ENHANCING SOYBEAN PRODUCTION, ECONOMICS AND ADOPTION AMONG SMALLHOLDER FARMERS IN THE CENTRAL HIGHLANDS OF KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University

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DEDICATION

This work is dedicated to my parents Mr. Cyrus Murage and Mrs. Lydia Murage for their commitment and sacrifice towards my education, and to my siblings, Peter and David for their continued support and to my dear wife Dorothy and son Travis.

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LIST OF ABBREVATIONS

AEZs	Agro-ecological Zones
AGRA	Alliance for Green Revolution in Africa
ANOVA	Analysis of Variance
BCR	Benefit cost ratio
g	Grams
Ha	Hectares
ICRAF	International Centre for Research in Agroforestry
ISFM	Integrated Soil Fertility Management
Kg	Kilogram
LH	Lower Highland
LM	Lower Midland
LR 2016	Long rain season, March-June 2016
LSD	Least Significant Difference
MAM	March, April and May season
Mg	Mega gram
MoA	Ministry of Agriculture
MT	Metric Tonne
N	Nitrogen
OND	October, November and December season
P	Phosphorous
RCBD	Randomized Complete Block Design
SSA	Sub-Saharan Africa
t	Tonne
TSP	Triple Super Phosphate
UM	Upper Midland
USD	United States Dollars

ABSTRACT

Current demand for soybean in Kenya is higher than production. The deficit which is over 95% is filled through importation from neighboring countries. Despite the high demand, adoption and production is low (0.56 to 1.1 t ha^{-1}) against potential yield of 3.0 – 3.6 t ha^{-1}. The low production is associated with low use of fertilizers. Farmers are using mineral fertilizers below recommended rates and they are not using organic fertilizers despite them being readily available. The objectives of the study was therefore to determine the effect of applying organic and inorganic fertilizers singly or in combination on grain yield of soybean, compare economics of soybean under organic and inorganic fertilizers and to determine factors influencing adoption of soybean by smallholder farmers in the central Highlands of Kenya. To achieve these objectives, on-farm experiments were set in Embu County and a survey was carried out in Embu, Meru and Tharaka Nithi Counties. The experiments had six treatments; (tithonia, tithonia plus fertilizer, fertilizer plus manure, fertilizer, manure and a control) arranged in Randomized Complete Block Design (RCBD). The plot sizes measured 6 m × 4.5 m and the main data collected was yield and labour. In the survey, the sample size was 210 farmers. Net benefits, benefit cost ratio and return to labor were used as the economic tools in data analysis. All biophysical data was subjected to analysis of variance (ANOVA). To determine factors influencing adoption of soybean, data was subjected to Cross-tabulation for categorical variables to test for association using Pearson chi-square statistic, the data was also subjected to a binary logistic regression model to predict the factors affecting adoption of soybean in the central highlands of Kenya. Results showed that there was a significant difference in soybean yield among treatments in LR 2016 and SR 2016, ($P= <0.0001$) and ($P= <0.0033$) respectively. A combination of manure plus fertilizer and tithonia plus fertilizer recorded a significant higher soybean yield than the control in both seasons. Manure plus fertilizer recorded a significantly higher net benefit and return to labour than the control in both seasons and it is the only treatment that recorded a return to labour of greater than 2.0, which is the minimum acceptable for smallholder farming activities. Out of 210 households interviewed, 41% were adopters while 59% were non-adopters. Total farm size, membership of a farmer group and attendance of training on soybean positively influenced adoption of soybean while age of household head negatively influenced adoption of soybean. The implication of these results is that farmers should be integrating organic and inorganic fertilizer in soybean farming in Embu County. Integration of manure and fertilizer should be advocated for in order to realize maximum economic benefits from soybean farming. Further, the adoption of soybean in the central Highlands of Kenya can be enhanced by targeting young household heads, household heads with bigger farm sizes, encouraging farmers to join farmer groups and increasing trainings on soybean. These findings provide a guide to the extension agents in the Ministry of Agriculture, Livestock and Fisheries (MoALF) in Embu, Meru and Tharaka Nithi Counties. This will help them in designing training manuals for farmers in regard to soybean production and increasing adoption of the crop in these Counties.

CHAPTER ONE

INTRODUCTION

1.1 Background information

Soybean (*Glycine max* L. Merrill) is an important legume crop, with potential for expansion in Africa. Globally, soybean accounts for about 84.5% of the grain legumes trade. Sub-Saharan Africa (SSA) accounts for about 1.3% of the total land area under soybean and 0.6% of production in the world (Abate *et al.,* 2012). Kenya's annual soybean production is very low, estimated at 2,007 metric tonnes (FAO, 2018). The annual demand is estimated at 120,000 metric tonnes, hence the huge deficit of over 95% is covered by importation from Uganda, Zambia, Malawi, Burundi, Zimbabwe, Brazil, and Argentina among others (Muriithi *et al.*, 2016).

Soybean is a multipurpose crop and therefore its increasing demand is based on its usefulness as a livestock feed, food and fuel crop (Mubichi, 2017). The crop also is an alternative to addressing malnutrition among agriculture dependent communities as it comprises more than 36% protein, 20% oil, 30% carbohydrates, dietary fiber, minerals, and vitamins (Bruns, 2016; Sales *et al.*, 2016). Despite these advantages, soybean production has remained very low in Africa (Abate *et al.,* 2012). Its adoption and production are below the potential (3.0 - 3.6 t ha^{-1}), with average yields in central highlands of Kenya ranging from 1.1 to 2.6 t ha^{-1} (Verde *et al.,* 2013). In SSA the average yield has also remained very low at 1.1 t ha^{-1} in the past four decades, this is below the world average of 2.4 t ha^{-1}. For instance, the average soybean yields in 2016/2017 in South Africa, Nigeria, Zambia, and Uganda was 2.29, 0.96, 1.94 and 0.6 t ha^{-1} respectively (Khojely *et al.*, 2018).

To meet the rapidly rising demand, SSA countries imported 6.8 million tonnes of soybeans annually at the cost of 4.4 billion USD from 2013 to 2016. Imports in 2011 were estimated at 1.6 million tonnes, valued at $1.22 billion (Khojely *et al.,* 2018). South Africa, Nigeria, and Kenya account for nearly 43%, 21% and 18% of the total import volume in this region, respectively. Other countries, including Ethiopia, Zambia, Zimbabwe, Seychelles, Botswana, Tanzania and Gabon also import significant amounts of soybean each year (Abate *et al.*, 2012). South Africa is the leading soy meal importer in SSA, with annual imports of over one half million tons (Rusike *et al.,* 2013). By increasing soybean yield, production, and adoption, SSA countries will become soybean demand-driven rather than supply-driven, given that soybean demand is still growing rapidly in SSA (Khojely *et al.*, 2018). The growing demand for soybeans offers a significant opportunity for smallholder farmers to increase incomes (Lubungu *et al.,* 2013). It is estimated that the global yield increase of 1.3% will not be sufficient to meet the required production by 2050 (Ray *et al.*, 2013), which suggests that adequate measures are required to promote soybean production. For Kenya to be self-sufficient in soybean, about 100,000 hectares would be required for the production of over 120,000 MT.

Several factors are responsible for the low production of soybean which includes: poor management practices, low use of agricultural inputs, inherent poor soil fertility and continuous decline of the soil fertility due to continuous cropping without adequate nutrient replenishment (Bationo *et al.*, 2006). Replenishment of nutrients can be through the use of organic and inorganic nutrient sources. However, very few farmers in the central highlands of Kenya can afford inorganic fertilizers, and those who are using the fertilizer rarely use the recommended rates (Mugwe *et al.*, 2009). In addition, the available added fertilizer is utilized with poor efficiency (Vanlauwe *et al.,* 2010), principally due to management factors (e.g. placement of fertilizer or poor timing), factors related to the soil (e.g. leaching, N volatilization and P fixation) as well as environmental factors (Mucheru-Muna *et al.,* 2013). The use of inorganic manure, on the other hand, is also limited by its low quantity and quality (Bationo and Waswa, 2011). Use of organic inputs which are locally available could reverse this declining soil fertility in central highlands of Kenya while a combination of organic and inorganic fertilizers can be considered as better options for increasing fertilizer use efficiency as they provide many agro-ecological benefits and have balanced supply of the nutrients.

