio-demographic factors affecting use of ISFM strategies for maize production intensification among farmers in Runyenjes sub-County

Results indicated that only 18% of the farmers interviewed in Runyenjes sub-County used sole fertilizer in maize production (Table 4.2). Only two percent of the farmers interviewed applied sole manure to their maize crop, while 4 farmers had no fertilizer or manure input on their maize farms (Table 4.2). Results showed 78% of the farmers as users of animal manure and out of this, 76 % combined fertilizer and animal manure in maize production (Table 4.2).

Table 4.2: Fertilizer application among farmers in Runyenjes sub-County

Type of application	Frequency (N=100)
Sole DAP application	3
Sole NPK application	1
Sole CAN application	0
Sole manure application	2
Combined DAP + NPK only	7
Combined DAP + CAN only	3
Combined NPK + CAN only	1
Combined DAP + NPK + CAN only	3
Combined DAP + manure only	7
Combined NPK + manure only	15
Combined CAN + manure only	1
Combined DAP + NPK + manure	22
Combined DAP + CAN + manure	7
Combined NPK + CAN + manure	6
Combined DAP + NPK + CAN + manure	18
No input	4

Fertilizer input	Frequency (%)	Rate of use among users(kg/ha)	Rate of use among whole sample (kg/ha)
DAP	70	87.76	63.84
NPK 23:23:0	73	109.67	87.73
CAN	38	94.13	35.77

Results also indicated that there were 70 users of DAP fertilizer, 73 users of NPK and 38 users of CAN out of the 100 farmers interviewed in Runyenjes sub-County. The average rate of DAP fertilizer application in maize fields in Runyenjes sub-County was 63.84 kg/ha (Table 4.2). The average rate of NPK 23:23:0 application in the study area 87.73 kg/ha, while that of CAN was 35.77kg/ha (Table 4.2).

In recent years, there has been an increased use of high nutrient fertilizers, mainly for economic reasons (Ademba *et al*., 2015), and this might be responsible for the increasing rates of fertilizer use in rural areas. A study by Rware *et al*. (2014), reported that fertilizer recommendations were still not followed in Kenya. This was attributed to the financial constraints commonly among the smallholder scale farmers that limit fertilizer use as they strive to maximize net returns on their investments.Lack of suitable fertilizer application rates and soil acidity could also result in the decline in fertilizer application since the current research recommendations were developed more than two decades ago (Ademba *et al*., 2015).

4.2.1 Factors affecting use of inorganic fertilizer for maize production intensification among farmers in Runyenjes sub-County

4.2.1.1 Use of phosphorus fertilizer for maize production intensification by farmers in Runyenjes sub-County

A negative strong linear correlation was observed between size of land under maize and rate of DAP use, Pearson correlation = -0.534, p = 0.0001 (2-sided). This implies that as the size of land increases the rate of use of DAP decreases. The explanation for this is that a larger piece of land demands more fertilizer resources that a smallholder farmer might not have access to. A strong negative linear correlation was also observed between size of land under maize and rate of NPK 23:23:0 use, Pearson correlation = -0.581, p = 0.0001 (2-sided). This implies that larger land sizes are likely to have a lower rate of NPK use as larger farm holdings demand more fertilizer resources. This was also expounded by Zingore *et al*. (2007), who mentioned that farmers will little inputs usually apply them on farms where the main crop is grown; and these farms are usually near the homesteads. This means that farms further from the homes are usually not fertilized.

DAP and NPK application in kg/ha observations were evenly distributed. The interquartile range for DAP lied between 0 and 100 kg/ha while that of NPK lied between 0 and 120 kg/ha (Figure 4.1). The median for DAP was about 50 kg/ha while for NPK 23:23:0 was about 60 kg/ha.

Four farmers applied fertilizer in rates that were in the outlier region (Figure 4.1), these farmers applied fertilizer at significantly higher rates as compared to the other farmers in the random sample. Two farmers application of DAP lied on the outlier region. Likewise, two farmers' rate of NPK fertilizer also lied in the outlier region. Data showed that these farmers had significantly higher income than the others and probably would have resulted in their capacity to purchase more fertilizer than the other farmers.

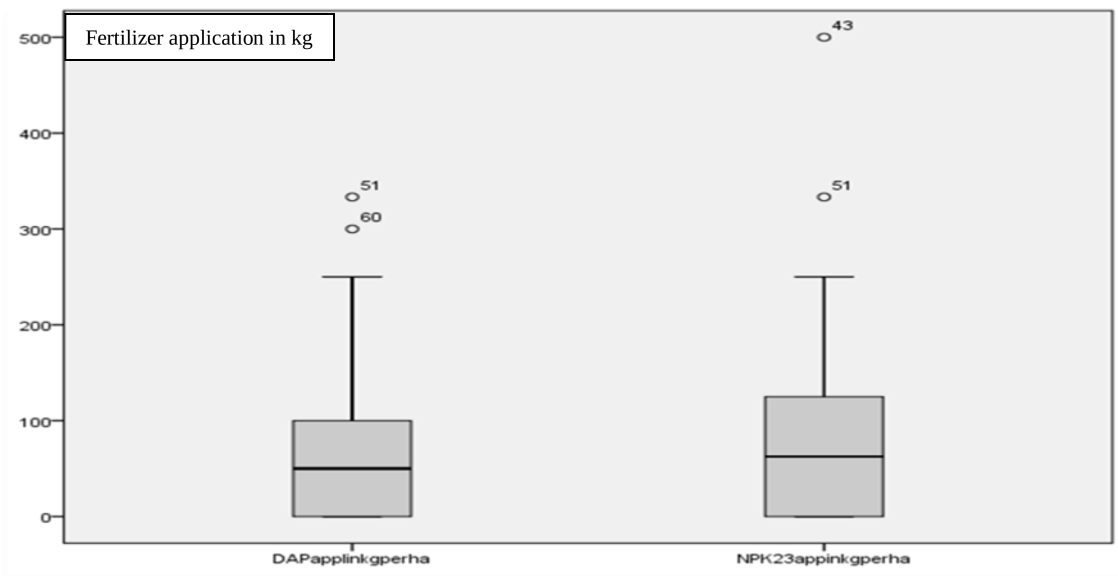

Figure 4.1: Box plots displaying rates of DAP and NPK 23:23:0 application on maize by farmers in Runyenjes sub-County

4.2.1.2 Socio-demographic factors affecting amounts of phosphorus fertilizer used by farmers in Runyenjes sub-County

Out of 100 farmers interviewed, 94% used some phosphorus fertilizer, either solely or in combination with other types of fertilizers. The mean area under maize for those using phosphorus fertilizers for maize production was 0.56 ha while the mean area under maize of those not using was 0.43 ha (Table 4.3). There was a significant difference in yield between user and non-users of phosphorus fertilizer. Users of phosphorus fertilizers had an average yield of 1.18t/ha while non-users had an average yield of 0.63 t/ha (Table 4.3). Phosphorus fertilizer users owned significantly larger pieces of land and tropical livestock units (Table 4.3). These resources enabled them to be categorized as richer farmers who could probably purchase inorganic fertilizers.

Results showed that three variables positively influenced the use of phosphorus fertilizer by farmers in maize production (Table 4.4). These were household size, off-farm income and maize yield. The size of land under maize was negatively associated with phosphorus fertilizer use. This implies that as the household size and off-farm income of the household increased the higher the likelihood of using phosphorus fertilizer.

Table 4.3: Socio-demographic factors affecting phosphorus fertilizer use by farmers in Runyenjes sub-County

Independent variables		**Farmers using phosphorus fertilizers**	**Farmers not using phosphorus fertilizers**
Gender of household head	Male	67	5
	Female	27	1
Education of household head	No education	16	0
	Primary	42	3
	Secondary	31	2
	Tertiary	5	1
Occupation of household head	Farming	77	2
	Business/Employed	17	4
Off-farm earnings	Below 10000	73	4
	10000 to 30000	16	2
	Above 30000	5	0

Values are percentages, N=100

	Mean	**Mean**
Age of household head	55.4(15.4)	58.3 (13.8)
Size of household	5 (3)	4 (2)
Farming experience (yrs)	30.1(17.3)	28.5 (16.9)
Total land owned (ha)	1.19 (1.74)	0.77 (0.55)
Size of land under maize (ha)	0.56 0.39)	0.43 (0.40)
Tropical Livestock Unit	1.59 (1.30)	0.50 (0.55)
Months household bought food	1 (2)	4 (4)
Yield (t/ha)	1.18(0.90)	0.63 (0.60)

Values in parentheses are standard deviations, N=100

Similarly, as the maize yields obtained increased, the farmer is more likely to use phosphorus fertilizer. On the other hand, as the size of land under maize increased the farmer was less likely to use phosphorus fertilizer.

Results indicated that a large household is more likely to use phosphorus fertilizer for maize production (Table 4.4). Large households always demand more food resources and thus the need to increase maize production. Furthermore, family labor associated with larger households is cheap and readily available and thus increases the tendency to use new technologies. As Marenya and Barret (2007) explain, family labor assumes great importance given that low incomes associated with rural smallholder farmers constrain financial liquidity for hiring wage laborers. Mugwe *et al*. (2009a) and Mugwe *et al*. (2008) confirm the positive association of household labour and adoption of soil improving technologies.

Table 4.4: Socio-demographic factors affecting amounts of phosphorus fertilizer used by farmers in Runyenjes sub-County

Independent variables	**β**	**S.E.**	**Beta**	**t**	**Sig.**
(Constant)	250.227	82.164		3.045	0.003
HHH gender	-15.775	24.824	-0.058	-0.635	0.527
HHH age	-0.650	1.221	-0.081	-0.532	0.596
HHH education	-20.209	15.564	-0.133	-1.298	0.198
HHH occupation	-22.865	17.316	-0.127	-1.320	0.190
HH size	8.979	4.837	0.185	1.856	0.067*
Farming experience (yrs)	-0.382	1.160	-0.053	-0.330	0.742
Total land owned (ha)	0.430	2.916	0.015	0.148	0.883
Size of land under maize (ha)	-41.467	14.301	-0.328	-2.900	0.005***
Off-farm earnings (Ksh)	16.130	6.364	0.236	2.534	0.013**
Tropical Livestock Unit	4.428	9.213	0.046	0.481	0.632
Yield (t/ha)	30.660	12.605	0.226	2.432	0.017**
HH food security	-1.966	4.980	-0.036	-0.395	0.694

Dependent Variable: Amount of phosphorus fertilizer applied per season
N =100, ***Significant at 1% probability level, **Significant at 5% probability level, *Significant at 10% probability

Maize yield was found to be positively associated with the use of phosphorus fertilizer in maize production (Table 4.4). This reveals that households with increased yields attributable to inorganic fertilizer use were more likely to use phosphorus fertilizer in maize production. Mucheru-Muna *et al*. (2014) and Mucheru-Muna *et al*. (2007) concluded that inorganic fertilizer was a very important input in the increase of maize yields in the Central Highlands of Kenya. With the poor fertility of soils in SSA, farmers are increasingly being aware of the fact that inorganic fertilizer is playing a major role in the increase of crop yields. Mapila *et al*. (2012) and Morris *et al*. (2007) explained that a household's potential profitability from using fertilizer is determined by the responsiveness of the crop to which fertilizer is applied.

The positive association of off-farm income with increased use of phosphorus fertilizers (Table 4.4) in maize production is attributed to the fact that inorganic fertilizer purchase requires some monetary allocation. Having an off-farm income could enable a farmer to purchase fertilizer. Muzari *et al*. (2012) confirm this in that higher levels of income from other sources will lead to higher rates of adoption of yield-raising technology. Similarly, Marenya and Barret (2007) states thatnon-farm income from informal and formal non-agricultural employment proved quite important in fostering adoption of the integrated soil fertility management technologies in western Kenya.

The negative association of size of land under maize and phosphorus fertilizer use (Table 4.4) indicated that a farmer with a larger area under maize was less likely to use phosphorus fertilizer for maize production. Large farms demand more in terms of inputs and resources, and this might be a challenge to rural farmers who in most cases are poor. This agreed with Marenya and Barret (2007) who found that size of land was a significant factor affecting fertilizer use although estimated marginal effect of farm size was largest for inorganic fertilizer. Wiredu *et al*. (2014) measured the intensity of ISFM adoption by the proportion of land that was assigned to it, showing land as an important factor in adoption.

4.2.2 Socio-demographic factors affecting use of animal manure among farmers in Runyenjes sub-County

Results indicated that 78% of farmers in Runyenjes sub-County used animal manure on their maize farms. The users of animal manure had an average TLU of 1.86 implying availability of some manure (Table 4.5).