In addition to low inputs use, adoption of soybean has also remained low in the central highlands of Kenya. This is probably due to lack of knowledge on soybean farming; lack of market of soybean and the extensive process of processing soybean as it cannot be consumed raw like the common beans. Increased adoption and production of soybean can be a sure way of bridging the gap between production and demand and increasing food security in Embu, Meru, and Tharaka-Nithi Counties. Previous studies on grain legumes have focused on agronomic issues such as effects of soybean on soil fertility and yield improvement through breeding (Mburu, 2004; Macharia *et al.,* 2011). However, these results on agronomic issues alone cannot provide a complete picture when assessing a given technology (Onyango, 2010). More insights from economic analysis and understanding of farmer perceptions are essential to enable a comprehensive evaluation of technologies (Odendo *et al.*, 2006). Few studies have been carried out to investigate the production and economics of soybean under different nutrient sources and factors affecting the adoption of soybean in the central highlands of Kenya are not known. The few studies conducted have focused on the performance of these inputs at research stations. Therefore, this study sought to determine soybean yield and economic returns on using manure, tithonia and inorganic nitrogen fertilizer in Embu County and to assess socioeconomic factors influencing the adoption of soybean in the Central Highlands of Kenya.

1.2 Statement of the problem

Efforts to increase soybean production in the Central Highlands of Kenya are constrained by low yields and slow adoption. The low soybean yield is attributed to the low use of organic and inorganic fertilizers. Smallholder farmers have been using mineral fertilizers below recommended rates despite the low soybean yields. They have also not been using the organic fertilizers despite them being readily available. In addition, there is inadequate information on factors that drive the adoption of soybean in this region. Therefore, this study was carried out to determine the effect of manure, tithonia and inorganic nitrogen fertilizer on soybean grain yield and economic returns. Socioeconomic factors influencing the adoption of soybean in Embu, Meru, and Tharaka Nithi Counties were also assessed.

1.3 Justification of the study

The findings of this study provide farmers with information on effect of manure, tithonia and inorganic nitrogen fertilizer on soybean yield and economic returns. This will help them reap the maximum economic benefits from soybean farming. Extension agents are informed of the factors influencing the adoption of soybean in Embu, Meru, and Tharaka

Nithi Counties. This will help them with coming up with policies for enhancing soybean adoption in the central highlands of Kenya.

1.4 Research questions

The study sought to answer the following questions:

1. What is the effect of applying manure, tithonia and inorganic nitrogen fertilizer on soybean grain yield under on-farm conditions in Embu County?
2. What is the effect of applying manure, tithonia and inorganic nitrogen fertilizer on economic returns of soybean under on-farm conditions in Embu County?
3. Which socioeconomic factors influence adoption of soybean by smallholder farmers in Embu, Meru, and Tharaka Nithi Counties?

1.5 Objectives

1.5.1 General objective

To determine the effect of manure, tithonia and inorganic nitrogen fertilizer on soybean grain yield and economic returns under on-farm conditions in Embu County and to assess the socioeconomic factors that influence the adoption of soybean in Embu, Meru, and Tharaka-Nithi Counties.

1.5.2 Specific objectives

The specific objectives of the study were:

1. To determine the effect of manure, tithonia and inorganic nitrogen fertilizer on grain yield of soybean under on-farm conditions in Embu County.
2. To determine the effect of manure, tithonia and inorganic nitrogen fertilizer on economic returns of soybean under on-farm conditions in Embu County.

3. To determine the socioeconomic factors influencing the adoption of soybean by smallholder farmers in Embu, Meru, and Tharaka Nithi Counties.

1.6 Hypotheses

The study sought to test the following hypotheses:

1. There is no significant difference on soybean grain yield following application of manure, tithonia and inorganic nitrogen fertilizer in Embu County.
2. There is no significant difference on the economic returns of soybean following application of manure, tithonia and inorganic nitrogen fertilizer in Embu County.
3. Socioeconomic factors has no influence on the adoption of soybean in Embu, Meru, and Tharaka Nithi Counties.

1.7 Conceptual framework

Adoption of soybean can be described as a process that involves decision making mostly known as the innovation-decision process. Farmers will pass through the stage of awareness of soybean to the formation of a negative or positive attitude towards it and finally to decide whether to adopt it or not. This is following the diffusion of innovation theory by Rogers (Rogers 2003). This process of adoption can be influenced by different factors which include household socioeconomic factors and farm characteristics. Figure 1.1 shows a simple schematic framework for studying soybean adoption by farmers in this study. Adoption of different agricultural technologies, especially integrated soil fertility management practices (Mugwe *et al.*, 2008) have applied this framework. The framework was modified in this study and formed the basis for selecting variables to be included in the model.

Adoption of new technologies by farmers is characterized well by a binary logit model. Previous adoption studies which have used this function are Chianu and Tsujii (2004); Gillespie *et al.* (2014); Miheretu and Yimer, (2017) and hence the reason for using it in this study. Early adopters demonstrate the new technology and through this knowledge, information and experience spread to other farmers who are potential adopters and this increases the adoption rate. This continues until all the potential adopters adopt the new technology.

On the other hand, incorporation of organic and inorganic fertilizers is hypothesized to increase soybean production and this will increase the economic returns from soybean and this coupled with adoption of soybean will lead to increased farmers income, increased food security, improved household nutrition, improved soil fertility and finally reduced poverty levels in central highlands of Kenya.

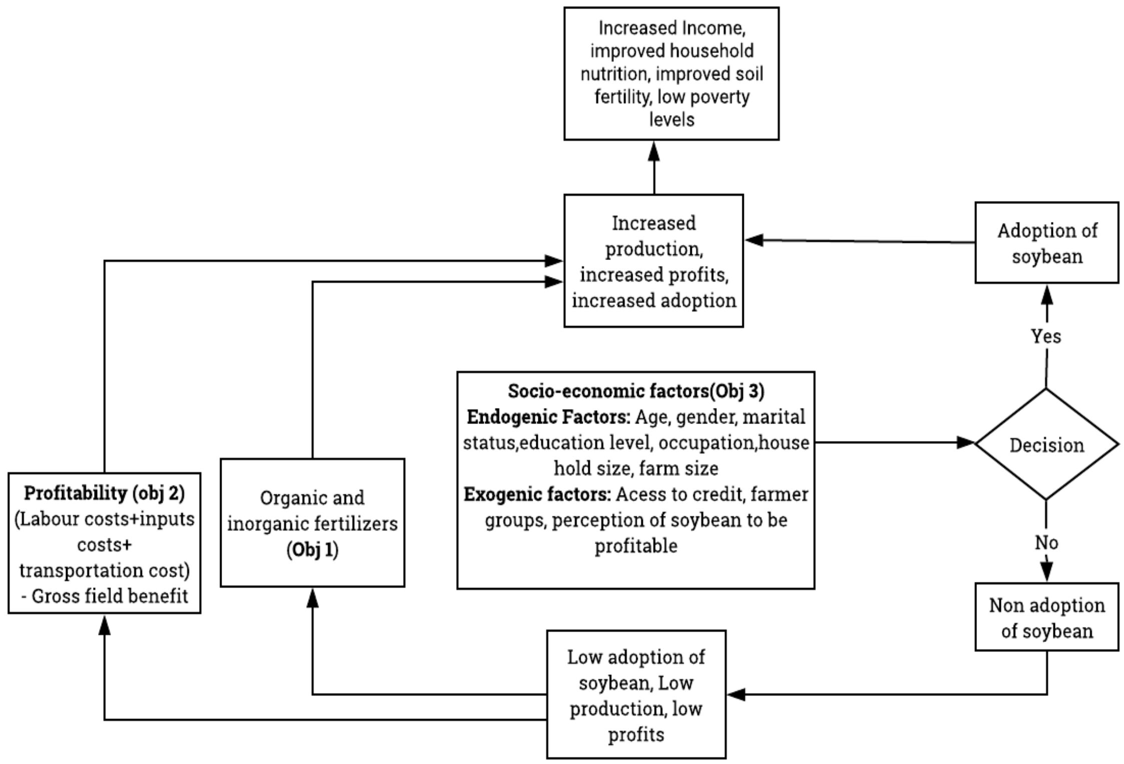

Figure 1.1: Conceptual framework showing factors influencing decision to adopt Soybean in central highlands of Kenya

CHAPTER TWO

LITERATURE REVIEW

2.1 Effects of inorganic fertilizers on crop yields

Generally, inorganic fertilizers containing Nitrogen, Phosphorous, Potassium, and Sulphur (N, P, K and S respectively) has been found to not only increase crop yield but also improve nutritional quality of crop yields, such as protein, oil, starch, essential amino acids and vitamins in pulses, oilseeds, tubers, and vegetables respectively (Wang *et al*., 2008). This is because nutrients in mineral fertilizers are immediately available for plant uptake. Several studies carried out showed that inorganic fertilizer increased soybean yield, for example, Mugendi *et al.* (2010), who worked in Muthambi and Chuka in Meru South District found a significant increase in weight of 1000 seeds and fresh pod weight of soybean with the application of 50 kg of P_20_5 ha^{-1}. In Nigeria, Mahamood *et al.* (2009) found that the application of P fertilizer at the rate of 30 kg of P_20_5 ha^{-1} significantly increased soybean grain yield. Mabapa *et al.* (2010) in South Africa reported a significant increase in grain yield and biomass of soybean following application of 60 kg P_2O_5 ha^{-1}.