Table 4.5: Socio-demographic factors affecting use of animal manure by farmers in Runyenjes sub-County

Independent variables		Farmers using animal manure	Farmers not using animal manure
Gender of household head	Male	57	15
	Female	21	7
Occupation of household head	Farming	65	14
	Business/Employed	13	8
Education of household head	No education	13	3
	Primary	37	8
	Secondary	23	10
	Tertiary	5	1
Off-farm earnings	Below 10000	60	23
	10000 to 30000	13	8
	Above 30000	56	0
Training on inorganic fertilizer	Yes	14	6
	No	64	16

Values are percentages, N=100

	Mean	Mean
Age of household head	56.2 (14.9)	59.4 (16.7)
Size of household	5 (3)	4 (2)
Farming experience	31.3 (17.0)	26.4 (17.7)
Size of land under maize (ha)	1.4 (1.0)	1.28 (0.87)
Yield (t/ha)	1.26 (0.95)	0.79 (0.60)

Values in parentheses are standard deviations, N=100

Regression results showed that use of animal manure in maize production was influenced by five variables. These were household head occupation (negative), size of land under maize (positive), off-farm earnings (positive), maize yield (positive) and training on animal manure (positive) (Table 4.6).

The negative influence of household occupation on the use of manure is an implication that farmers who practised farming as their sole occupation were less likely to apply animal manure to their maize. This can be attributed to the lack of resources that can be obtained off-farm that in turn support a farmer in purchasing livestock that produces animal manure. The amount of manure in a household is dependent on the number of animals owned. For example, Adolwa *et al*. (2012) and Akinola *et al*. (2010) emphasize the importance of off-farm income in the adoption of integrated soil fertility management technologies.

Table 4.6: Socio-demographic factors influencing use of animal manure among farmers in Runyenjes sub-County

Independent variables	β	S.E.	Beta	T	Sig.
(Constant)	0.201	1.134		0.178	0.859
HHH gender	-0.386	0.270	-0.139	-1.428	0.157
HHH age	-0.001	0.013	-0.012	-0.072	0.943
HHH education	0.056	0.165	0.036	0.339	0.735
HHH occupation	-0.586	0.306	-0.192	-1.918	0.058*
HH size	0.060	0.051	0.123	1.184	0.240
Farming experience (yrs)	0.002	0.013	0.028	0.163	0.871
Size of land under maize (ha)	0.495	0.127	0.386	3.885	0.000***
Off farm earnings (Ksh)	0.138	0.069	0.199	2.016	0.047**
Maize yield in (t/ha)	0.275	0.134	0.200	2.053	0.043**
Training on animal manure	0.477	0.285	0.154	1.674	0.098*

a. Dependent Variable: use of animal manure (TLU)
N =100, ***Significant at 1% probability level, **Significant at 5% probability level, *Significant at 10% probability

The positive association between the size of land under maize and use of manure (Table 4.6) implies that households with a larger size of land under maize were more likely to apply manure to all their land as opposed to farmers with a smaller size of land under maize. A larger maize farm puts pressure on a farmer to apply fertilizer to achieve his goal produce.This is especially practical to ‘resource rich’ farmers who can afford inputs for their large farms (Zingore *et al*., 2007). In the study area, farmers have on average two heads of livestock and hence are able to use the manure from their livestock on their maize crop.

The positive association of off-farm income and animal manure use (Table 4.6) in maize cultivation means that a household with an off-farm income in the study area is more likely to use animal manure in maize cultivation. Limited manure availability is common in sub-Saharan Africa and a household with extra income probably from off-farm sources is able to purchase livestock that produces animal manure. Off-farm income enables a farmer to purchase inputs (Adolwa *et al*., 2012; Akinola *et al*., 2010) including livestock which is the main source of manure (Ajayi *et al*., 2007). For example, according to Zingore *et al*. (2007), smallholder farmers with limited inputs resources usually apply them to farms near the homesteads only and neglect farms further from the homestead as opposed to farmers who are 'resource richer' who can afford to have resources enough for all the farms they have.

Maize yield positive association with the use of animal manure (Table 4.6) in maize cultivation implies that a household with high maize yield was more likely to use animal manure in maize cultivation. Animal manure has been long known to improve soil fertility and increase yield (Mucheru-Muna *et al*., 2014; Ajayi *et al*., 2007; Mucheru-Muna *et al*., 2007). Good yields can allow a farmer to sell excess produce and purchase livestock associated with the production of animal manure.

Training had a positive effect on the use of animal manure (Table 4.6). The training helps farmers to correctly use animal manure for crop production. Macharia *et al*. (2012) emphasizes that having knowledge on a technology puts a farmer in a position to use the technology. According to Misiko and Ramisch (2007) integrated soil fertility management strategies have been met with major challenges because they are knowledge-intensive and their adaptations and applications are diverse (Adolwa *et al*., 2012), often requiring training for proper utilization.

4.2.3 Socio-demographic factors affecting use of combined inorganic and organic manure with improved seeds among farmers in Runyenjes sub-County

Results indicate that 68% of the farmers interviewed used combined inorganic fertilizer and animal manure with improved maize seeds (Table 4.7). Users had significantly high average tropical livestock unit (1.88) compared to that of the non-users (0.54). A high tropical livestock unit means more manure availability for maize production. Household members averaged at 5 for users which was higher than that of non-users at 4 (Table 4.7). This shows that larger households probably need to maximize farm inputs to ensure food security.

Table 4.7: Socio-demographic factors affecting use of combined inorganic and organic manure with improved seeds by farmers in Runyenjes sub-County

Independent variables		**Farmers using combined fertilizer+ improved seeds**	**Farmers not using combined fertilizer+ improved seeds**
Gender of household head	Male	52	20
	Female	16	12
Education of household head	No education	11	5
	Primary	33	12
	Secondary	20	13
	Tertiary	4	2
Household head occupation	Farming	56	23
	Business/ Employed	12	9
Off-farm earnings	Below 10000	51	7
	10000 to 30000	12	1
	Above 30000	5	0
Enough household labour	Yes	11	10
	No	57	22
Values are percentages, N=100			
		Mean	**Mean**
Age of HHH		56.3 (14.7)	53.9 (16.6)
Size of HH		5 (3)	4 (2)
Farming experience (yrs)		31.1 (16.8)	28.2 (18.3)
Size of land under maize (ha)		0.53 (0.39)	0.60 (0.40)
TLU		1.88 (1.09)	0.54 (1.08)

Values in parentheses are standard deviations, N=100

Regression results showed that size of land under maize (negative), household labour (positive), off-farm income (negative) and tropical livestock unit (positive) had significantly statistically association with the use of combined inorganic fertilizer and animal manure with improved seeds (Table 4.8). The size of land under maize was negatively associated with the use of combined inorganic fertilizer and animal manure with improved seeds (Table 4.8).

This shows that household with larger sizes of land under maize were less likely to use a combination of inorganic fertilizer and animal manure with improved seeds in maize cultivation. Although farmers owning large pieces of land are associated with use of technologies (Barret and Marenya, 2007; Mugwe *et al*., 2008), this is otherwise for farmers with large pieces of land under maize crop. The demand for resources and inputs associated with a large piece of land under maize can hinder a household's ability to acquire them. Macharia *et al*. (2012) also found farm size to be a negative predictor as adoption increased with decrease in farm size.

Table 4.8: Socio-demographic factors affecting use of combined inorganic, animal manure and improved seeds among farmers in Runyenjes sub-County

Independent variables	**B**	**S.E.**	**Beta**	**t**	**Sig.**
(Constant)	0.317	0.363		0.874	0.384
HHH gender	-0.140	0.097	-0.149	-1.445	0.152
HHH age	-0.006	0.005	-0.209	-1.187	0.238
HHH education	0.062	0.058	0.118	1.064	0.290
HHH occupation	0.058	0.111	0.057	0.528	0.599
HH size	0.028	0.018	0.167	1.576	0.118
Farming experience	0.007	0.005	0.290	1.546	0.126
Size of land under maize	-0.133	0.047	-0.307	-2.857	0.005**
Enough HH labour	0.266	0.105	0.258	2.548	0.013**
Off farm earnings	-0.043	0.025	-0.182	-1.704	0.092*
TLU	0.099	0.036	0.291	2.726	0.008**

a. Dependent Variable: combined use of inorganic fertilizer, animal manure and improved seeds

N =100, **Significant at 5% probability level, *Significant at 10% probability

Enough household labour was a significant factor influencing the use of combined inorganic fertilizer and animal manure with improved seeds for maize production (Table 4.8). Households with enough and available family labour have been known to use technologies. Marenya and Barret, (2007) agrees that enough family labour reduces a household dependence on hired labor that often also requires supervision. Mugwe *et al*. (2008) mentioned household labor as a factor immensely influencing adoption of soil management technologies.

Having an off-farm earning was negatively associated with the combined use of inorganic fertilizer and animal manure with improved seeds (Table 4.8). Farmers with off-farm incomes were less likely to use a combination of inorganic fertilizer and animal manure with improved seeds. Adolwa *et al*. (2012) explains that it is probable that individuals with higher off-farm incomes invested their time, energies and money in non-farm activities at the expense of ISFM, hence the disparity with other studies. It is thus not surprising that Reardon *et al*. (2000) identified having an off-farm income as one of the reasons for farmers' failure to adopt hybrid maize in Botswana.

Tropical livestock unit had a positive significant association with the combination of inorganic fertilizer and animal manure with improved seeds for maize production (Table 4.8). This implies that a household with a higher livestock number is more likely to use a combination of inorganic fertilizer and animal manure with improved seeds in maize production. Livestock is very crucial in a farming system as it is the major source of manure and draft power (Adolwa *et al*., 2012). Livestock ownership is an indication of wealth status of smallholder farmers (Adolwa *et al*., 2012; Zingore *et al*., 2007). Farmers can sell portions of their livestock to acquire maize inputs, as livestock and household assets increase the availability of capital, which in turn makes an investment on land-enhancing technologies feasible (Akinola *et al*., 2010).

4.3 Knowledge levels of Integrated Soil Fertility Management Strategies

4.3.1 Use of inorganic fertilizer knowledge level among farmers in Runyenjes sub-County

The mean knowledge level was 4 implying high knowledge levels in the use of inorganic fertilizer among farmers interviewed in Runyenjes sub-County (Table 4.9).

Table 4.9: Smallholder farmers knowledge levels in the use of inorganic fertilizer among farmers in Runyenjes sub-County

ISFM strategy questions	Knowledge level					Total	Means (rank)
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree		
Quickest and surest nutrient supply	73	23	3	1	0	100	4.68(1)
More accurate as supply specific nutrient	58	39	2	1	0	100	4.54(3)
Timely application result in efficiency	49	29	21	1	0	100	4.26(6)
Correct amount and type is important	55	18	8	11	8	100	4.01(8)
Blended fertilizer provides is affordable	47	28	20	4	1	100	4.16(7)
N applied as top-dressing in moist soil	40	22	30	6	2	100	3.92(9)
Important to determine soil fertility level	49	17	14	8	12	100	3.83(12)
Purchase labeled at authorized dealers	74	18	2	4	2	100	4.58(2)
Liming to correct acidity is important	12	3	79	6	0	100	3.21(15)
Know recommended maize fertilizers	42	28	15	9	6	100	3.91(10)
DAP important to maize	68	20	6	4	2	100	4.48(4)
NPK 23:23:0 and CAN improve yield	38	21	32	8	1	100	3.87(11)
Important split basal and top-dressing	22	17	52	7	2	100	3.5(14)
Continuous fertilizer destroys soil structure	45	20	10	10	15	100	3.7(13)
Excessive fertilizer can harm environment	64	23	5	4	4	100	4.39(5)
Mean knowledge level							4

Mean <3 = Low knowledge, Mean 3 = Moderate knowledge, Mean >3 = High knowledge

Most farmers (73%) strongly agreed that inorganic fertilizer was the quickest and surest nutrient supply method to maize crop. Seventy-four percent of farmers strongly agreed that good fertilizer was supposed to be well labelled and acquired from authorized dealers. Farmers (58%) also strongly agreed that inorganic fertilizer was a more accurate nutrient supply as it supplies specific nutrients in known specific forms. A good number of the farmers (68%) strongly agreed that DAP fertilizer was important to their maize crop (Table 4.9).

A favorable percentage (64%) of the farmers strongly agreed that excessive fertilizer application was wasteful and could harm the environment. Farmers (49%) strongly agreed that timely application of fertilizer during planting and growth stages resulted in fertilizer use efficiency. Farmers (47%) strongly agreed that blended fertilizer provided farmers with an affordable fertilizer with a correct ratio of nutrients. Farmers' response on whether the correct amount and type of fertilizer was important resulted in 55% of the farmers strongly agreeing (Table 4.9).

Forty percent of the farmers strongly agreed that nitrogen fertilizers were supposed to be applied as top-dressing when soils are moist. Forty-two percent of the farmers strongly agreed that they knew the recommended types of fertilizers for maize crop. On whether NPK 23:23:0 and CAN fertilizers can increase maize yields, 38% of the farmers strongly agreed. On whether determining soil fertility levels was important; 49% of the farmers strongly agreed that soil testing was important (Table 4.9). Forty-five percent of the farmers strongly agreed that continuous sole application of inorganic fertilizer could destroy the soil structure. On whether it was important to have split basal and top-dressing of fertilizer in maize cultivation, 52% were not sure. Seventy-nine percent of the farmers were not sure that it was important for a farmer to practice liming as a means of correcting acidity (Table 4.9).

This shows that farmers in the study area had high knowledge in the use of inorganic fertilizer. Use of an ISFM strategy is strongly associated with knowledge levels. Macharia *et al*. (2012) also found knowledge level in the use of inorganic fertilizer in the Central Highlands of Kenya to be significantly high. The ease of use, the high cost and the high yields associated with the inorganic fertilizers could have prompted the farmers in learning more about the inorganic fertilizers (Macharia *et al*., 2012); he further continues that this is so since farmers would not be willing to invest in a technology without enough knowledge about its economic feasibilities and agricultural productivity.

Even so, issues with low means must be given priority during training and extension work, as integrated soil fertility management strategies are knowledge intensive (Misiko and Ramisch, 2007).

4.3.2 Use of organic fertilizer knowledge level among farmers in Runyenjes sub-County

The mean knowledge level was 4 implying high knowledge levels in the use of organic fertilizer among farmers interviewed in Runyenjes sub-County (Table 4.10). Most farmers (84%) strongly agreed that although organic fertilizers released nutrients slowly, they improved soil physical characteristics.

Table 4.10: Smallholder farmers knowledge levels in the use of organic manure among farmers in Runyenjes sub-County

ISFM strategy	Knowledge level					Total	Means
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree		
Improves soil physical characteristics	84	15	1	0	0	100	4.83(1)
I know how to prepare and use manure	41	38	8	8	5	100	4.02(9)
Good manure management ensures quality	72	26	1	1	0	100	4.69(2)
Farmyard manure covered during curing	58	13	8	7	14	100	3.94(10)
Cowshed covered to prevent leaching	61	21	8	8	2	100	4.31(4)
Ready manure should not have litter	58	16	10	7	9	100	4.07(7)
Proper incorporation prevents seed burns	62	31	6	1	0	100	4.54(3)
Compost manure made near maize farm	21	12	56	5	6	100	3.37(14)
6 to 8 weeks sufficient to prepare compost	26	7	54	4	9	100	3.37(14)
Ready manure is loose, dry and no smell	63	18	5	6	8	100	4.22(5)
Green manure important to maize	25	14	54	5	2	100	3.55(13)
Biomass transfer is labour intensive	37	33	29	1	0	100	4.06(8)
Agroforestry trees provide green manure	47	14	27	9	3	100	3.93(11)
Agroforestry trees prevent runoff	47	21	32	0	0	100	4.15(6)
Manure should be taken directly to farm	38	26	13	3	20	100	3.59(12)
Mean knowledge level							4

Mean <3 = Low knowledge, Mean 3 = Moderate knowledge, Mean >3 = High knowledge

Farmers (72%) strongly agreed that good manure management was essential in ensuring good quality manure. Sixty-two percent of the farmers strongly agreed that proper incorporation of manure ensures no burns of seeds. On the statement on whether the cowshed was to be covered to prevent leaching of nutrients, 61% of the farmers strongly agreed with the statement (Table 4.10).

Sixty-three percent of farmers strongly agreed that ready manure was supposed to be loose, dry with no smell. On whether agroforestry prevented erosion and runoff, a good percentage of the farmers (47%) strongly agreed. Fifty-eight percent of the farmers strongly agreed that ready manure is not supposed to have visible material such as grass and leaves. On whether biomass transfer is labour intensive, 37% of the farmers strongly agreed. Forty-one percent of the farmers strongly agreed that they knew how to properly prepare and use manure. On whether farmyard manure is supposed to be covered during curing, 58% of the farmers strongly agreed (Table 4.10).

On whether agroforestry trees provide green manure, 47% of the farmers strongly agreed. Thirty-eight percent of the farmers also strongly agreed that it was important to take ready manure directly to the maize farm from where it had been prepared. Fifty-four percent of farmers strongly agreed that green manure is important to maize. On whether it was important for compost manure to be prepared near the maize farm where it would be used, 56% of the farmers were not sure about this. On whether 6 to 8 weeks was sufficient for compost manure to be ready, 54% of the farmers interviewed were not sure about this (Table 4.10).

Knowledge levels in the use of organic fertilizer were high in Runyenjes sub-County probably due to the fact organic manure is probably more available than inorganic fertilizer as most smallholder farmers are poor. Organic manure does not require much financial input other than having cattle for manure or/and trees associated with green manure. More so, concerns by the farmers regarding the limitations in quality and quantity of animal manure (Mugwe *et al.*, 2009b) may have created the urge for the farmers to look for information on how to improve the manures especially through trainings from various stakeholders, thus increasing their levels of knowledge (Macharia *et al*., 2012).

4.3.3 Use of combined inorganic and organic fertilizer knowledge level among farmers in Runyenjes sub-County

The mean knowledge level was 3 implying moderate knowledge levels in the combined use of inorganic fertilizer and organic fertilizer among farmers interviewed in Runyenjes sub-County (Table 4.11). Forty-nine percent of the farmers interviewed in Runyenjes sub-County strongly agreed that combination of both inorganic and organic fertilizer is the best way of enhancing soil fertility to boost maize production. Forty six percent of the farmers strongly agreed that maize yield would increase by fifty percent if a farmer used both inorganic and organic fertilizer in maize cultivation. Farmers were also asked if the use of combined fertilizer provided a more balanced nutrient supply, 34% of the farmers strongly agreed with this (Table 4.1).

Table 4.11: Smallholder farmers knowledge levels in the use of combined inorganic and organic fertilizer in among farmers in Runyenjes sub-County

ISFM strategy	Knowledge level					Total	Means
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree		
50% yield increased with combined fertilizer	46	24	10	11	9	100	3.87(2)
Combination has best effect on soil fertility	49	30	1	10	10	100	3.98(1)
Cheaper to combine than use inorganic alone	41	14	10	16	18	100	3.41(4)
Combined provides a balanced nutrient supply	34	30	4	21	10	100	3.54(3)
Ratio of combined should be 1:1	17	15	45	9	14	100	3.12(7)
Combining means half recommended rates	18	19	34	19	10	100	3.16(6)
Labour intensive to use combined fertilizer	20	29	18	16	17	100	3.19(5)
Mean knowledge level							3

Mean <3 = Low knowledge, Mean 3 = Moderate knowledge, Mean >3 = High knowledge

On whether it was cheaper to combine both inorganic and organic fertilizer than using inorganic fertilizer alone, 41% of the farmers strongly agreed. On whether it was labour intensive to combine inorganic and organic fertilizer, 29% of the farmers agreed. When asked whether the combination of inorganic and organic fertilizer means half-recommended rates, 34% were not sure about this. On whether the ratio of combination is 1:1 of inorganic and organic fertilizer, 45% of the farmers were not sure about this (Table 4.11).

Farmers have been known to use fertilizers separately. For example, in the study area over 70% of the farmers used inorganic fertilizer separately and over 75% of the farmers used animal manure separately. This might have had the moderate outcomes in the combined use of inorganic and organic fertilizers. For example, Macharia *et al*. (2012), emphasizes that the lack of awareness of the details on the combined use of animal manure and inorganic fertilizers could have rendered the majority of farmers in the Central Highlands of Kenya to possess moderate levels of knowledge.

4.3.4 Use of improved seeds knowledge level among farmers in Runyenjes sub-County

Knowledge levels on improved seeds use had a mean of 3 implying moderate knowledge levels (Table 4.12). Fifty-one percent of the farmers strongly agreed that it was important to plant two seeds of maize per hole to allow for thinning after emergence, although they did not practice this often. Fifty-seven percent of the farmers strongly agreed that it was important to acquire seeds from authorized dealers. Fifty-six percent of the farmers strongly agreed that improved seeds were more adapted to soils and climate of the area.

Table 4.12: Smallholder farmers knowledge levels in the use of improved seeds among farmers in Runyenjes sub-County

ISFM strategy	Knowledge level					Total	Means
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree		
High yields are realized with improved seeds	52	6	1	4	37	100	3.32(7)
Spacing is important to reduce competition	48	12	10	20	10	100	3.68(5)
75 by 25cm is maize recommended spacing	20	22	32	2	24	100	3.12(8)
Seeds are acquired from authorized dealers	57	13	4	2	24	100	3.77(2)
2 seeds per hole for thinning after emergence	51	22	3	7	17	100	3.83(1)
Local seeds from previous yields discouraged	15	11	2	26	46	100	2.23(9)
Improved seeds more responsive to nutrients	45	24	6	9	16	100	3.73(4)
Improved seeds adapted to soil and climate	56	12	5	5	22	100	3.75(3)
Improved seeds resistant to pest and diseases	45	15	3	20	17	100	3.51(6)
Mean knowledge level							3

Mean <3 = Low knowledge, Mean 3 = Moderate knowledge, Mean >3 = High knowledge

Forty-five percent of the farmers strongly agreed that improved seeds were more responsive to nutrients that local seeds (Table 4.12).

Farmers were asked whether spacing was important when planting maize to reduce competition for water and nutrients, 48% of the farmers strongly agreed. When asked whether improved seeds were more resistant to pest and diseases than local seed, 45% of the farmers strongly agreed. On whether high yields of maize are realized with improved seeds, 52% of the farmers strongly agreed. Farmers were also asked if they agreed with the recommendation of 75 by 25cm maize spacing during planting, 32% of the farmers were not sure with about this (Table 4.12).

Forty-six percent of the farmers strongly disagreed with the statement that seeds obtained from previous yields were discouraged (Table 4.12) as most of them used seeds from their previous yields provided they were dried and stored for a period of one to two seasons. Farmers have not fully embraced the improved seeds phenomenon in maize production in the study area. For example, a good amount of farmers continued used seeds from the previous crop as long as they gave the seeds two seasons to rest. They said that is it only fair to return seeds from good harvest back to the farm to maintain a good yield.

4.3.5 Combined use of inorganic and organic fertilizer with improved seeds knowledge level among farmers in Runyenjes sub-County

The mean knowledge level was 4 implying high knowledge levels in the combined use of inorganic fertilizer and organic fertilizer with improved seeds among farmers interviewed in Runyenjes sub-County (Table 4.13). Farmers (63%) strongly agreed that improved seeds gave more yield when fertilized appropriately with both inorganic and organic fertilizer than local seeds. Seventy percent of the farmers strongly agreed that combined fertilizer is half recommended rates with improved seeds. Sixty-eight percent of the farmers strongly agreed with this statement that combined fertilizer increases yields with improved seeds. On whether thorough mixing of inorganic and organic fertilizer with soil was important in preventing scorching of seeds, 37% of the farmers agreed (Table 4.13).

Table 4.13: Smallholder farmers knowledge levels in the use of combined inorganic and organic fertilizer with improved seeds among farmers in Runyenjes sub-County

ISFM strategy	Knowledge level					Total	Means
	Strongly agree	Agree	Not sure	Disagree	Strongly disagree		
Combined fertilizer with improved seeds increase yields	68	22	4	6	0	100	4.34(3)
Improved seeds give more yields when fertilized appropriately than local seeds	63	26	4	1	6	100	4.52(1)
Combined fertilizer are half recommended rates with improved seeds	70	6	8	8	8	100	4.39(2)
Thorough mixing of fertilizer with soil to prevent scorching of seeds	56	37	6	1	0	100	4.22(4)
Mean knowledge level							4

Mean <3 = Low knowledge, Mean 3 = Moderate knowledge, Mean >3 = High knowledge

The combination of the use of inorganic and organic fertilizer with improved seeds had a high score denoting high knowledge levels. It is fair to note that on the separate use of fertilizer, the farmers in Runyenjes sub-County have high knowledge levels and this impacted on the knowledge levels in the combined fertilizer use with improved seeds.

4.4: Factors affecting levels of knowledge in the use of ISFM strategies for maize production intensification among farmers in Runyenjes sub-County

4.4.1 Factors affecting levels of knowledge in the use of inorganic fertilizer among farmers in Runyenjes sub-County

Results of univariate analysis of factors showed that education of the household head and household size as significant factors in explaining knowledge levels of farmers in the use of inorganic fertilizer (Table 4.14).