Increased soybean grain yield have also been reported in Nigeria after application of P fertilizers (Kamara *et al.*, 2011). Another study by Boroomandan *et al.* (2009) found that applying 40 kg ha^{-1} starter-N increased soybean seed yield by 19% compared with where starter-N was not applied. Similarly, application of starter N boosted soybean yield from 2.2 to 2.5 t ha^{-1}in South Dakota, USA (Osborne and Riedell, 2006). Other research suggests that there is no benefit in applying N to soybean (Schmitt *et al.*, 2001) which reported that application of N fertilizer in-season did not improve soybean yield over control plots in twelve sites in Minnesota, USA.

2.2 Effects of organic fertilizers on crop yields

Organic fertilizers also referred to as organic sources are described as those organic materials that are used in agriculture as external or recycled inputs to produce crops either for subsistence or for commercial purposes. These include fresh, dried or composted livestock and poultry manure, crop residues that are recycled after a crop is harvested, green manure obtained either on or off the farm, biomass resulting from short to long-term fallows, agro-industrial by-products such as coffee husks or sugarcane bagasse, forest litter, bark or wood shavings, and coarse organic materials applied as surface mulches (Lekasi, 2003). These sources have been recognized as alternative nutrient sources to smallholder farmers to fertilize their soils as their socio-economic limitations prevent them from using mineral fertilizers properly (Bala *et al.,* 2011).

The organic sources have been reported to improve the soil fertility, promote good soil aggregation, improve moisture infiltration and increase the water holding capacity of the soil, increase the soil organic carbon, increase soil available nutrients (N, P, and K), soil enzymes (dehydrogenase and alkaline phosphatase), and microbial biomass C in the top 0-15cm soil, improve the fertilizer use efficiency to a great extent, and to have the ability to prevent nutrient losses due to irregular and heavy rainfall (Dudal, 2002; Mugwe *et al.,* 2007; Ramesh *et al.,* 2009; Bala *et al.,* 2011). Additionally, they have the ability to increase the phosphorous availability of the already present phosphorous by rendering it more accessible to crops through reducing the soil phosphorous absorption capacity, increasing the pH by decreasing the exchangeable acidity and aluminium in soil solution through chelation, and increasing the soil biological activity of the soil (Nziguheba *et al.*, 2002; Bationo *et al.*, 2007; Mukuralinda *et al.*, 2010).

Several studies carried out in central Kenya have confirmed the potential of organic resources on crop yields. For instance, Gitari *et al.* (2002) reported yields of 6.5 Mg ha^{-I} and 3.1 Mg ha^{-I} using mucuna green manure in Karurina and Gachoka in Embu. This was against 3.5 and 2.7 Mg ha^{-I} achieved in farmer practice of mineral fertilizers in both sites, respectively. In another study carried out in Chuka, Mucheru (2003) reported yields of 6.4, 5.4, 5.7, Mg ha^{-I} using biomass of *Tithonia diversifolia*, *Calliandra calothyrsus*, and *Leucaena trichandra*, compared to 5.3, and 2.2 Mg ha^{-I} for recommended mineral fertilizer rates and the control (no inputs), respectively. An increase of 92% of grain yield of maize was reported after applying farmyard manure as compared to the control (Kimani *et al.*, 2004). Another study by Mucheru-Muna *et al.* (2007) reported more than a 50% increase of grain yield of maize above the control in the application of *Tithonia diversifolia* in the soil. Gitari *et al.* (1998) reported a 46% increase in maize yield above the farmers' practice on the application of *Mucuna pruriens* biomass into the soil.

Similar results have been reported in studies carried in Western Kenya. For instance, yields of 7.2, 6.9, 7.4, 7.1, and 6.6 Mg ha^{-1}were recorded using mucuna, soybeans, crotalaria, cowpeas, and dolicos green manures, respectively. This was against farmers' practice of mineral fertilizers which recorded a yield of 4.4 Mg ha^{-1} (Kamidi *et al.*, 2000). Yield increases of between 72 to 157% over no inputs were reported by Kipsat *et* *al.* (2004) in another study using tithonia, tephrosia, and crotalaria. Ayuke *et al.* (2004) reported yields of 0.8, 1.1, and 1.3 Mg ha^{-1} under control (no inputs), *Tithonia diversifolia* and mineral fertilizer, respectively. This represented a yield increase of up to 63% over the control. Javaid and Mahmood (2010) in Pakistan, found a significant effect of manure on a number of pods of soybean. Elsewhere, the application of poultry manure also increased grain yield of soybean (Chiezey and Odunze, 2009).

2.3 Effects of combined use of inorganic fertilizers and organic sources on crop yields

Combining mineral fertilizers with organic inputs can substantially improve the agronomic efficiency of the nutrient use compared to the same amount of nutrients applied through either source alone (Sanginga and Woomer, 2009). Results by Vanlauwe *et al.* (2006) in Western Kenya revealed the need to apply both mineral and organic sources in a combined fashion.

While the main role of mineral inputs is to supply nutrients or correct unfavorable soil pH conditions, organic resources contain carbon, which drives all microbial and faunally mediated soil processes and finally replenishes the soil organic matter (SOM) pool, which maintains the physical and physiochemical components contributing to soil fertility such as cation exchange capacity (CEC) and soil structure (Vanlauwe and Giller, 2006). Inorganic fertilizers are able to increase both crop yields and additionally produce enough residues for soil fertility management issues, while organic sources are able to rehabilitate less responsive soils and make them responsive to fertilizers (Vanlauwe *et al.*, 2010). This is the key factor in improved fertilizer efficiency when mineral fertilizers are combined with organic sources. Blackshaw and Brandt (2009), recognized that the additional Phosphorus (P) supplied by this combination may result in additional benefits in terms of yield and quality as it plays key roles in cellular energy transfer, respiration, and photosynthesis. Maize yields were increased with increasing rates of farmyard manure application, however, maize grain yields above 3.5 Mg ha^{-1} were only obtained when both farmyard manure and NP fertilizers were applied (Kihanda, 1996). Leucaena biomass combined with mineral fertilizer gave higher crop yields as compared to the sole use of mineral fertilizer or sole Leucaena biomass (Mugendi *et al.*, 1999). Combined organic and inorganic fertilizers have also been reported to increase soybean yield by 12.9% in India, Maheshbabu *et al.* (2008), 19% in Indonesia relative to sole application of inorganic fertilizer, Yamika and Ikawati (2012) and 50% against sole application of manure (Zerihun *et al.*, 2013).

2.4 Economic returns of organic and inorganic fertilizers

According to Negatu and Parikh (1999), farmer's decisions are rational and therefore are made based on utility maximization. The financial gains associated with technology use should outweigh the costs of its use. Studies conducted in northern Honduras found that the relative profitability of a *Mucuna pruriens* system was not solely dependent on the higher maize yields, labor costs and lower production risk but also on the seasonally high prices that favored the second season maize crop. In analyzing the profitability of integrated soil fertility management (ISFM) technologies, most researchers concentrate on controlled experiments which do not represent the farmer conditions. For instance, the researcher managed trials in Kenya using tithonia biomass showed both increased soybean yields and profitability. The yields and profits were even higher where tithonia was supplemented with phosphorus inorganic fertilizer, however, the use of the technology has remained low (Ajayi *et al.,* 2007). Research has shown that gross margins of soybeans can range from Ksh 11,043.95 ha^{-1} to Ksh 42,684.78 ha^{-1} under on-farm conditions in Western Kenya (Chianu *et al.,* 2006)

Studies on economic analyses have shown organic and inorganic fertilizers to give higher returns in comparison to where fertilizer is not applied at all. In central Kenya, for instance, Mucheru (2003) reported net benefits of \$784, \$653, and \$780 $ha^{-1}year^{-1}$ using *Tithonia diversifolia*, *Calliandra calothyrsus*, and *Leucaena trichandra* respectively in an on-station study. This was against farmers' practice net benefits of \$272 ha^{-1}. Benefit-cost ratios (BCR) were 4.0, 5.8, and 7.0 and returns to labor 4.0, 6.9, and 7.0, for *Tithonia diversifolia*, *Calliandra calothyrsus*, and *Leucaena trichandra* respectively (Mucheru, 2003). In another study carried out on-farm, Adiel (2004) reported BCR of 5.4 for tithonia, 4.4 for tithonia plus the half rate of recommended mineral fertilizer, 4.2 for tithonia plus manure, 3.3 for manure plus mineral fertilizer and 3.2 and 2.4 for sole mineral fertilizer and farmers' practice of no inputs, respectively.