Table 4.14: Univariate results of factors influencing levels of knowledge in the use of inorganic fertilizer among farmers in Runyenjes sub-County

Independent variables		**Knowledge level**			**χ^2 P value**
		Low	**Moderate**	**High**	
Gender of household head	Male	4	33	35	Ns
	Female	4	13	11	
Education of household head	No education	3	10	3	0.046*
	Primary	5	19	21	
	Secondary	0	12	21	
	Tertiary	0	5	1	
Occupation of household head	Farming	7	38	34	Ns
	Business/Employed	1	8	12	
Off-farm earnings (Ksh)	Below 10000	6	36	35	Ns
	10000 to 30000	2	8	8	
	Above 30000	0	2	3	
Training on inorganic fertilizer	Yes	2	5	12	Ns
	No	6	41	34	

Values are percentages, N=100

	Mean	**Mean**	**Mean**	**t-test**
Age of household head (yrs)	63.3 (15.4)	55.1 (15.4)	54.9 (15.1)	Ns
Size of house hold	6 (4)	5 (2)	5 (2)	0.024*
Farming experience (yrs)	40.0 (12.3)	27.7 (18.3)	31.1 (16.4)	Ns
Size of land under maize (ha)	0.31 (0.25)	0.52 (0.39)	0.61 (0.40)	Ns
Maize yield (t/ha)	1.24 (1.10)	1.03 (0.67)	1.26 (1.07)	Ns
Total land owned (ha)	0.74 (0.66)	1.36 (2.4)	1.05 (0.67)	Ns

Values in parentheses are standard deviations, N=100

*association significant at $\alpha = 0.05$, Ns=Not significant

Results showed two predictors; the size of maize land (negative) and off-farm earning (negative) as significant in determining whether a farmer's knowledge level was low relative to high in regards to the use of inorganic fertilizer for maize production intensification (Table 4.15). Results also showed six predictor variables; household head gender (negative), household head education (negative), household size (negative), size of maize land (negative), off-farm earning (negative) and maize yield (positive) as significant in determining whether a farmer's knowledge level was moderate relative to high in the use of inorganic fertilizer for maize production (Table 4.15).

Table 4.15: Factors affecting levels of knowledge in the use of inorganic fertilizer among farmers in Runyenjes sub-County

Independent variables	**Low knowledge level**					**Moderate knowledge level**				
	β	**S.E.**	**Wald**	**Sig.**	**Exp(β)**	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(β)**
Intercept	12.249	6.827	3.219	0.073	_	12.372	5.450	5.154	0.023	_
HHH gender	-1.828	1.496	1.493	0.222	0.161	-2.188*	1.241	3.106	0.078	0.112
HHH age	-0.082	0.088	0.865	0.352	0.921	-0.067	0.049	1.835	0.176	0.936
HHH education	-2.000	1.226	2.661	0.103	0.135	-1.810*	0.994	3.317	0.069	0.164
HH size	-0.104	0.287	0.131	0.717	0.901	-0.386*	0.206	3.528	0.060	0.680
Farming experience	0.102	0.084	1.466	0.226	1.107	0.047	0.043	1.223	0.269	1.048
Size of land under maize	-2.365*	1.229	3.705	0.054	0.094	-1.112**	0.513	4.702	0.030	0.329
Off-farm earnings	-1.130**	0.499	5.130	0.024	0.323	-0.477*	0.262	3.323	0.068	0.621
Yield	1.359	1.203	1.277	0.259	3.892	1.995*	1.024	3.794	0.051	7.355
Training	-0.047	1.448	0.001	0.974	0.954	1.103	1.018	1.174	0.279	3.014
Total land owned	-0.053	0.525	0.010	0.920	0.949	0.205	0.199	1.062	0.303	1.228

Reference category is high levels of knowledge
N =100, **Significant at 5% probability level, *Significant at 10% probability level

The size of land under maize was statistically significantly and negatively associated with a farmer having low relative to high knowledge on the use of inorganic fertilizer (Table 4.15). Farmers with small farms under maize are likely to have low relative to high knowledge levels on the use of inorganic fertilizer. This can be attributed to the fact that having a small farm can reduce the interest of a farmer in searching for knowledge. For a farmer to invest a lot of his resources in search of knowledge; he has to see a viable amount of yield at the end of a planting season. And although inorganic fertilizer use offers an option for increasing agricultural production, it does not provide the whole solution (Mapila *et al*., 2012), especially where maize farms are small.

Off-farm earnings was negatively associated with a farmer's knowledge level being low relative to high in the use of inorganic fertilizer (Table 4.15). This means that a household with no off-farm income is more likely to have a low relative to high level of knowledge in the use of inorganic fertilizer. This can be attributed to the fact that having an off-farm income gives a farmer resources that can be used in the search for knowledge on fertilizer use as opposed to a farmer whose main livelihood is on farm and have no extra income. Marenya and Barrett, (2007) found off-farm income to positively influence farmer uptake of ISFM technologies. This was also the case of Martey *et al*. (2014), who found that a farmer with an off-farm income has more resources to use for inputs and to search for knowledge.

Gender was found to be negatively association with a farmer having moderate relative to high level of knowledge in the use of inorganic fertilizer (Table 4.15). The implication of this is that if the head of a household is female, the level of knowledge is likely to be moderate relative to high in the use of inorganic fertilizer. Females are normally occupied with domestic activities, they also do not have enough financial and human resources and this negatively impact on both use decision and the extent of fertilizer use (Martey *et al*., 2014). This was also the case of Macharia *et al*. (2014) who found gender to be a positive predictor of knowledge levels and that a female household head was less likely to have more knowledge than their male counterparts.

Education of the household head was found to be negatively associated with a farmer having moderate relative to high knowledge levels in the use of inorganic fertilizer (Table 4.15). This means that educated farmers were more likely to have moderate relative to high knowledge levels in the use of inorganic fertilizer. Education's negative association may be because of better opportunities in the non-farm sector, especially for the educated folk. Educated people tend to search for employment off-farm that might give more income. Reardon *et al*. (2000), confirms that better opportunities in the non-farm sector may divest investments from the farm forcing capital substitution, thus resulting in non-adoption of new agricultural technologies. As much as educated household heads are able to decipher information and apply it to their agricultural activities, they might be involved in other off-farm activities and this may hinder the use of these technologies. Adolwa *et al*. (2012) showed that off-farm income was negatively and significantly associated with ISFM uptake, more so, of educated individuals who seek employment off-farm. Similar to our study Mugwe *et al*. (2012) also found education to have a negative effect on the adoption of ISFM.

Household size was also found to be statistically significant and negatively associated with a farmer having moderate relative to high knowledge levels on the use of inorganic fertilizer (Table 4.15). This means that a household with less number of members was more likely to have moderate relative to high knowledge levels in the use of inorganic fertilizer. This can be attributed to the fact that a household with more members has to produce more to feed their large numbers and thus are more likely to use technologies that can increase their yields. The willingness of a household to use fertilizer is shaped by the household's level of knowledge and skills regarding fertilizer technologies and their capacity to evaluate potential gains from fertilizer (Mapfumo *et al*., 2012).

The size of land under maize was found to be negatively associated with a farmer having moderate relative to high knowledge levels in the use of inorganic fertilizer (Table 4.15). This means that a farmer with less size of land is more likely to have moderate relative to high knowledge in the use inorganic fertilizer. Mugi-Ngenga *et al*. (2016) and Macharia *et al*. (2014) also found land size to be a significant negative predictor in determining knowledge levels of new technologies.

Off-farm income was a negative significant factor influencing whether a farmer's knowledge level was moderate relative to high in the use of inorganic fertilizer (Table 4.15). This means that a household that has no off-farm income is more likely to have a moderate relative to high levels of knowledge in the use of inorganic fertilizer. This can be attributed to the fact that having an off-farm income gives a farmer a source of income and thus can invest in seeking of inorganic fertilizer use knowledge to increase yield. This agrees with Marenya and Barret (2010) who found off-farm income to positively influence farmer uptake of ISFM technologies.

Maize yield was found to be statistically significant and positively associated with a farmer having moderate relative to high knowledge level in the use of inorganic fertilizer (Table 4.15). This means that farmers with more yields are more likely to have moderate relative to high knowledge levels in the use of inorganic fertilizer. Maize yields in rural Kenya have remained low due to different factors, and although some farmers have been realizing more yield than others, knowledge levels have to be increased so as to achieve the potential of 6 t/ha that is possible with judicious management of resources (Ngetich *et al*., 2012; Jerenyama *et al*., 2000; Giller *et al*., 1994). Results of this study show an average yield of 1.17t/ha with a minimum of 0.56 and a maximum of 4.44t/ha showing serious difference in yield of farmers within the same region.

4.4.2 Factors affecting levels of knowledge in the use of organic fertilizer among farmers in Runyenjes sub-County

Results of univariate analysis of factors influencing knowledge level in the useee of organic fertilizer indicated that off-farm earnings and farming experience as significant in explaining knowledge levels in the use of organic manure (Table 4.16).

Farmers with off-farm income are associated with resources that can be handy in acquiring information resources. Purchase of radio, television sets, newspapers (some of the sources of ISFM knowledge), travel to demonstration sites, acquisition of brochures and agricultural books requires some monetary allocation. And, this is more practical to farmers with extra income, possible from off-farm sources. Farmers with more farming experience are more likely to have more knowledge given the time they have had experimenting with new technologies (Adolwa *et al*., 2012).

Table 4.16: Univariate results of factors influencing levels of knowledge in the use of organic fertilizer among farmers in Runyenjes sub-County

Independent variables		**Knowledge level**			**χ^2 P value**
		Low	**Moderate**	**High**	
Gender of household head	Male	2	21	48	Ns
	Female	2	6	21	
Education of household head	No education	1	4	12	Ns
	Primary	2	14	29	
	Secondary	1	7	24	
	Tertiary	0	2	4	
Off-farm earnings (Ksh)	Below 10000	3	20	56	0.091*
	10000 to 30000	0	7	11	
	Above 30000	1	0	2	
Training on animal manure	Yes	0	2	18	Ns
	No	4	25	51	
Values are percentages, N=100					
		Mean	**Mean**	**Mean**	**t-test**
Age of household head (yrs)		65.8 (15.1)	56.7 (15.3)	54.6 (15.3)	Ns
Size of house hold		6 (3)	4 (2)	5 (3)	Ns
Farming experience (yrs)		40.8 (8.6)	27.3 (18.3)	31.0 (17.0)	0.054*
Size of land under maize (ha)		0.60 (0.24)	0.48 (0.37)	0.57 (0.40)	Ns
Yield (t/ha)		1.1 (0.56)	1.14 (0.87)	1.15 (0.94)	Ns
Total land owned (ha)		1.15 (0.87)	0.89 (0.86)	1.28 (1.96)	Ns

Values in parentheses are standard deviations, N=100
*association significant at $\alpha = 0.05$, Ns=Not significant

Only one variable was found to be significant in determining whether a farmer had moderate relative to high knowledge levels at 1% probability level in the use of organic fertilizer (Table 4.17).

Training was found to be statistically significant and positively associated with a farmer having moderate relative to high knowledge levels in the use of organic fertilizer (Table 4.17). This means that a farmer with training on organic manure is more likely to have moderate relative to high level of knowledge in the use of organic manure. Studies by Macharia *et al*. (2014); Geta *et al.* (2013) and Macharia *et al*. (2012) showed that having been trained in organic fertilizer was a significant factor in determining whether a household used organic fertilizer.

Table 4.17: Factors affecting levels of knowledge in the use of organic fertilizer use among farmers in Runyenjes sub-County

Independent variables	Low knowledge level					Moderate knowledge level				
	β	S.E.	Wald	Sig.	Exp(β)	B	S.E.	Wald	Sig.	Exp(β)
Intercept	-5.551	6.151	0.814	0.367	_	1.214	2.637	0.212	0.645	_
HHH gender	0.799	1.353	0.349	0.555	2.224	0.000	0.823	0.000	1.000	1.000
HHH age (yrs)	0.046	0.068	0.462	0.497	1.047	0.001	0.035	0.001	0.969	1.001
HHH education	-0.559	0.916	0.373	0.541	0.572	-0.575	0.489	1.382	0.240	0.563
HH size	0.026	0.260	0.010	0.922	1.026	-0.062	0.145	0.181	0.671	0.940
Farming experience	-0.011	0.060	0.032	0.857	0.989	-0.012	0.033	0.126	0.723	0.988
Size of land under maize	0.016	0.742	0.000	0.982	1.016	-0.482	0.364	1.757	0.185	0.618
Off-farm earnings	0.004	0.362	0.000	0.991	1.004	0.038	0.198	0.036	0.849	1.038
Maize yield	0.088	0.734	0.014	0.905	1.092	-0.050	0.346	0.021	0.885	0.951
Training in animal manure	1.077	1.350	0.637	0.425	2.936	1.765***	0.670	6.931	0.008	5.841
Total land	0.031	0.219	0.019	0.889	1.031	0.091	0.124	0.535	0.465	1.095

Reference category is high levels of knowledge
N =100, ***Significant at 1% probability level

Furthermore, factors relating to the availability of information and training, and incentives that are associated with the dissemination of the technology play important roles (Ajayi *et al.*, 2007) in their use.

4.4.3 Factors affecting levels of knowledge in the use of inorganic fertilizer and organic fertilizer among farmers in Runyenjes sub-County

Results of univariate analysis showed occupation of the household head as having a significant association with knowledge levels in the combined used of inorganic and organic fertilizers in maize cultivation (Table 4.18). Similar to this, a recent study by Mugi-Ngenga *et al.* (2016) showed occupation as a significant factor in determining knowledge and use of new technologies.

Table 4.18: Univariate results of factors influencing levels of knowledge in the combined use of inorganic and organic fertilizer among farmers in Runyenjes sub-County

Independent variables		**Knowledge level**			**χ^2 P value**
		Low	**Moderate**	**High**	
Gender of household head	Male	6	28	40	Ns
	Female	2	14	10	
Education of household head	No education	5	8	4	Ns
	Primary	2	21	21	
	Secondary	1	11	21	
	Tertiary	0	2	4	
Occupation of household head	Farming	5	37	34	0.047*
	Business/Employed	3	5	16	
Off-farm earnings (Ksh)	Below 10000	7	36	31	Ns
	10000 to 30000	1	6	14	
	Above 30000	0	0	5	
Household monthly income	Below 10000	8	36	36	Ns
	10000 to 30000	0	4	12	
	Above 30000	0	2	2	
Values are percentages, N=100					
		Mean	**Mean**	**Mean**	**t-test**
Age of household head		51.4 (13.3)	59.5 (16.1)	52.8 (14.3)	Ns
Size of household		4 (2)	5 (3)	5 (2)	Ns
HH members farming		2 (1)	3 (2)	2 (1)	Ns
Farming experience		30.0 (11.7)	35.0 (18.1)	26.4 (16.2)	Ns
Yield (t/ha)		0.67 (0.61)	0.97 (0.66)	1.33 (1.05)	Ns
Total land owned (ha)		0.76 (0.46)	1.36 (2.5)	1.05 (0.75)	Ns

Values in parentheses are standard deviations, N=100
*association significant at $\alpha = 0.05$, Ns=Not significant

Regression results indicated gender, number of household members farming, maize yield and off-farm earnings as predictors of whether farmer knowledge level was low relative to high in the combined use of inorganic and organic fertilizer. The model also predicted household head age, number of household head members farming and farming experience as predictors of whether a farmer had moderate relative to high knowledge in the combined use of inorganic and organic fertilizer (Table 4.19).

Table 4.19: Factors affecting levels of knowledge in the combined use of inorganic fertilizer and organic fertilizer among farmers in Runyenjes sub-County

Independent variables	**Low knowledge level**					**Moderate knowledge level**				
	β	**S.E.**	**Wald**	**Sig.**	**Exp(β)**	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(β)**
Intercept	-0.210	3.907	0.003	0.957	–	2.135	3.377	0.400	0.527	–
HHH gender	2.323*	1.393	2.780	0.095	10.206	1.127	1.324	0.724	0.395	3.086
HHH age	-0.062	0.044	1.928	0.165	0.940	-0.084**	0.041	4.285	0.038	0.919
HHH education	-0.439	0.633	0.482	0.488	0.645	-0.056	0.564	0.010	0.921	0.945
HHH occupation	1.189	1.266	0.883	0.347	3.285	0.903	1.089	0.688	0.407	2.467
HH size	-0.356	0.233	2.328	0.127	0.700	-0.290	0.194	2.243	0.134	0.748
HH members farming	1.366**	0.555	6.057	0.014	3.918	1.071**	0.516	4.300	0.038	2.918
Farming experience	0.069	0.041	2.747	0.097	1.071	0.071*	0.037	3.638	0.056	1.074
Total land owned	-0.100	0.152	0.432	0.511	0.905	-0.008	0.088	0.009	0.924	0.992
Maize yield in t/ha	-1.008*	0.518	3.792	0.051	0.365	-0.634	0.390	2.645	0.104	0.530
Off-farm earnings	-0.576**	0.283	4.152	0.042	0.562	-0.277	0.193	2.046	0.153	0.758
HH monthly income	0.113	0.395	0.082	0.774	1.120	0.259	0.304	0.726	0.394	1.296

Reference category is high level of knowledge

N =100, **Significant at 5% probability level, *Significant at 10% probability level

The gender of the household was found to be positively associated with a having farmer had low relative to high knowledge level in the combined use of inorganic and organic fertilizer (Table 4.19). This implies that a male household head is more likely to have low relative to high level of knowledge in the combined use of inorganic and organic fertilizer. Although males command most of the household resources, including use of cash income, it is the females that are left to take care of the farm work (Waithaka *et al.*, 2007). This makes females more likely to be more aware of information on new technologies.

The number of household members farming was found to be statistically significant and positive in predicting whether a farmer had low relative to high level of knowledge in the combined use of inorganic and organic fertilizer (Table 4.19). This implies that a farmer with a large household is more likely to have low relative to high knowledge levels in the combined use of inorganic and organic fertilizer. Large households demand more resources, thus little resources are set aside in search of knowledge. A study by Marenya and Barret (2007) in western Kenya confirms resource constraints limit many farmers' adoption and use of ISFM techniques and this may impact their knowledge of the same.

Maize yield was found to be negatively associated with whether a farmer had low relative to high knowledge level in the combined use of inorganic and organic fertilizer for maize production (Table 4.19). This means that a farmer with less maize yield is more likely to have low relative high levels of knowledge in the combined use of inorganic and organic fertilizer for maize production. It is proper to assume that farmers with more yields are more knowledgeable on the use of ISFM. It is thus important and paramount to account for economic returns of introduced soil technologies (Mucheru-Muna *et al*., 2014; Mucheru-Muna *et al*., 2007), probably through yield and associated gains from sales of excessive produce.

Off-farm farming income was a negative predictor of whether a farmer had low relative to high knowledge in the combined use of inorganic and organic fertilizer (Table 4.19). This implies that a farmer without an off-farm income is more likely to have low relative to high knowledge levels in the combined use of inorganic and organic fertilizer. A study by Adolwa *et al*. (2012) and Akinola *et al*. (2010) also linked having an off-farm income with having access to resources that can increase knowledge of strategies. Farmers with off-farm sources of income can be able to purchase resources that are knowledge sources; these include radios, television sets, newspaper among others. These farmers are also able to attend field days and demonstrations further from their homes as opposed to farmers with less income who can only attend those organized within walking distances.

Age was found negatively associated with whether a farmer had moderate relative to high knowledge level in the combined use of inorganic and organic fertilizer (Table 4.19). This implies that younger farmers are more likely to have moderate relative to high knowledge in the combined use of organic and inorganic fertilizer. This agrees with Macharia *et al*. (2014), Macharia *et al*. (2012) and Geta *et al*. (2013) studies that showed younger farmers having less experience to give them enough knowledge on the use of combined fertilizer as opposed to their much older farmer counterparts.

The number of household members farming found to positively predict whether a farmer had moderate relative to high knowledge level in the combined use of inorganic and organic fertilizer (Table 4.19). This shows that a household with a large number of members involved in farming was more likely to have moderate relative to high level of knowledge in the use of combined inorganic and organic fertilizer. As much as having a good number of members of a household involved in farming is a boost in labour availability, the large households may spend much income on food and other essential expenditures, leaving little for investment on farms including the purchase of farm resources (Waithaka *et al*., 2007) of which might be knowledge sources.

Farming experience was found to be a significant positive predictor of whether a farmer had moderate relative to high levels of knowledge in the combined use of inorganic and organic fertilizer (Table 4.19). This means that a farmer with more experience in farming is more likely to have moderate relative to high knowledge in the combined use of inorganic and organic fertilizer. This can be attributed to the fact that experienced farmers are more skeptical to new technologies as opposed to less experienced farmers who are eager to experiment new technologies. Experienced farmers are accustomed to certain ways of doing things (Akinola *et al*., 2010).

4.4.4 Factors affecting knowledge levels of improved seeds use among farmers in Runyenjes sub-County

Results of univariate analysis of variables influencing knowledge in improved seeds showed that four variables were significant in explaining knowledge levels of farmers in the use of improved seeds. Occupation of household head, off-farm earnings, enough household labour and farming experience were all variables found to have a significant association with knowledge in the use of improved seeds (Table 4.20).

Table 4.20: Univariate results of factors influencing levels of knowledge in the use of improved seeds among smallholder farmers in Runyenjes sub-County

Independent variables		**Knowledge level**			**χ^2 P value**
		Low	**Moderate**	**High**	
Household head gender	Male	2	29	41	Ns
	Female	1	9	18	
Education of household head	No education	0	8	8	Ns
	Primary	1	17	27	
	Secondary	2	11	20	
	Tertiary	0	2	4	
Occupation of household head	Farming	1	27	51	0.028*
	Business/Employed	2	11	8	
Off-farm earnings (Ksh)	Below 10000	3	28	46	0.007*
	10000 to 30000	0	10	8	
	Above 30000	0	0	5	
Enough household labour	Yes	1	12	8	0.09*
	No	2	24	51	
Training in improved seeds	Yes	0	11	11	Ns
	No	3	25	48	

Values are percentages, N=100

	Mean	**Mean**	**Mean**	**t-test**
Age of household head (yrs)	60.3 (13.1)	56.1 (17.8)	55.0 (13.8)	Ns
Size of household	4 (2)	5 (2)	5 (3)	Ns
Farming experience (yrs)	36.7 (5.8)	30.5 (18.5)	29.7 (16.9)	0.054*
Size of land under maize (ha)	0.37 (0.25)	0.57 (0.41)	0.55 (0.39)	Ns
Total land owned (ha)	0.56 (0.40)	1.36 (2.5)	1.40 (2.14)	Ns
Months household buys food	0 (0)	0.86 (0.57)	1.0 (2.0)	Ns
Yield (t/ha)	0.38 (0.25)	1.16 (1.00)	1.19 (0.85)	Ns

Values in parentheses are standard deviations, N=100
*association significant at $\alpha = 0.05$, Ns=Not significant

Mugi-Ngenga *et al*. (2016), Martey *et al*. (2014) and Geta *et al*. (2013) found that farmers who solely practised farming to be more likely to invest in inputs to increase yields. These farmers have their farms as their main source of livelihood and thus have to search for knowledge and resources to increase their yields. It is thus not surprising that Marenya and Barret (2007) found off-farm income and family labor to influence farmer ISFM uptake.

The regression results indicated that household size was a significant predictor of whether a farmer had low relative to high knowledge level in the use of improved seeds. The model also showed that household head education, total land owned and maize land as significant predictors of whether a farmer had moderate relative to high knowledge in the use of improved seeds at 10% probability level (Table 4.21).

Table 4.21: Factors affecting levels of knowledge in the use of improved seeds among farmers in Runyenjes sub-County

Independent variables	Low knowledge level **B**	**S.E.**	**Wald**	**Sig.**	**Exp(β)**	Moderate knowledge level **β**	**S.E.**	**Wald**	**Sig.**	**Exp(β)**
Intercept	8.539	5.840	2.138	0.144	_	11.216	5.631	3.967	0.046	_
HHH gender	-0.144	1.111	0.017	0.897	0.866	-0.156	1.025	0.023	0.879	0.855
HHH age	0.025	0.058	0.194	0.659	1.026	-0.027	0.057	0.231	0.631	0.973
HHH education	-1.019	0.794	1.645	0.200	0.361	-1.487**	0.757	3.863	0.049	0.226
HHH occupation	0.310	1.205	0.066	0.797	1.364	-0.733	1.155	0.403	0.526	0.480
HH size	-0.382*	0.230	2.753	0.097	0.683	-0.315	0.207	2.312	0.128	0.730
Farming experience	-0.045	0.050	0.785	0.375	0.956	-0.044	0.050	0.785	0.376	0.957
Total land owned	0.573	0.967	0.351	0.554	1.773	1.758*	0.974	3.259	0.071	5.799
Land under maize	0.178	1.361	0.017	0.896	1.195	-2.787*	1.445	3.719	0.054	0.062
HH labour	-1.761	1.358	1.681	0.195	0.172	-0.282	1.309	0.046	0.830	0.754
Off-farm earnings	0.080	0.309	0.067	0.796	1.083	-0.094	0.276	0.117	0.733	0.910
Months HH bought food	0.240	0.294	0.669	0.413	1.272	0.078	0.291	0.072	0.788	1.081
Yield in t/ha	0.799	0.747	1.143	0.285	2.223	0.812	0.703	1.333	0.248	2.253
Training	-1.153	1.144	1.017	0.313	0.316	-0.102	1.102	0.009	0.926	0.903

Reference category is high levels of knowledge
N =100, **Significant at 5% probability level, *Significant at 10% probability level

Household size was found to be a negative predictor of whether a farmer had low relative to high knowledge in the use of improved seeds (Table 4.21). This means that smaller households are more likely to have low relative to high knowledge levels in the use of improved seeds. Small households do not require a lot of resources and this might hinder their quest for knowledge to increase their maize yield.

The education level of the household head was found to be negatively associated with whether knowledge level of a farmer was moderate relative to high in the use of improved seeds (Table 4.21). This implies that farmers with low levels of education were more likely to have moderate relative to high knowledge level in the use of improved seeds improved maize seeds. The process of information seeking and its accessibility generally requires the information seeker to have attained some level of literacy (Adolwa *et al*., 2012). Similarly, education level of the farmer critically influenced uptake of integrated soil fertility management (Adolwa *et al*., 2012; Marenya and Barret, 2007).