Similar studies conducted in western Kenya have also reported variable economic returns among different organic resources. For instance, benefit-cost ratios of 1.08 for tithonia plus mineral fertilizer, 1.04 for manure plus mineral fertilizer, and 0.87 for tithonia were reported by Kipsat *et al.* (2004). In another trial, Jama *et a1.* (1997) reported positive returns from calliandra biomass (\$136 ha^{-1}), manure applied in spots (\$293 ha^{-1}), manure broadcasted (\$255 ha^{-1}), and mineral fertilizer (\$98 ha^{-1}) at 44 kg N plus 10 kg P. Increasing the level of P application to 30 kg ha^{-1} increased returns to \$344 ha^{-1}. These trials were conducted in P deficient soils to establish the attractiveness of organic materials as a source of P. Another study conducted by Nziguheba *et al.* (2002) found that sourcing tithonia from existing niches gave higher returns of \$494 ha^{-1} compared to \$152 ha^{-1} using tithonia grown on the farm. This was attributed to the low opportunity costs of producing tithonia on the farm.

Positive returns from organic resources in maize production systems have also been reported in a study carried out in Zimbabwe using manure fortified with mineral fertilizers at different rates (Mutiro and Murwira, 2004). In the trial, net benefits for control (no inputs) was \$20.9 ha^{-I} compared to sole manure (\$142.8 ha^{-1}), manure plus 20 kg N (\$244.8 ha^{-I}) and manure plus 40 kg N (\$326.0 ha^{-1}). In another study in Zimbabwe, Mekuria and Waddington (2002) reported a return to labor of \$1.35 per day for manure plus mineral fertilizer compared to \$0.25 for the sole mineral fertilizer treatment, indicating that integration of manure with mineral fertilizer yielded better returns. These findings show that apart from using mineral fertilizers, farmers can get positive returns by using organic resources solely or combined with mineral fertilizers in maize production systems.

2.5 Factors affecting the decision to adopt technologies by farmers

Adoption is the acceptance and use of new agricultural technologies by the farmers. The Farmers' decision to adopt technology is greatly influenced by their perception about it. According to Wiredu *et al.* (2014) information on the factors that can constrain or accelerate uptake are key to effective promotion of integrated soil fertility management practices. Farmers' adoption of technology is a process that begins with information acquisition, testing of the technology and eventual adoption of the technology. Macharia *et al.* (2014); Akinola *et al.* (2010); Ajayi *et al.* (2007) and Mugwe *et al.* (2009) demonstrated that a number of variables may affect a farmer's decision to either adopt or not to adopt a technology. According to Mowo *et al.* (2006), a farmer has three functions as an entrepreneur, manager, and craftsman. The farmers define the objectives and mission of the farm and come up with strategies to meet the set objectives (entrepreneur). Allocation of resources to meet the objectives, deciding what to do analyzing of farm operations, planning, executing and controlling the thing to be done (manager) and the farmer needs the technical skills to carry out activities for optimal performance of the farm (craftsman).

Adoption is a dynamic process and factors (for example, gender, farm size, age, household size, etc.) are taken to be independent variables but most likely they influence one another, therefore, ignoring their interdependencies and treating them in isolation reduces the adoption decision to a zero-sum game (Ajayi *et al.*, 2007). Socioeconomic and demographic factors that include the age of the household head, 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 have been found to influence adoption of integrated soil fertility management (ISFM) technologies (Odendo *et al.*, 2009; Mugwe *et al.*, 2008). Several studies Macharia *et al.* (2014); Geta *et al.* (2013) and Odendo *et al.* (2009) found gender, researcher's contacts, farm size and asset, experience, labor resources, credit, extension, training, management skills, location, livestock ownership and expenditure to influence adoption of ISFM technologies.

It is good to note that, factors can have a negative or positive effect on adoption, for example, the age factor can have both a positive and a negative effect. For example, younger farmers have been found to be more knowledgeable about new practices and may be more willing to bear the 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 methods and ways. 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; Akinola *et al.,* 2010). The education level of the household head 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 (Kimaru *et al.,* 2012).

Ayinde *et al.* (2010) found that education level of farmers; farming experience; farm size; access to extension agents and access to credit have a significant and positive influence on the adoption of agricultural technology. In the study conducted by Kudi *et al.* (2011), farmers' awareness had considerable influence on the rate of adoption of agricultural innovation. Adoption studies by Bamire *et al.* (2010); Odoemenem and Obinne (2010) showed that farmer's education, farm size, fertilizer usage, and access to extension service exert positive and significant influence on utilization of improved cereal production technologies.

2.6 Summary of literature and research gaps identified

The review has shown that organic and inorganic fertilizers increase soybean yields and integrating them is a better option for replenishing soil nutrients. The literature review has also shown that several factors influence adoption of agricultural technologies and some of them are; household size, educational level, farm size, farming experience, the income of the farmer, access to credit and extension contacts. Production and economic returns of technology need to be taken into consideration when studying the adoption of new technologies because promising new technologies are not adopted by farmers because they are not economical. Few studies have evaluated economic benefits of soybean under organic and inorganic fertilizers and those which have evaluated them concentrated on controlled experiments with the controls depicting the farmer conditions and factors affecting the adoption of soybean in the central highlands of Kenya are not known.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

The experiment was carried out in selected farmers' farms in Embu County while the survey was carried out in Embu, Meru and Tharaka Nithi Counties.

Embu County is located approximately between latitude 00^{0} 8' and 00^{0}50' South and longitude 37^{0} 3' and 37^{0} 9' East. Average annual rainfall ranges from 886 mm to 1894 mm. The rainfall pattern is bi-modal with two distinct rainy seasons. Long rains occur between March and June while the short rains fall between October and December. Average temperatures are 23.9^{0} C. The study was carried out in these agro-ecological zones (AEZs): UM1, and UM2 (Jaetzold *et al.*, 2006).

Tharaka Nithi County lies between latitude 00^{0} 07' and 00^{0} 26' South and between longitudes 37^{0} 19' and 37^{0} 46' East. Average annual rainfall ranges from 664 mm - 2128 mm. The rainfall pattern is bi-modal with two distinct rainy seasons. Long rains occur between March and June while the short rains fall between October and December. The average temperatures are 24.1^{0} C (Jaetzold *et al.*, 2006).

Meru County lies 00^{0} 6' North and about 00^{0} 1' South, and latitudes 37^{0} West and 38^{0} East. Average annual rainfall ranges from 633 mm - 2177 mm. The rainfall pattern is bi-modal with two distinct rainy seasons. Long rains occur between March and June while the short rains fall between October and December. Average temperatures are 23.7^{0} C (Jaetzold *et al.*, 2006).

3.2 Research design

In this study, both experiment and a survey were used. On-farm experiments were set in Embu County for objectives one and two, while for objective three a survey was carried out where 210 households from Embu, Tharaka Nithi and Meru Counties were interviewed using a questionnaire (Appendix 5.1).

3.2.1 Experimental design

The experimental design was a Randomized Complete Block Design (RCBD) with six treatments; tithonia, tithonia plus fertilizer, manure plus fertilizer, fertilizer, manure, and control (Table 3.1). The test crop was soybean (Gazelle Variety). The study was conducted during Long rains (LR) 2016 and Short rains (SR) 2016 seasons in ten farmers' fields in Embu County where each farm acted as a replicate. The plot sizes were 6 m × 4.5 m.

Table 3. 1: Experimental treatments

S/No	**Treatment**	
1	Manure plus Fertilizer	Manure (30 kg N ha^{-1}) + Fertilizer (30kg N ha^{-1})
2	Tithonia plus Fertilizer	Tithonia (30 kg N ha^{-1}) + Fertilizer (30 kg N ha^{-1})
3	Fertilizer	Fertilizer (60 kg N ha^{-1})
4	Manure	Manure (60 kg N ha^{-1})
5	Tithonia	Tithonia (60 kg N ha^{-1})
6	Control	No inputs

3.2 Management of the experiment

Land preparation was done manually. Soybean seeds were inoculated with *Rhizobia* biofix inoculum just before planting to facilitate effective nitrogen fixation. Compound fertilizer (23:23:0) was the source of inorganic N and was applied during planting. Cattle manure and *Tithonia diversifolia* were applied as organic fertilizers during land preparation. Three soybean seeds were planted per hill, with a spacing of 0.5 m between rows and 0.1 m within rows, and were thinned out to two plants per hill two weeks after planting to attain the recommended plant density. Manure, fertilizer, and tithonia were applied to give an equivalent amount of 60 kg N/ha the recommended rate of N to meet soybean nutrient requirements for optimum crop production in the area (FURP, 1987). This was a type 2 experiment where the researcher designed the experiment while the farmers managed the experiment.

3.4 Data collection

3.4.1 Grain and biomass yields

Soybeans were harvested when they were completely dry from a net plot of $17.5m^2$. The upper and lower rows of soybean and 50 cm from both edges were left on each plot to minimize the edge effect. The plants were cut at the ground level and the above biomass was weighed using a weighing balance and the weight recorded. Soybean was then threshed and weight of grains was recorded and moisture of the grains taken using a moisture meter. The grain yield weight was adjusted to 12.5%, the standard moisture content for soybean, and converted to t ha^{-1}.

3.4.2 Labour data

Detailed data on labor requirements were collected every season for each of the field operations (land preparation, planting, fertilizer application, tithonia application, thinning, weeding, pest control and harvesting). The time taken to perform every activity was recorded and the labor was valued at the local wage rate per working day (8 hours) at a price of 3 USD per day.

3.4.3 Economic data

The following values were calculated on per hectare basis; gross field benefits and total variable costs. Net benefit was derived by subtracting total variable costs from gross field benefits while benefit-cost ratio (BCR) was derived by dividing net benefit by total variable costs (TVC). Return to labor was derived by dividing net benefit by labor costs. Variable costs included all the expenses of buying, transporting and applying inputs. Gross field benefits included all the gains obtained from selling the soybean grain at the farm gate price after harvest. The experimental component was fully farmer managed and therefore yields were not adjusted to meet farmers conditions (CIMMYT, 1988). Soybean yield adjusted to standard moisture content was used in the economic analysis.

Table 3.2 Values used for cost benefit analysis

Parameter	Actual Values
Price of NP fertilizer (23:23:0)	$ 0.16 Kg^{-1} N
Transport of fertilizer to farm	$ 0.98 100 Kg^{-1}
Labour costs	$ 0.368 hr^{-1}
Price of soybean	$ 0.59 Kg^{-1}
Exchange rate	$ 1= Ksh. 101.90

3.5 Survey

A survey was carried out in Embu, Tharaka Nithi and Meru counties in March 2017 to meet objective three. Adoption was defined as a binary variable that is "adopters" and "non- adopters" who assumed a value of 1 and 0 respectively. A farmer who adopted soybean, "adopter", was defined as a farmer who had soybean in the field during the time of the interview, planted soybean for at least three consecutive seasons from March, April and May season in the year 2014 (MAM 2014) and who had a plan of continuing growing soybean.

3.5.1 Sampling procedure and sample size

To select respondents for the study, purposive and random sampling techniques were used. Groups participating in soybean farming were identified. In the first stage, twenty one groups from the ones practicing soybean farming were purposively selected (seven groups from each county). The second stage involved selecting a proportionate number of respondents from each of the twenty-one groups. The selection was done randomly at this stage. Two hundred and ten households were finally used for this study and interviewed using a questionnaire (Appendix 5.1). Pretesting of the questionnaires was done to ensure that the data collected was precise and accurate.

3.6 Statistical data Analysis

Data on soybean yield and economic returns were subjected to analysis of variance (ANOVA) using SAS software version 9.2. (SAS, 2008). The Means were separated using Tukey's procedure at the $P < 0.05$ level of significance. Net benefit, Benefit-Cost ratio (BCR) and Return to Labour were the economic tools used in the economic analysis. The data from the survey were analyzed using the Statistical Package for Social Sciences (SPSS) and the adopters assumed code of 1 while non-adopters assumed code of 0. Data were subjected to Cross-tabulation for categorical variables to test for association using Pearson chi-square statistic, it was also subjected to a binary logistic regression model to predict factors affecting the adoption of soybean in central highlands of Kenya. The coefficients in the logistic regression were estimated using the maximum likelihood estimation method (Garson, 2008). The inverse linearizing transformation for the logit is directly interpretable as a log-odds as compared to the inverse transformation which does not have a direct interpretation and hence the reason for choosing it for this study.

The model was as follows:

$Ln\ Y = Ln\ (P_i / 1 - P_i)$

$Ln\ (Pi / 1 - Pi) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots.. \beta_{11} X_{11} + e$

Where,

Y = Binary variable defined as 1 if the farmers adopts soybean and 0 if the farmer does not

P_i = Probability of adoption of soybean

Ln = Natural logarithm function

β_0 = Intercept term

$\beta_1 - \beta_{11}$ = Logistic regression coefficients

e = Error term

$X_1 - X_{11}$ = Explanatory variables (Table 3.2)

Table 3.3 Definition of study variables influencing adoption of soybean in the central highlands of Kenya

Independent variable	Description	
X_1: AGE	Age in years of head of household	(continuous variable)
X_2: MSHH	Marital status of the household head	(1= Single, 2 = Married, 3= Widowed, 4= Divorced)
X_3: OHD	Occupation of household head	(1= Farming, 2= Off-farm business, 3= Employed, 4=other)
X_4: EDLH	Education level of household head	(1= No education, 2= Lower Primary 3=Upper primary 4=Secondary 5=Tertiary)
X_5: HHSIZE	Household size	(continuous variable)
X_6: YFE	Years of farming experience	(continuous variable)
X_7: FSIZE	Farm size	(continuous variable)
X_8: PSP	Perception of soybean to be profitable	(1= yes, 2= No)
X_9: BFG	Belong to a farmer group	(1= yes, 2= No)
X_{10}: ATRAIN	Attendance of training	(1=yes, 2= No)
X_{11}: ACSF	Availability of agricultural credit	(1= yes, 2= No)

Selection of the explanatory variables to be included in the model was based on evidence from the theory from past studies. Correlation analysis was used to confirm that the explanatory variables are not internally correlated, avoid biased estimates, and ensure the usefulness of the predictions and policy implications based on the findings of the study (Chianu et al., 2007). Independent variables were also tested for endogeneity using STATA software. Before running the logit regression, Durbin–Wu–Hausman test was done to the independent variables to test for endogeneity. The variables were found to be exogenous as shown below.

Durbin (Score) Chi2 (3) = 5.3493 (P = 0.1479)

Wu-Hausman F (3, 190) = 1.7228 (P = 0.1637)

CHAPTER FOUR

RESULTS

4.1 Effect of organic and inorganic fertilizers on grain yield of soybean under on-farm conditions

Yield increase of soybean over the control ranged from 36% (Tithonia) to 102% (Manure plus fertilizer) in long rains (LR 2016) season. During LR 2016 season manure plus fertilizer, treatment recorded the highest soybean yield of 2.02 Mg ha^{-I} although it was not significantly different from sole manure treatment and a combination of fertilizer plus tithonia treatments. Control recorded the lowest yield of 1.09 Mg ha^{-I}, which was not significantly different from sole tithonia and fertilizer treatments (Table 4.1). There was a significant (P<0.0001) difference in soybean yield among the treatments in LR 2016. Application of manure plus fertilizer, sole manure and a combination of fertilizer plus tithonia gave a statistically higher yield than the control which recorded the lowest soybean yield of 1.09 Mg ha^{-I} in LR 2016 season (Table 4.1).

Table 4.1 Soybean yield response to organic and inorganic fertilizers during long rain 2016 and short rain 2016 in Embu, County

	Long Rains 2016		**Short Rains 2016**	
Treatment	**Yield (Mg ha^{-I})**	**% increase**	**Yield (Mg ha^{-I})**	**% increase**
Manure and fertilizer	2.02^{a}	102	1.73^{a}	73
Manure	1.67^{ab}	67	1.47^{ab}	47
Fertilizer and Tithonia	1.63^{ab}	63	1.55^{a}	55
Fertilizer	1.49^{bc}	49	1.45^{ab}	45
Tithonia	1.36^{bc}	36	1.44^{ab}	44
Control	1.09^{c}	00	1.11^{b}	00
P Value	<0.0001		0.0033	

Note: Figures in each column followed by the same letter are not significantly different at $p < 0.05$

Soybean yield ranged from 1.11 Mg ha^{-I} (Control) to 1.73 Mg ha^{-I} (Manure plus fertilizer) in SR 2016 (Table 4.1). Yield increase with the addition of organic and inorganic fertilizer ranged from 44% (Tithonia) to 73% (manure plus fertilizer). Control treatment and application of either sole organic or sole inorganic fertilizer gave statistically similar yields in SR 2016 season. A combination of the organic and inorganic fertilizer gave a significantly higher yield than the control treatment in SR 2016 but the yields were not significantly different from sole manure, fertilizer and sole tithonia treatments in SR 2016 season.

4.2 Economic returns of organic and inorganic fertilizers

Return to labor, benefit-cost ratio (BCR) and net benefit were used as the financial performance indicators. Results on economic analysis indicate that there was a significant difference (P=0.0005, P=0.007, P=0.0045) among the treatments in terms of net benefit, BCR and return to labor respectively in LR 2016 season (Table 4.2). The highest net benefit was recorded from three treatments; Manure plus fertilizer, sole manure and a combination of fertilizer plus tithonia. On the other hand, control recorded the lowest net benefit with 327.33 USD ha^{-I} which was statistically similar to that of tithonia, fertilizer, and combination of fertilizer plus tithonia treatments in LR 2016 season. Manure plus fertilizer recorded the highest BCR of 1.84, which was not significantly different from all other treatments apart from the control. In this first season (LR 2016) control recorded statistically similar return to labor with all other treatments apart from manure and fertilizer treatment.