Total land owned was found to be statistically significant and positively associated with a farmer having moderate relative to high knowledge level in the use of improved seeds (Table 4.21). This indicates that farmers with less land are more likely to have moderate relative to high level of knowledge in the use of improved seeds. In Macharia *et al*. (2012) study, land size was found to be a significant positive predictor of knowledge levels in the use of integrated soil fertility management strategies. This means that owning large pieces of land are likely to have more knowledge in improved seeds use.

Total land under maize was found to be a negative in determining whether knowledge level of a farmer was moderate relative to high in the use of improved seeds (Table 4.21). This means that a farmer with a smaller size of land under maize is more likely to have moderate relative to high knowledge in the use of improved seeds. Given the resource constraint nature of smallholder farmers in rural Africa, they are probably only able to allocate little resources in the quest for knowledge. Ajayi *et al*. (2007) explain that investment on farming by a household is closely related to a household's resource endowment and a household ability to purchase farm inputs. Marenya and Barret (2007) clearly stated that unobserved constraints and shadow prices facing households vary systematically with farm size.

4.4.5 Factors affecting knowledge levels on the use of combined inorganic and organic fertilizer with improved seeds use in Runyenjes sub-County

Results of univariate analysis showed that one variable was significant in explaining knowledge levels in the use of combined inorganic and organic fertilizer with improved seeds (Table 4.22).

Table 4.22: Univariate analysis of factors affecting levels of knowledge in the combined use of inorganic and organic fertilizer with improved seeds among farmers in Runyenjes sub-County

Independent variables		**Knowledge level**			**χ^2 P value**
		Low	**Moderate**	**High**	
Gender of household head	Male	1	10	51	Ns
	Female	0	8	30	
Education of household head	No education	1	7	4	Ns
	Primary	0	8	40	
	Secondary	0	3	31	
	Tertiary	0	0	6	
Occupation of household head	Farming	1	13	63	Ns
	Business/Employed	0	5	18	
Off-farm earnings (Ksh)	Below 10000	1	15	64	Ns
	10000 to 30000	0	3	13	
	Above 30000	0	0	4	
Monthly income (Ksh)	Below 10000	1	15	66	Ns
	10000 to 30000	0	1	12	
	Above 30000	0	2	3	
Enough household labour	Yes	0	5	12	Ns
	No	1	13	69	
Values are percentages, N=100					
		Mean	**Mean**	**Mean**	**t-test**
Age of household head (yrs)		62.5 (0)	55.4 (15.6)	53.9 (14.1)	Ns
Size of household		5 (0)	6 (3)	5 (2)	Ns
HH members farming		2 (0)	3 (2)	2 (1)	Ns
Farming experience (yrs)		38.8 (0)	31.4 (19.5)	27.8 (16.2)	Ns
Yield (t/ha)		0.90 (0)	0.97 (0.66)	1.23 (0.94)	0.059*
Total land owned (ha)		0.85 (0)	1.04 (0.90)	1.28 (2.0)	Ns

Values in parentheses are standard deviations, N=100
*association significant at $\alpha = 0.05$, Ns=Not significant

The regression results indicated off-farm income and household labour as significant predictors of whether a farmer had moderate relative to high knowledge level in the use combined inorganic and organic fertilizer with improved seeds at 10% significant level.

Off-farm income was statistically significantly and negatively associated with a farmer having moderate relative to high knowledge in the use of combined inorganic and organic fertilizer with improved seeds (Table 4.23). This shows that households with less off-farm income are more likely to have moderate relative to high knowledge in the use of combined inorganic and organic fertilizer with improved seeds. Martey *et al*. (2014) and

Waithaka *et al*. (2007) realized that household heads who are engaged in farming as their main occupation were more likely to be aware of more technologies to improve their yields as their farms were their main source of livelihood.

Table 4.23: Factors affecting levels of knowledge in the combined use inorganic and organic fertilizer with improved seeds use in Runyenjes sub-County

Independent	**Low knowledge level**					**Moderate knowledge level**				
variables	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(β)**	**β**	**S.E.**	**Wald**	**Sig.**	**Exp(β)**
Intercept	-0.318	4.292	0.005	0.941	–	0.163	2.217	0.005	0.941	–
HHH gender	0.810	1.103	0.539	0.463	2.247	0.111	0.597	0.034	0.853	1.117
HHH age	0.018	0.051	0.132	0.717	1.019	0.027	0.028	0.905	0.341	1.027
HHH education	-0.863	0.764	1.274	0.259	0.422	-0.114	0.336	0.116	0.733	0.892
HHH occupation	0.043	1.377	0.001	0.975	1.044	0.688	0.642	1.147	0.284	1.989
HH size	0.220	0.266	0.682	0.409	1.246	-0.034	0.125	0.073	0.787	0.967
HH members farming	0.205	0.379	0.291	0.589	1.227	-0.091	0.216	0.175	0.675	0.913
Farming experience	-0.064	0.051	1.526	0.217	0.938	-0.004	0.026	0.028	0.866	0.996
Total land owned	-1.017	1.269	0.643	0.423	0.362	-0.081	0.187	0.187	0.665	0.922
Yield in t/ha	0.212	0.565	0141	0.707	1.237	0.387	0.275	1.974	0.160	1.472
Off-farm earnings	-0.295	0.361	0.668	0.414	0.744	-0.321*	0.186	2.983	0.084	0.725
Monthly income	0.101	0.484	0.043	0.835	1.106	0.024	0.232	0.010	0.919	1.024
HH labour	-0.767	1.220	0.395	0.530	0.464	-1.314**	0.633	4.305	0.038	0.269

Reference category is Very high levels of knowledge
N =100, **Significant at 5% probability level, *Significant at 10% probability level

Household labour was found to be a negatively associated with whether a farmer had moderate relative to high knowledge levels in the combined inorganic and organic fertilizer with improved seeds use (Table 4.23). This implies that a household with inadequate household labour was more likely to have moderate relative to high knowledge level in the combined use of inorganic and organic fertilizer with improved seeds. Mugi-Ngenga *et al*. (2016) and Macharia *et al*. (2012) also realized that availability of labour associated with a large household size to have positive associations with use of technologies.

4.5 Farmers level of knowledge and use of ISFM strategies for maize production intensification

4.5.1 Farmers levels of knowledge and use of inorganic fertilizer in Runyenjes sub-County

The results showed that majority (94%) of the households interviewed used inorganic fertilizer in the cultivation of maize (Table 4.24).

Table 4.24: Farmers levels of knowledge and use of inorganic fertilizer among farmers in Runyenjes sub-County

Level of knowledge of inorganic fertilizer	**Use of inorganic fertilizer**		**Total**
	Use (%)	Do not use (%)	
Low	7(7%)	1(1%)	8%
Moderate	41(41%)	5(5%)	46%
High	46(46%)	0(0%)	46%
Total	**94(94%)**	**6(6%)**	**100(100%)**

Out of the users, 46% had high knowledge levels in inorganic fertilizer, 41% had moderate levels of knowledge as 7% had low knowledge levels in the use of inorganic fertilizer (Table 4.24). The non-users of inorganic fertilizer had 1% of the farmers interviewed having high knowledge levels and 5% having moderate knowledge levels (Table 4.24). There was no significant association between use of inorganic fertilizers and levels of knowledge in inorganic fertilizers (χ^2=3.343, *p*=0.188). This was also similar to the study of Macharia *et al.*, (2012)who acknowledged that having high knowledge on inorganic fertilizers does not necessarily lead to its use during farming.

4.5.2 Farmers levels of knowledge and use of organic fertilizer in Runyenjes sub-County

The results show that a large percentage of the households interviewed (78%) used organic fertilizer in the cultivation of their maize crop (Table 4.25).

Table 4.25: Farmers levels of knowledge and use of organic fertilizer among farmers in Runyenjes sub-County

Level of knowledge of organic fertilizer	**Use of organic fertilizer**		**Total**
	Use (%)	Do not use (%)	
Low	4(4%)	1(1%)	5%
Moderate	20(20%)	7(7%)	27%
High	54(54%)	15(15%)	69%
Total	**78(78%)**	**22(22%)**	**100(100%)**

Out of the users interviewed, 54% had high knowledge levels, 20% had moderate knowledge levels as another 4% had low knowledge levels in the use of organic fertilizer (Table 4.25). The non-users of organic fertilizer had 15% of the farmers interviewed having high knowledge levels, 7% having moderate knowledge levels and 1% having low knowledge levels. There was no significant association between the use and knowledge level of organic fertilizer (χ^2=1.373, p=0.503)**.** This implies that farmers used organic manure regardless of the level of knowledge they had on organic manure.

4.5.3 Farmers levels of knowledge and use of combined inorganic and organic fertilizer in Runyenjes sub-County

The results show the use of combined inorganic and organic fertilizer in the cultivation of their maize crop had 76% users (Table 4.26).

Table 4.26: Farmers levels of knowledge and use of combined inorganic and organic fertilizer among farmers in Runyenjes sub-County

Level of knowledge of combined organic and inorganic fertilizer	**Use of combined fertilizer**		**Total**
	Use (%)	Do not use (%)	
Low	7(7%)	1(1%)	8%
Moderate	30(30%)	12(12%)	42%
High	39(39%)	11(14%)	50%
Total	**76(76%)**	**24(24%)**	**100(100%)**

Out of the farmers interviewed, 39% users had high knowledge levels, 30% had moderate knowledge levels, as another 7% had low knowledge levels in the combined used of inorganic and organic fertilizer (Table 4.26**)**. The non-users of combined inorganic and organic fertilizer had 11% of the farmers having high knowledge level, 12% having moderate knowledge levels as 1% had low knowledge levels in the combined used of inorganic and organic fertilizer (Table 4.26).

There was no significant association between the use and knowledge level of inorganic and organic fertilizer (χ^2=0.186, *p*=0.911)**.** This implies that in the study area having knowledge in the combined inorganic and organic fertilizer does not necessarily necessitate its use in maize cultivation.

4.5.4 Farmers levels of knowledge and use of improved seeds in Runyenjes sub-County

The results show that majority (92%) of the households interviewed used improved seeds in the cultivation of maize (Table 4.27).

Table 4.27: Farmers levels of knowledge and use of improved seeds in among farmers Runyenjes sub-County

Level of knowledge of improved seeds	**Use of improved seeds**		**Total**
	Use (%)	Do not use (%)	
Low	3(3%)	0(0%)	3%
Moderate	31(31%)	7(7%)	38%
High	58(58%)	1(1%)	59%
Total	**92(92%)**	**8(8%)**	**100(100%)**

A majority (58%) of the users of improved seeds had high knowledge levels in its use, 31% of the users had moderate knowledge levels as 3% had low knowledge levels (Table 4.27). The non-users had 1% having high knowledge levels and 7% having moderate knowledge levels in the use of improved maize seeds (Table 4.27).There was a significant association between the use and knowledge level of improved seeds (χ^2= 9.055, *p*=0.011). This implies that the use of improved seeds in maize cultivation strongly relied on the knowledge level of a farmer in the use of improved seeds for maize cultivation.

4.5.5 Farmers levels of knowledge and use of combined inorganic and organic fertilizer with improved seeds in Runyenjes sub-County

Results indicate that a favorable percentage of the households interviewed (68%) used combined inorganic and organic fertilizer with improved seeds in the cultivation of their maize crop (Table 4.28).

Table 4.28: Farmers levels of knowledge and use of combined inorganic and organic fertilizer with improved seeds among farmers in Runyenjes sub-County

Level of knowledge of combined organic and inorganic fertilizer with improved seeds	**Use of combined fertilizer with improved seeds**		**Total**
	Use (%)	Do not use (%)	
Low	0(0%)	1(1)	1%
Moderate	12(12%)	6(6%)	18%
High	56(56%)	25(25%)	81%
Total	**68(68%)**	**32(32%)**	**100(100%)**

The results show that 56% of the farmers interviewed also used combined inorganic and organic fertilizer with improved seeds had high knowledge in its use, 12% had moderate knowledge levels on the same (Table 4.28). The non-users had 25% of the farmers having high knowledge in the use of combined inorganic and organic fertilizer with improved seeds, 6% having moderate levels of knowledge as 1% had low knowledge levels in the combined use of inorganic and organic fertilizer with improved seeds (Table 4.28). There was no significant association between the use and knowledge level of inorganic and organic fertilizer (χ^2=2.188, p=0.335). This shows that regardless of the farmers being significantly knowledgeable in the combined inorganic and organic fertilizer with improved seeds, it did not necessary lead to its use in maize cultivation.

4.6 Management factors affecting phosphorus levels in farmers' soils

Results showed the mean available phosphorus level in the study area as 39.75 mg/kg P, the farm with the lowest available phosphorus level had 10.0 mg/kg while the farm with the highest level had 125.0 mg/kg. The available P observations were evenly distributed. The interquartile range for available P lied between 35 and 40 mg/kg while the median was about 35 mg/kg (Figure 4.2).