Table 4.2 Economic returns of organic and inorganic fertilizers during long rains 2016 in Embu, County

Treatment	Net benefit (US$/ha)	Benefit cost ratio	Return to labour
Manure and fertilizer	756.41[a]	1.84[a]	2.20[a]
Manure	620.25[ab]	1.76[a]	1.76[ab]
Fertilizer and Tithonia	501.66[abc]	1.12[ab]	1.40[ab]
Fertilizer	369.39[bc]	1.08[ab]	1.18[b]
Tithonia	442.31[bc]	1.27[ab]	1.27[b]
Control	327.33[c]	0.75[b]	1.08[b]
P Value	0.0005	0.007	0.0045

Note: Figures in each column followed by the same letter are not significantly different at $p < 0.05$

On the other hand, during the short rains (SR 2016) season it was observed that all the treatments recorded statistically similar net benefits apart from the control treatment (Table 4.3). In addition, the control also had the lowest return to labor of 0.87, which was not significantly different from all the treatments apart from manure plus fertilizer treatment. Manure plus fertilizer treatment gave a statistical higher net benefit than the control in SR 2016. There was no significant difference (P= 0.0974) in BCR among the treatments in SR 2016.

Table 4.3 Economic returns of organic and inorganic fertilizers during short rains 2016 in Embu, County.

Treatment	Net benefit(US$/ha)	Benefit cost ratio	Return to labour
Manure and fertilizer	597.47[a]	1.56[a]	1.73[a]
Tithonia	474.96[ab]	1.33[a]	1.36[ab]
Manure	471.31[ab]	1.30[a]	1.44[ab]
Fertilizer and Tithonia	447.47[ab]	1.00[a]	1.24[ab]
Fertilizer	437.01[ab]	1.16[a]	1.30[ab]
Control	284.97[b]	0.78[a]	0.87[b]
P Value	0.0286	0.0974	0.0444

Note: Figures in each column followed by the same letter are not significantly different at $p < 0.05$

4.3 Soybean farming by adopters and non-adopters

4.3.1 Planting of soybean by adopters and non-adopters in different seasons

The total number of respondents interviewed was 210, Out of the households interviewed, (86; 41%) were adopters while (124; 59%) were non-adopters. In March, April and May season in the year 2014 (MAM 2014), (24; 28%) adopters planted soybean while (10; 8%) of non-adopters planted soybean (Figure 4.1). In the following season, October, November, and December in the year 2014 (OND 2014) adopters who planted soybean increased to (25; 29%) while non-adopters reduced to (9; 7%). In October, November, December season in the year 2016 (OND 2016) adopters who planted soybean increased to (76; 88%) while non-adopters reduced to (7; 6%). The number of adopters who planted soybean kept on increasing (Figure 4.1).

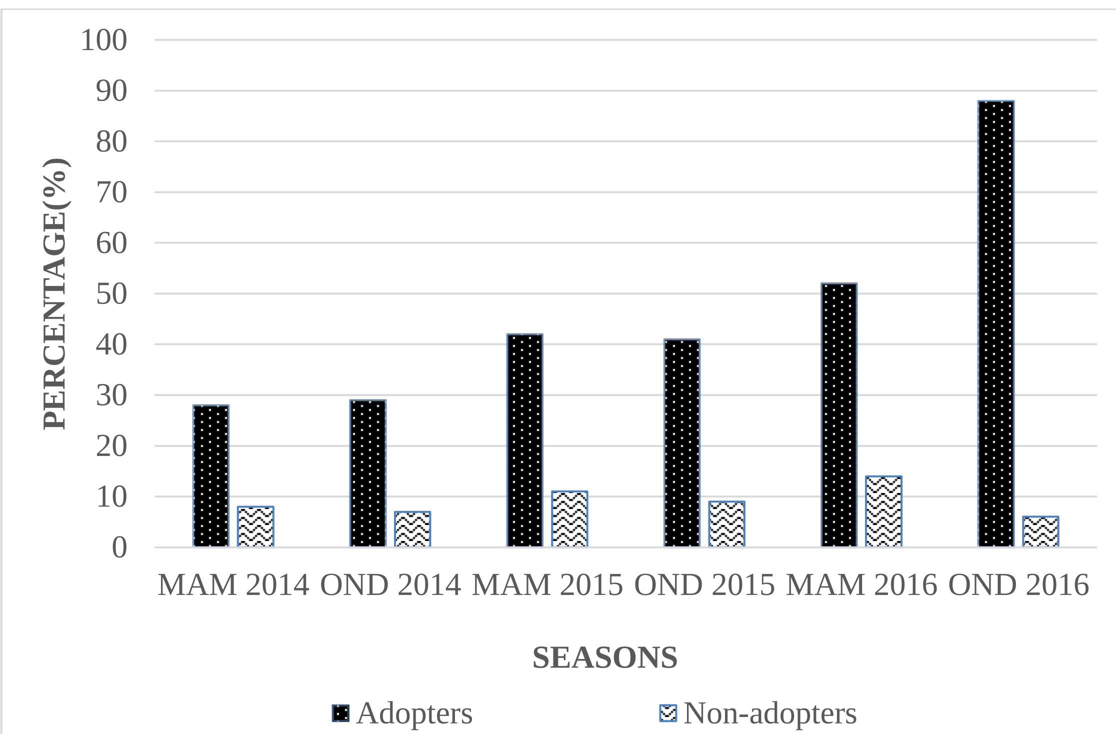

Figure 4.1 Percentage of adopters and non-adopters in different seasons

4.3.2 Quantity of soybean planted by adopters and non-adopters in different seasons

Majority of the adopters and non-adopters 72% and 92%, respectively did not plant soybean in MAM 2014 season. In OND 2014 season (14; 16%) adopters planted between one and two kilograms of soybean while only (4; 3%) non-adopters planted between one and two kilograms of soybean (Table 4.4). In the following season, MAM 2015 adopters who planted between one and two kilograms of soybean increased to (25; 29%) while (53; 62%) non-adopters did not plant soybean. Non-adopters who did not plant soybean in MAM 2016 increased to (109; 87%) while adopters reduced to (42; 49%) (Table 4.4). At the end of the sixth season, OND 2016 adopters who planted between one and two kilograms of soybean had increased to (49; 57%) while non-adopters had reduced to (3; 2%). The soybean planted by adopters kept on increasing with seasons implying that if the trend continues there will be an increased amount of soybean planted by adopters in this region.

4.3.3 Area planted by adopters and non-adopters in different seasons

Adopters who planted between a quarter and a half of an acre of soybean in MAM 2014 were (13; 15%) while (2; 2%) non-adopters planted less than a quarter an acre in this season (Table 4.5). In the following season, OND 2014 adopters who planted between a quarter and a half of an acre of soybean increased to (16; 19%) while non-adopters. Remained the same (4; 3%). In MAM 2015, (18; 21%) adopters and (6; 5%) non-adopters planted between a quarter and a half of an acre of soybean (Table 4.5). Adopters who planted more than one acre of soybean in OND 2015 were (2; 2%). In the same season, 21% more adopters than non-adopters planted between a quarter and a half of an acre of soybean. In the sixth season, OND 2016 adopters who planted between a quarter and a half of an acre of soybean increased by 123% while non-adopters remained at 4%. These results imply that the area planted by adopters increased over the seasons while that of non-adopters remained constant.

Table 4.4 Amount of Soybean planted by adopters and non-adopters in different seasons in Kgs

Mean soybean planted in Kgs	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters
	MAM 2014		**OND 2014**		**MAM 2015**		**OND 2015**		**MAM 2016**		**OND 2016**	
1-2	17 (20%)	5 (4%)	14 (16%)	4 (3%)	25 (29%)	8 (6%)	23 (27%)	6 (5%)	31 (36%)	8 (7%)	49 (57%)	3 (2%)
3-4	4 (5%)	1 (1%)	5 (6%)	1 (1%)	5 (6%)	3 (2%)	2 (2%)	2 (2%)	9 (11%)	1 (1%)	14 (16%)	2 (2%)
5-6	1 (1%)	1 (1%)	1 (1%)	0 (0%)	1 (1%)	2 (2%)	1 (1%)	1 (1%)	2 (2%)	0 (0%)	2 (2%)	0 (0%)
Above 6	2 (2%)	2 (2%)	2 (2%)	3 (2%)	2 (2%)	1 (1%)	4 (5%)	1 (1%)	2 (2%)	6 (5%)	5 (6%)	3 (2%)
None	62 (72%)	115 (92%)	64(75 %)	116 (94%)	53 (62%)	110 (89%)	56 (65%)	114 (91%)	42 (49%)	109 (87%)	16 (19%)	116 (94%)

Adopters = 86; Non-adopters = 124

Table 4.5 Area planted by adopters and non-adopters in different seasons

Area planted with Soybean in acres	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters
	MAM 2014		**OND 2014**		**MAM 2015**		**OND 2015**		**MAM 2016**		**OND 2016**	
< 0.25	9 (11%)	3 (2%)	13 (15%)	3 (2%)	14 (16%)	5 (4%)	16 (19%)	5 (4%)	18 (21%)	5 (4%)	24 (28%)	5 (4%)
0.25-0.5	13 (15%)	4 (3%)	16 (19%)	4 (3%)	18 (21%)	6 (5%)	24 (28%)	4 (3%)	26 (30%)	3 (2%)	29 (34%)	4 (3%)
0.51-1	2 (2%)	2 (2%)	0 (0%)	1 (1%)	3 (4%)	2 (2%)	1 (1%)	1 (1%)	7 (8%)	8 (7%)	1 (1%)	1 (1%)
> 1	0 (0%)	1 (1%)	1 (1%)	0 (0%)	0 (0%)	3 (2%)	2 (2%)	1 (1%)	0 (0%)	2 (2%)	2 (2%)	1 (1%)
None	62 (72%)	115 (92%)	56 (65%)	116 (94%)	51 (59%)	108 (87%)	43 (50%)	113 (91%)	35 (41%)	106 (85%)	30 (35%)	113 (91%)

Adopters = 86; Non-adopters = 124

Table 4.6 Soybean harvested by adopters and non-adopters in different seasons

Soybean harvested in Kgs	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters	Adopters	Non-adopters
	MAM 2014		**OND 2014**		**MAM 2015**		**OND 2015**		**MAM 2016**		**OND 2016**	
1-10	9 (10%)	5 (4%)	16 (19%)	2 (2%)	21 (24%)	7 (6%)	23 (27%)	5 (4%)	27 (31%)	6 (5%)	30 (34%)	2 (2%)
10-25	7 (8%)	0 (0%)	9 (10%)	1 (1%)	10 (12%)	2 (2%)	13 (15%)	2 (2%)	15 (18%)	2 (2%)	17 (20%)	0 (0%)
26-50	5 (6%)	0 (0%)	7 (8%)	1 (1%)	9 (10%)	1 (1%)	9 (11%)	2 (2%)	10 (12%)	3 (2%)	11 (13%)	0 (0%)
51-100	3 (3%)	2 (2%)	3 (4%)	1 (1%)	5 (6%)	3 (2%)	7 (8%)	0 (0%)	7 (8%)	0 (0%)	7 (9%)	1 (1%)
>100	1 (1%)	2 (2%)	1 (1%)	3 (2%)	1 (1%)	1 (1%)	2 (2%)	2 (2%)	1 (1%)	5 (4%)	2 (2%)	3 (2%)
None	62 (72%)	115 (92%)	50 (58%)	115 (93%)	40 (47%)	100 (88%)	32 (37%)	113 (90%)	26 (30%)	108 (87%)	19 (22%)	118 (95 %)

Adopters = 86; Non-adopters = 12

4.3.4 Soybean harvested by adopters and non-adopters in different seasons

In OND 2014 (16; 19%) adopters harvested between one and ten kilograms of soybean while only (2; 2%) non-adopters harvested between one and ten kilograms of soybean. In the following season, MAM 2015 adopters who harvested between one and ten kilograms of soybean increased to (21; 24%) and only 1% of adopters harvested over hundred kilograms of soybean (Table 4.6). In OND 2015 season 27% and 4% adopters and non-adopters respectively harvested between one and ten kilograms of soybean and (13; 15%) adopters harvested between ten and twenty-five kilograms. In the following season, MAM 2016 adopters who harvested between one and ten kilograms of soybean increased to (27; 31%) while non-adopters increased to (6; 5%). In the last season, OND 2016 adopters who planted between one and ten kilograms of soybean increased by 233% while non-adopters reduced by 60%. These results imply that if the trend continues the gap between demand and production will be reduced and this will reduce importation.

4.4 Socio-demographic factors in relation to adoption of soybean in central highlands of Kenya

4.4.1 Age and household size of adopters and non-adopters

Mean age of adopters was 54.38 years while the mean age of non-adopters was 53.70 years although there were not significantly different (Table 4.7). This implies that adopters were older than non-adopters. Non-adopters had a higher household size of 1.58 than adopters who had a mean household size of 1.45 although these means were not significantly different (Table 4.7).

Table 4.7 Mean age and household size of adopters and non-adopters

Characteristic	Adopters n=86	Non-adopters n=124	*t*-test p-value
Age of the Household head in Years	54.38	53.70	Ns
Household size	1.45	1.58	Ns

Ns= Not Significant

4.4.2 Marital status of the household head

Majority of the respondents (169; 80%) were married out of this 59% were non-adopters while 41% were adopters (Table 4.8). There was an association between marital status of the household head and the adoption of soybean (Pearson $\chi 2$ = 215.304, p = 0.001). This implies that spouses provide additional labor which is essential in soybean farming therefore, households with this additional labor have a higher probability of adopting soybean.

Table 4.8 Marital status of the household head and adoption of soybean

Marital status of Household head	Adopters n=86	Non-adopters n=124	X^2 p-value
Married	70 (41%)	99 (59%)	
Windowed	12 (52%)	11 (48%)	0.001*
Single	2 (17%)	10 (83%)	
Divorced	2 (31%)	4 (67%)	

∗Association significant at α = 0.05

4.4.3 Occupation of the household head

Majority of the respondents (171; 81%) practiced farming as their source of livelihood (Table 4.9). Majority of adopters (80%) practiced farming as their source of livelihood. There was a significant relationship between the occupation of household head and adoption of soybean (Pearson $\chi 2$ = 216.004, p = 0.001). This implies that household heads who practice farming as their main source of livelihood are more likely to adopt soybean than household heads who are employed or who have an off-farm business. Those who practice farming are more likely to use and adopt a new strategy to increase yield and diversify their usual practices compared to those who are employed or have off-farm businesses.

Table 4.9 Occupation of the household head and adoption of soybean

Occupation of the household head	Adopters n=86	Non-adopters n=124	X^2 p-value
Farming	69 (40%)	102 (60%)	
Employed	5 (45%)	6 (55%)	
Off farm business	2 (18%)	9 (82%)	0.001*
Retired	7 (64%)	4 (36%)	
Others	3 (50%)	3 (50%)	

∗Association significant at $\alpha = 0.05$.

4.4.4 Education level of the household head

There was a significant relationship between the education level of the household head and the adoption of soybean (Pearson $\chi 2$=211.689, *p*=0.001). Majority of the respondents (80; 38%) had upper primary education. Majority of adopters (36%) had attained education up to upper primary level (Table 4.10). Lack of education poses a challenge on a farmer's ability to understand the information in brochures and when taught by extension agents. It is more likely that a farmer who has gained education will access up-to-date agricultural information as opposed to a farmer who is illiterate and has no education at all and would not be able to get and understand the information in a simple agricultural brochure or even from a workshop organized by extension workers or agents.

Table 4.10 Education level of the household head and adoption of soybean

The education level of the household head	Adopters n=86	Non-adopters n=124	X^2 p-value
No education	6 (46%)	7 (54%)	
Upper primary education	31 (39%)	49 (61%)	0.001*
Secondary education	30 (44%)	38 (56%)	
Lower primary education	10 (38%)	16 (62%)	
Tertiary education	9 (39%)	14 (61%)	

∗Association significant at α = 0.05.

4.5 Farm characteristics in relation to adoption of soybean in central highlands of Kenya

4.5.1 Farm size and years of farming experience of adopters and non-adopters

The average farm size of adopters was 3.24 acres while that of non-adopters was 3.04 acres (Table 4.11). The implication of this is that adopters tended to have bigger farm sizes than non-adopters. Adopters had a significant (p=0.0269) higher farming experience of 19 years than non-adopters who had a mean of farming experience of 17 years (Table 4.11).

Table 4.11 Mean farm size and years of farming experience of adopters and non-adopters

Characteristic	Adopters n=86	Non-adopters n=124	*t*-test p value
Farm size in acres	3.24	3.04	Ns
Farming experience in years	19	17	0.0269*

∗Association significant at α = 0.05, Ns= Not Significant

4.6 Perception of soybean to be profitable in relation to the adoption of soybean in the central highlands of Kenya

The majority of households, (172; 82%) perceived soybean to be profitable while the rest (38; 28%) did not perceive soybean to be profitable (Table 4.12). There exists a significant relationship between perception of soybean to be profitable and the adoption of soybean (Pearson $\chi2 = 218.942$, $p = 0.001$). This implies farmers with a positive perception of the profitability of soybean have a higher likelihood of adopting soybean than those farmers with negative perception on the profitability of soybean.

Table 4.12 Perception of soybean to be profitable and adoption of soybean

Perception of soybean to be profitable	**Adopters n=86**	**Non-adopters n=124**	**X^2 p-value**
Yes	78 (45%)	94 (55%)	0.001*
No	7 (23%)	23 (77%)	

∗Association significant at $\alpha = 0.05$.