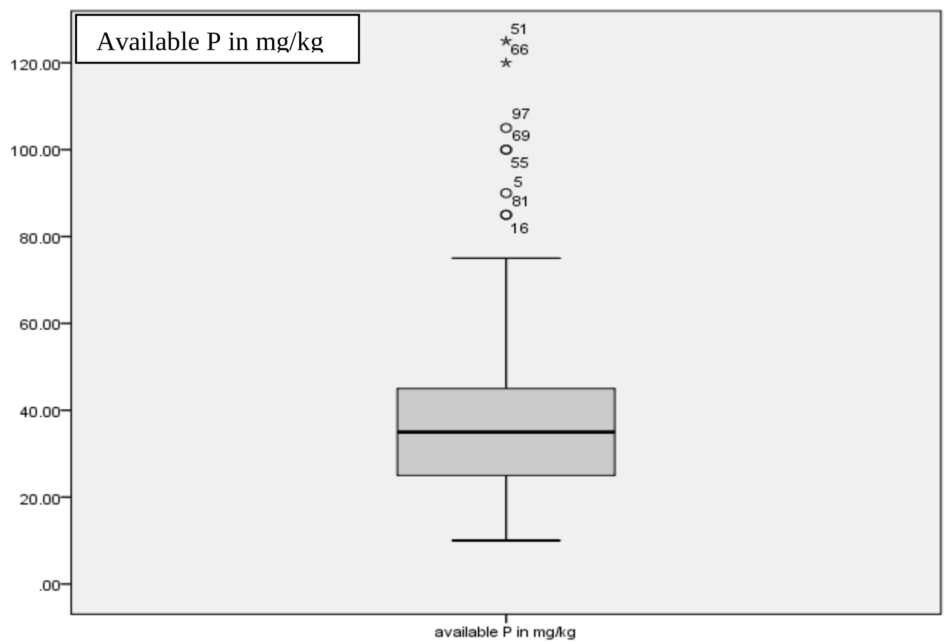

Figure 4.2: Box plot displaying levels of available phosphorus within smallholder farms in Runyenjes sub-County

Several farmers (8) had available P on their farms falling in the outlier region (Figure 4.2). These farmers had high available P on their maize farms. Data showed that these farmers had several factors in common. For example, they applied significantly higher amounts of P fertilizer on their maize farms. This can be attributed to the high off-farm income that they had that enabled them to purchase more fertilizer. According to Barret and Marenya (2007), off-farm income plays a significant role in fertilizer acquisition and use. These farmers also had significant tropical livestock units, and according to Adolwa *et al*. (2012), livestock is very crucial in a farming system as they are a major source of manure.

Results also indicated that all the farms surveyed had acidic soils (Figure 4.3), the mean pH for the farms was recorded at 5.9. The pH ranged from 4.33 to 6.95, while the interquartile range of pH lied between 5.50 and 5.60. The median was also about 5.60.

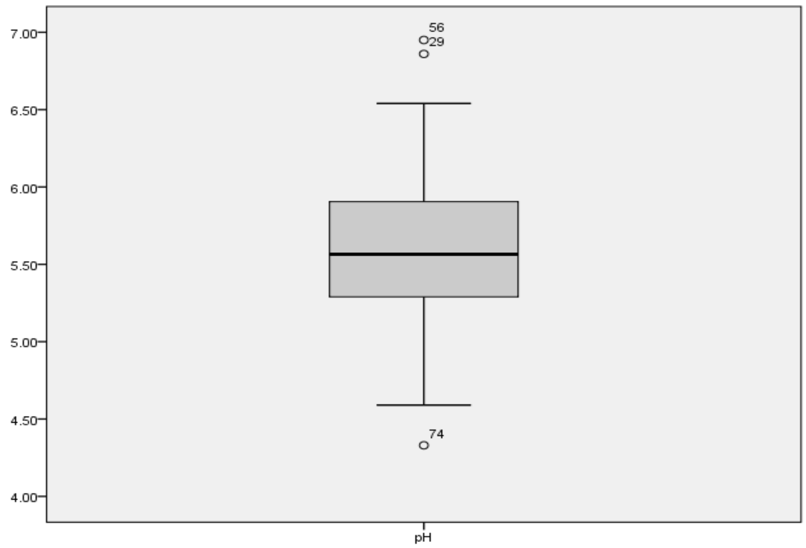

Figure 4.3: Box plot displaying pH levels within smallholder farms in Runyenjes sub-County

Two farmers had maize farms with pH of almost neutral alkalinity. From data collected, it was not surprising that these farmers practice liming on their maize farms, probably reducing acidity. According to Mbakaya *et al*. (2008), liming reduces acidity and increases nutrient availability. It is thus not surprising that results from his study experiment showed a tremendous increase in maize yield in plots where lime was added. Furthermore, these farmers were among those who controlled erosion on their farms and thus experienced less runoff and leaching that are partly responsible for acidity in soils. One farmer had very acidic soil, and from the data, we can associate this with the lack of erosion control given that his maize farm experienced erosion. The farmer also did not use any manure on his maize farm.

4.6.1 Farmer management factors affecting phosphorus levels in farm soils of Runyenjes sub-County

Results showed that amount of NPK 23:23:0, intercropping of maize, liming, soil testing and total land owned as positive significant management factors affecting amounts of available P in farmer soils (Table 4.29). The amount of NPK 23:23:0 a farmer applied on his maize farm had significant and positive associations with the amounts of available P in smallholder farms in the study area.

Table 4.29: Farmers management factors affecting available phosphorus amounts in maize farms of Runyenjes sub-County

Independent variable	β	S.E.	Beta	t	Sig.
(Constant)	66.254	36.888		1.796	0.076
Amount of DAP applied	-0.026	0.099	-0.034	-0.259	0.796
Amount of NPK 23:23:0 applied	0.137	0.082	0.200	1.683	0.096*
Amount TSP applied	-0.122	0.343	-0.040	-0.357	0.722
Amount CAN applied	0.022	0.063	0.050	0.343	0.732
Amount of foliar applied	5.571	10.878	0.086	0.512	0.610
Intercropping of maize	11.301	5.474	0.227	2.064	0.042**
Continuous P application	4.287	4.832	0.098	0.887	0.378
Animal manure use	-3.663	7.676	-0.059	-0.477	0.634
Liming of soil	46.442	17.684	0.368	2.626	0.010***
Training on inorganic fertilizer	2.980	3.087	0.114	0.965	0.337
Training on animal manure	-5.290	6.641	-0.098	-0.796	0.428
Size of land under maize	-3.805	2.995	-0.171	-1.270	0.207
Total land owned by farmer	1.327	0.592	0.261	2.242	0.028**

Dependent Variable: P in mg/kg
N =100, **Significant at 5% probability level, *Significant at 10% probability level

This means that a farmer who applied more NPK 23:23:0 on his maize farm was more likely to have a farm with high levels of available P. High phosphorus (P) fixation is a serious problem in Africa, and although phosphatic fertilizers are imported and costly for the average farmer (Yamoah *et al*., 1996), it is one of the most viable and practical ways of increasing phosphorus levels in the soil.

Intercropping of maize with a legume was found to be a positive predictor of whether levels of available phosphorus were high in smallholder farms in Runyenjes sub-County

(Table 4.29). This implied that farmers who intercropped their maize with other legumes were more likely to have high amounts of available P in their maize farms. Synergies between N (probably added by legume intercrop) and P nutrients allow for more uptake of P than sole P application. Ademba *et al*. (2015) and Teng and Timmer (1994) explained that there is higher P nutrient availability with combined N and P than the sole P application, and this could be attributed to the synergistic N enhancement of P uptake.

Liming of soil by a smallholder farmer was found to be statistically significant and positively associated with high available P amounts (Table 4.29). This shows the more a farmer applied lime to reduce soil acidity, the more the amount of available P. Sustainable agriculture is threatened by widespread acidity in many parts (Yamoah *et al*., 1996), however, application of lime has been reported to significantly improve soil fertility (Nduwumuremyi *et al*., 2013). In regards to this, liming must be done considerably. For example, Yamoah *et al*. (1996) explain that experimental results showed that liming was most effective at low P rates and its effect on yield diminished with increasing P fertilization. Reduced acidity results in more nutrient availability, especially of nutrients prone to leaching and movement during rainfall. Mbakaya *et al*. (2011) explain that acidity has been found to retard plant growth through H^+ and Al^{3+} ionic effects, mineral ion toxicity or by indirectly interfering with mineral availability.

Soil testing by the farmer was found to be positively associated with available P amounts in smallholder farms of Runyenjes sub-County (Table 4.29). This shows that a farmer who tested their soil for the nutrient level was likely to have high levels of available P on his maize farm. Soil testing enables a farmer to know which nutrients are insufficient and thus fertilize his farm appropriately. The extent of nutrient depletion is unknown and phosphate fertilizer and manure application by farmers are not commensurate with the plant requirements and/ or nutrient levels in the soil (Ademba *et al*., 2015), and thus the importance of soil fertility determination testing for recommendation and fertilization.

Total land owned by had positive in determining whether available P levels were high in smallholder farms in Runyenjes sub-County (Table 4.29). This shows that farmers having large tracts of land were more likely to have high levels of available P on their maize lands. This can be attributed to the fact that farmers that own big sizes of land are associated with being rich and can be able to purchase inputs in adequacy. A farmer with big pieces of land can hire out or even sell part of his land to purchase farm inputs. Such a farmer has resources to purchase livestock responsible for most of the organic inputs in rural areas. Zingore *et al*. (2007) explain that resource 'rich' farmers are able to provide inputs to all their land. In addition, Mutegi and Zingore (2013) explained that insufficient nutrient application happens because inorganic fertilizers are often too expensive for most of the rural farmers, whilst organic resources are available in limited quantities. This implies that only resource rich farmers can be able to provide inputs in adequate quantities. Furthermore, available P is also a good indicator for predicting previous land management that is also invariably linked to farmer resource endowment (Chikowo *et al*., 2014).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Summary of results and conclusions

Household size, off-farm income, the size of land under maize and maize yield were factors found to be significant in predicting phosphorus fertilizer use for maize production among smallholder farmers in Runyenjes sub-County. Occupation of the household head, the size of land under maize, off-farm income, maize yield and training were significant predictors of animal manure use for maize production among smallholder farmers in Runyenjes sub-County. In regards to the use of combined inorganic fertilizer and animal manure with improved maize seeds, the size of land under maize, enough household labor, off-farm income and tropical livestock unit were significant predictors.

Results showed that in the use of inorganic fertilizer, knowledge levels among farmers was high. In the use of organic fertilizer, knowledge levels were also high. In the combined use of inorganic and organic fertilizer, there were moderate knowledge levels among farmers. In the use of improved seeds, mean knowledge level implied moderate knowledge levels. In the combined use of organic and inorganic fertilizer with improved seeds, the mean knowledge level implied high knowledge levels.

In inorganic fertilizer use knowledge level; size of land under maize, off-farm income, household head gender, household head education level, household size and maize yield were found to be significant predictors of knowledge levels being either low relative to high or moderate relative to high. In the organic fertilizer use knowledge level, training in organic manure was found to be the only significant predictor of knowledge level being moderate relative high. In the combined use of inorganic and organic fertilizer knowledge level; household head age, household members involved in farming, yield and off-farm earnings were found to be significant predictors of knowledge levels being low relative to high or being moderate relative to high. In the use of improved maize seeds knowledge level; household head education, household size, total land owned and total land under maize were found to be significant predictors of knowledge levels being either low relative to high or moderate relative to high. In the combined use of inorganic and organic fertilizer with improved seeds, off-farm earnings and household labour were found to be significant predictors of knowledge levels being either low moderate to high or moderate relative to high.

There was no significant association between use and knowledge levels in the use of integrated soil fertility management strategies included in the study with the exception in the use of improved seeds strategy where there was a significant association between use and knowledge levels of the same. The amount of NPK applied, intercropping of maize, liming of soil, soil testing by a farmer and total land owned were all found to be significant predictors of available phosphorus amounts in smallholder farms in the study area.

5.2 Recommendations

The results from the study area lead to the following recommendations that could be implemented by extension workers and policy makers:

- Research should put into consideration the demographic and socioeconomic status of farmers too.
- The gender aspect should be considered and trainers should ensure that both female and male trainees are well represented during training.
- Factors affecting knowledge levels of ISFM strategies in maize cultivation, for example, off-farm income, gender, age, education level identified in this study must be put into consideration during demonstrations, training and field trials.
- Issues with lower scores for example on the use of combined inorganic fertilizer and animal manure and on the use of improved seeds should be emphasized during training to ensure that smallholder farmers grasp them more and put them into practice to improve their ISFM knowledge levels and in turn improve maize yields.

5.3 Further research

Further research is encouraged on:

- Determination of why there is an insignificant association of knowledge levels and use of ISFM strategies for maize production intensification.
- Assessment of the training methods and channels of ISFM strategies in smallholder farmer areas, their impact, their inadequacies, their breakthrough and on ways to improve them so that farmers can benefit fully.
- Further documentation on adoption break through by rural smallholder farmers and the improved yield impacts associated.
- More research on phosphorus should consider fertilizer application methods, for example when P has been applied in a band, concentrations may persist where the band was introduced, as this can make interpretation of soil test data a challenge.

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APPENDICES

APPENDIX 1: FARMERS' INTERVIEW SCHEDULE

Questions are addressed to the household head/or the key decision maker in the household

Enumerator: ....   Date: ....

Household Number: ....   Start time: ..../...............

GPS coordinates: S: ....º...........'.............''   E: ....º............'...........''

Altitude (meters above sea level).....................

The questions in this questionnaire are for research purposes only and its findings will provide information on farmers' knowledge levels of ISFM strategies as well as the socioeconomic status affecting the adoption and use of these strategies.

The information provided will be treated with utmost confidentiality. Your assistance in answering the questions truthfully and accurately will be highly appreciated.

No.	Variable label	Variable values and rules
1.	**Household Demographics and Socioeconomic Characteristics**	
(a)	Sub-County	
(b)	Division	
(c)	Location	
(d)	Sub-location	
(e)	Village	
(f)	Name of household head	
(g)	Position of respondent in the family	***Tick where appropriate*** *1 = Household head* ☐ *2 = Spouse of the household head* ☐

		3 = Grown up child ☐ *4 = Relative* ☐ *5 = other (specify)* ☐
(h)	Marital status of the household head	***Tick where appropriate*** *1 = single* ☐ *2 = married* ☐ *3 = polygamous* ☐ *4 = widowed* ☐ *5 = divorced* ☐
(i)	Gender of household head	***Tick where appropriate*** *1= Male* ☐ *2= Female* ☐
(j)	Age of household head ....years	
(k)	Education level of household head	***Tick where appropriate*** *1= no education* ☐ *2= primary education* ☐ *3= secondary education* ☐ *4= tertiary education* ☐ *5=if 4* ***(specify)***
(l)	Occupation of the household head	***Tick where appropriate*** *1= Farming* ☐ *2= Business* ☐ *3= Employed* ☐
(m)	Occupation of the household head spouse	***Tick where appropriate*** *1= Farming* ☐ *2= Business* ☐ *3= Employed* ☐
(n)	Household size................	*1= Females …………* *2= Males………………*
(o)	How many household members are actively involved in farming	*1= Females ………..* *2= Males…………*
(p)	How many years of farming experience do you have...yrs	
(q)	How did you acquire your land	***Tick where appropriate*** *1= Inherited* ☐ *2= Purchased* ☐ *3= Rented* ☐

		4= Other ☐ ***(specify)***
(r)	What is the size of your land.....................acres What is the size of your land under maize.......................acres	
(s)	Is the labour from your household enough	***Tick where appropriate*** *1= Yes* ☐ *2= No* ☐
(t)	If No (above), when do you supplement?	***Tick where appropriate*** *1= Land preparation* ☐ *2= Planting* ☐ *3= Weeding* ☐ *4 = Harvesting* ☐ *5 = Other* ***(specify)*** ☐
(u)	Does any member of the household work off farm How much do they earn	***Tick where appropriate*** *1= Yes* ☐ *2= No* ☐ ***Tick where appropriate*** *1= below Ksh. 5000* ☐ *2= btwn Ksh. 5,000-10,000* ☐ *3= btwn Ksh 10,000-20,000* ☐ *4= btwn Ksh. 20,000-30,000* ☐ *5= btwn Ksh. 30,000-40,000* ☐ *6= btwn Ksh. 40,000-50,000* ☐ *7=above Ksh. 50,000* ☐
(v)	What is the average monthly income of the household	***Tick where appropriate*** *1= below Ksh. 5000* ☐ *2= btwn Ksh. 5,000-10,000* ☐ *3= btwn Ksh 10,000-20,000* ☐ *4= btwn Ksh. 20,000-30,000* ☐ *5= btwn Ksh. 30,000-40,000* ☐ *6= btwn Ksh. 40,000-50,000* ☐ *7=above Ksh. 50,000* ☐
(w)	Do you grow cash crops	***Tick where appropriate*** *1= Yes* ☐ *2= No* ☐

	What income do you get from these cash crops annually	***Cash crop*** ***Income*** *Coffee* *Ksh.*________ *Tea* *Ksh.* ________ *Macadamia* *Ksh.* ________ *Mangoes* *Ksh.* ________ *Bananas* *Ksh.*________ *Other (specify*
(x)	What livestock do you keep and what is their number	***Livestock*** ***(no)*** *Cattle* ________ *Sheep* ________ *Goats* ________ *Pigs* ________ *Donkey* ________ *Poultry* ________ *Other* ________
(y)	How many months in a year do you buy food for your household..................................	
(z)	How many bags of maize do you harvest in a year	
2.Maize production		
(a)	What is the biggest challenge that you face in maize cultivation	***Tick where appropriate*** *1= Reduced yields* ☐ *2= Pest and diseases* ☐ *3=Lack of market* ☐ *4=Poor prices* ☐ *5=Lack of transportation* ☐ *6=Lack of access to inorganic fertilizer* ☐ *7=Lack of access to organic fertilizer* ☐ *8=Lack of access to improved seeds* ☐ *9=Lack of information* ☐ *10=any other (specify)* ☐
(b)	Do you think your soil loses fertility	***Tick where appropriate*** *1= Yes* ☐ *2= No* ☐
(c)	What do you think causes your soil to lose fertility	***Tick where appropriate*** *1= continuous cropping* ☐ *2= soil erosion* ☐

		3=grazing ☐ *4=0ther (specify)* ☐
(d)	Does your land experience soil erosion	***Tick where appropriate*** *1= Yes* ☐ *2= No* ☐
(e)	If (Yes) above, how do you manage soil erosion	***Tick where appropriate*** *0 = I do nothing about it* ☐ *1= I practice conservation tillage* ☐ *2= I have built gabion(s)* ☐ *3= I have planted agro-forestry trees and wind breaks* ☐ *4= I practice crop rotation* ☐ *5= I practice contour ploughing* ☐ *6=I plant cover crops* ☐ *7=I practice mulching* ☐ *8= I have built terraces* ☐ *9=I practice strip farming* ☐ *10=I plant grass and small trees on the steep areas of my field* ☐ *11=other **(specify)*** ☐
(f)	Which fertilizer have you applied to your maize field in the last 5 to 10 years Give amounts of fertilizer applied per year	***Tick where appropriate (can tick more than one)*** DAP ☐ NPK17:17:17 ☐ NPK 23:23:0 ☐ TSP ☐ CAN ☐ Other (specify) ☐ ***Fertilizer*** ***Amount (kg)*** DAP ☐ NPK17:17:17 ☐ NPK 23:23:0 ☐ TSP ☐ CAN ☐ Other (specify) ☐
(g)	Do you intercrop your maize With which crop(s)?	***Tick where appropriate*** *Yes* ☐ *No* ☐
(h)	How many times do you weed your maize crop?	
(i)	Do you continuously apply P fertilizer to your maize crop	***Tick where appropriate*** *Yes* ☐ *No* ☐

Please indicate which strategy you have been trained on and use in planting maize

ISFM strategy	***Indicate if using strategy in maize production*** *1=Yes* *2=No*	***Do you have knowledge on:*** *1=Yes* *2=No*	***How would you rate your knowledge on:*** *Scale:* *1 – 10* *1 being the lowest and 10 being the highest level of knowledge*	***Main source of information on:*** *1=demonstrations and field trials* *2=extension workers* *3= newspaper* *4= radio* *5= television* *6= books* *7= published papers/journals* *8= posters and brochures* *9=personal experience* *10= other farmer* *11= other (specify)*	***Have you had training on:*** *1=Yes* *2=No*	***How effective would you rate the training on:*** *Scale:* *1 – 10* *1 being the lowest and 10 being the highest effect of training*	***Frequency of training:*** *1=monthly* *2=quarterly* *3=biannually* *4=annually* *5=other (specify)*
mineral fertilizer							
compost manure							
animal manure							
improved maize seed varieties							
incorporation of green manure							
use of agroforestry trees							
Liming							
Soil testing							
Erosion control							

Please indicate if you strongly agree, agree, not sure, disagree or strongly disagree with these statements about your knowledge on ISFM strategies (tick where appropriate)

	ISFM Strategy	**1=Strongly agree**	**2=Agree**	**3=Not sure**	**4=Disagree**	**5=Strongly disagree**
1.	**Inorganic fertilizers**					
(a)	Inorganic fertilizer is the quickest and surest way of supplying nutrients in amounts, proportions and forms ready for uptake by maize crop					
(b)	Using inorganic fertilizers is more accurate because they can be formulated to supply specific nutrients					
(c)	Timely application to coincide with crop demands at specific growth stages results in fertilizer use efficiency (FUE)					
(d)	The correct amount and type of fertilizer during planting and top dressing is NOT very important					
(e)	Purchasing blended fertilizer provides a means for smallholder farmers to receive the correct ratio of NPK and micronutrients					
(f)	Most N-fertilizers are applied as top-dressing when maize crop is actively growing and soils are moist					
(g)	Determination of soil fertility level is NOT					

	necessary before fertilization					
(h)	It is important to purchase well labelled fertilizer and at recognized dealers					
(i)	Liming to correct acidity of soil is NOT important					
(j)	I know the recommended types of mineral fertilizers for my maize crop					
(k)	DAP fertilizer is important for my maize crop					
(l)	Using NPK (17-17-17) and urea on maize crop can make a farmer achieve his goal produce					
(m)	Correct split basal and top-dressing application of Nitrogen fertilizer is very important					
(n)	Continuous use of inorganic fertilizer destroys the soil structure					
(o)	Excessive fertilization can be wasteful and cause harm to the environment					
2.	**Organic fertilizers**					
(a)	Organic fertilizers release nutrients very slowly and in minute amounts but they improve soil physical conditions					
(b)	I know the proper method of preparation and utilization of manure					

(c)	Good manure management is necessary to obtain high quality manure					
(d)	Farmyard manure should NOT be covered during curing					
(e)	The cowshed should be covered to prevent leaching of valuable nutrients during rains					
	Ready manure should NOT have materials such as grass and leaves visible					
(f)	Proper incorporation of manure will ensure no burning of the seeds especially when its dry					
(g)	Compost for manure should be made at a location close to the place it will be used to minimize nutrient losses					
(h)	6-8 weeks is sufficient to prepare compost					
(i)	Ready manure is loose, dry and has no smell					
(j	Incorporation of green manure (tithonia, calliandra and leucaena) is important to my maize crop					
(k)	Biomass transfer is usually labour intensive as opposed to planting agro forestry trees within your land					
(l)	Agroforestry trees can provide green manure to my maize					
(m)	Agroforestry trees control soil erosion and runoff					

(n)	Manure should be taken to the farm directly from the cowshed					
(h)	It is labour intensive to use manure					
3.	**Combined use of inorganic and organic fertilizer**					
(a)	It is acknowledged that 50% of maize yield increase can be attributed to efficient fertilizer use when other factors remain constant					
(b)	Appropriate combinations of organic and mineral fertilizers may be the best way of effecting soil fertility to boost maize production					
(c)	It is cheaper to use both inorganic and organic fertilizer than inorganic fertilizer alone					
(d)	Combining both organic and inorganic fertilizer provide a more balanced nutrient supply					
(e)	The ratio of combining mineral and organic fertilizer should be 1:1 or 50/50					
(f)	Combined inorganic and organic fertilizer should be half the recommended rates each per seed					
(g)	During application, it is NOT a must for inorganic fertilizer to be 2.5 grams per seed and manure to be about half a handful per seed per hole					

(h)	It is labour intensive to use both inorganic fertilizer and manure than using inorganic fertilizer alone					
4.	**Use of improved seeds**					
(a)	Large yield increases are usually realized with the use of improved maize seeds					
(b)	Spacing of maize seeds during planting is important to reduce competition for water and nutrients during growth					
(c)	It is recommended to plant maize with a 75cm inter row spacing and 25cm spacing between maize crops					
(d)	It is NOT important to acquire seeds from authorised dealers					
(e)	Planting 2 seeds per hole is appropriate to allow for thinning after emergence					
(f)	Using seeds from my previous best maize crop will ensure maintenance of good yields					
(g)	Improved seeds are NOT more responsive to available and added nutrients than local maize seed varieties					
(h)	Improved maize seeds acquired from authorised dealers are more adapted to the local soils and climate yields					

(i)	Improved maize seeds are Not more resistant to pests and diseases than local maize seed varieties					
5.	**Combining mineral fertilizer, organic inputs and improved germplasm**					
(a)	Use of organic inputs, mineral fertilizer and improved maize yields can result in more than double yields					
(b)	Improved seeds produce higher yields when fertilized appropriately than local seed varieties					
(c)	When using improved seeds, the amount of inorganic fertilizer applied per seed should be about a tea spoon and the amount of manure applied per seed should be about a handful					
(d)	The combined inorganic fertilizer and manure should be thoroughly mixed with the soil to prevent scorching of maize seeds					

THANK YOU!