4.7 Membership of farmer group in relation to adoption of soybean in central highlands of Kenya

The majority of households, (119; 57%) are members of a farmer group while the rest (91; 43%) are not members of any farmer group. Majority of adopters, (74; 86%) are members of a farmer group while the majority of non-adopters, (78; 63%) are not members of any farmer group (Table 4.13). Adoption of soybean was associated with membership of the farmer group (Pearson $\chi2 = 262.514$, $p = 0.001$). This implies that when farmers are in a farmer group, they have a higher likelihood of adopting soybean than those farmers who are not in a farmer group and therefore encouraging and sensitizing farmers to join farmer groups would promote adoption.

Table 4.13 Membership to a farmer group and adoption of soybean

Member of a Farmer group	Adopters n=86	Non-adopters n=124	X^2 P value
Yes	74 (62%)	45 (38%)	0.001*
No	12 (13%)	78 (87%)	

∗Association significant at α = 0.05.

4.8 Availability of agricultural credit in relation to the adoption of soybean in the Central highlands of Kenya

In the majority of households, (117; 56%) agricultural credit was available, while the rest (93; 44%) agricultural credit was not available in agriculture. Majority of adopters households, (51; 59%) had accessibility to agricultural credit (Table 4.14). There exists a significant relationship between the availability of agricultural credit and the adoption of soybean (Pearson $\chi 2$ = 211.764, p = 0.001). This implies that farmers who can access agricultural credit have a higher likelihood of adopting soybean than those who cannot access agricultural credit, therefore, making agricultural credit available will increase adoption of soybean.

Table 4.14 Availability of agricultural credit and adoption of soybean

Availability of agricultural credit	Adopters n=86	Non-adopters n=124	X^2 P value
Yes	51 (44%)	66 (56%)	0.001*
No	35 (38%)	58 (62%)	

∗Association significant at α = 0.05

4.9 Logit regression model analysis of factors influencing adoption of soybean in the central highlands of Kenya

The results of the Logit model are presented in (Table 4.15). The model was significant at p<0.01 and it had good explanatory power and correctly predicted 77.9% and 87.1% adopters and non-adopters respectively.

Results showed that four factors significantly influenced the adoption of soybean in the central highlands of Kenya. Age of the household head negatively influenced adoption (β= -3.280, P=0.008) of soybean at 1% probability level (Table 4.15). It was the factor with the highest negative impact on the adoption of soybean. Implying that younger household heads had a higher probability of adopting soybean than older household heads.

Total farm size positively influenced the adoption of soybean (β= 1.347, P=0.015). It was the factor with the lowest positive impact on the adoption of soybean. This implies that farmers with bigger farm sizes have a higher probability of adopting soybean than farmers with smaller farm sizes. Membership of farmer group positively influenced adoption (β= 2.358, P=0.001) of soybean (Table 4.15). This implies that households which are in a farmer group are more likely to adopt soybean than households which are not in a farmer group.

Attendance of training on soybean positively influenced adoption (β= 3.136, P=0.041). It was the factor with the highest positive impact on the adoption of soybean. Implying that increasing training on soybean production will increase adoption of the crop in the central highlands of Kenya (Table 4.15).

Table 4.15 Factors influencing adoption of soybean in the central highlands of Kenya

Independent Variables	β	S.E.	Wald	Sig.	Exp (β)
Age of household head	-3.280*	1.229	7.123	0.008	0.038
Marital status of household head	1.679	1.182	2.015	0.156	5.358
Occupation of the Household head	0.592	1.263	0.219	0.640	1.807
Education level	0.393	1.023	0.147	0.701	1.481
Household size	0.591	0.631	0.877	0.349	0.554
Years of farming experience	1.480	1.049	1.988	0.159	4.392
Total farm size	1.347**	0.555	5.888	0.015	3.847
Perception of soybean to be profitable	-0.675	0.711	0.901	0.343	0.509
Membership of farmer group	2.358*	0.537	19.279	0.001	0.095
Attendance of trainings	3.136**	1.536	4.170	0.041	0.043
Availability of agricultural credit	0.426	0.475	0.805	0.370	1.531
Constant	2.458	1.554	2.502	0.114	11.683
Correctly predicted adopters as adopters	77.9%				
Correctly predicted non-adopters as non-adopters	87.1%				

N=210, *Significant at 1% probability level; **Significant at 5% probability level

CHAPTER FIVE

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

5.1 DISCUSSION

5.1.1 Effect of organic and inorganic fertilizers on grain yield of soybean results

Results indicated that the application of a combination of fertilizer plus manure and combination of fertilizer plus tithonia significantly increased soybean yield in comparison to the control in both seasons. Manure plus fertilizer treatment recorded the highest soybean yield although it was not significantly different from sole manure and a combination of fertilizer plus tithonia treatments in LR 2016 season. Similarly, application of a combination of manure plus fertilizer and combination of fertilizer plus tithonia recorded the highest percentage increase in soybean yield of 73% and 55% over the control, respectively in SR 2016.

Soybean yield did not increase significantly over the control with the application of either organic or inorganic fertilizer in SR 2016. The fact that application of a combination of fertilizer with either manure or tithonia gave significantly different soybean yield over the control treatment in both seasons implies that farmers need to be integrating the organic and inorganic fertilizers for soybean yield to respond to the application of these inputs in Embu County. The results of this study agree with previous studies by Kamidi *et al.* (2000); Gitari *et al.* (2002); Nziguheba *et al.* (2004); Mutiro and Murwira (2004); Kipsat *et al*. (2004); Ayuke *et al.* (2004) and Mucheru *et al.* (2004) on soil fertility management studies using organic and inorganic inputs. Similarly, Ahmad *et al.* (2008) also reported better crop yield in manure plus mineral fertilizer treatment. According to Vanlauwe *et al.* (2002), a combination of organic and inorganic fertilizer has synergistic effects and improved conservation and synchronization of nutrient release and uptake by crop leading to increased fertilizer efficiency and higher yields. This is especially so when the levels of mineral fertilizers used are relatively low as it is the case in most smallholder farms of central Kenya.

Danga *et al.* (2009) reported that manure, when combined with mineral fertilizer, contributed to improved soil physical conditions and nutrient use efficiency and soybean yields. Similarly, a significant increase in soybean yields when manure was applied in combination with mineral fertilizers than control has been successfully reported by Zingore and Giller (2012) and Peter and Ayolagha (2012). Similar results were reported by Kimani *et al.* (2004) who observed greater improvement in maize yields in treatments with cattle manure and mineral fertilizer than when the inputs were applied separately.

This higher soybean yield over the control on the use of a combination of organic and inorganic fertilizer is due to enhancement of nutrient use efficiency, synergy and improved synchronization of nutrient release and uptake by soybean plants leading to higher soybean yield compared to the control. The lack of response in the application of sole manure could be due to low rates of manure decomposition and subsequent N release to the soybean crop.

5.1.2 Economics of soybean under organic and inorganic fertilizers

One of the reasons for the acceptance of technology by farmers is the profitability of the technology. Farmers will tend to adopt a technology that will offer more net benefit but considering net benefit alone may be misleading for benefit-cost ratio seems to be the most appropriate economic tool for determining the most economical soil fertility improvement technology. Manure plus fertilizer is the only treatment that recorded a significantly higher net benefit than the control in both seasons. This indicates that adding manure alone, tithonia, fertilizer and a combination of fertilizer plus tithonia did not offer an economic benefit. The higher net benefit than the control in manure plus fertilizer treatment is due to the high soybean yield as earlier discussed. This indicates that the application of half rate of manure and half rate of fertilizer in soybean farming in Embu County offer the greatest economic benefit to farmers. Soybean yields influenced the economic returns of the different treatments and this shows that yield output can highly influence the economic returns from an enterprise (Mucheru-Muna *et al.*, 2013). Also, Morris *et al*. (2007) and Mapila *et al*. (2012) explained that a household's potential profitability from using fertilizer is determined by the responsiveness of the crop to which fertilizer is applied.

The benefit-cost ratio of one (1) is the breakeven point for the farmer while BCR of below one (1) implies that the farmer is not recovering the cost. Manure plus fertilizer and sole manure treatments recorded a significant higher BCR of 1.84 and 1.76 respectively than the control treatment in LR 2016 season. The higher BCR in the use of manure and a combination of manure plus fertilizer treatments in comparison to the control is attributed to high yields and lower labor costs. Manure is locally available on the farms thus fewer costs associated with its collection and transportation. The integration of mineral fertilizers with organic inputs or sole application of organic inputs has been regarded as a more profitable alternative in low input systems, countering the large cost of fertilizers (Mucheru- Muna *et al., 2007*). This study has confirmed that the integration of manure and inorganic fertilizer can be an alternative to the limited use of fertilizers by the farmers. All the treatments recorded a BCR of below 2.0, the minimum acceptable for most smallholder farming communities.

Manure plus fertilizer is the only treatment that recorded a significantly higher return to labor than the control and it is the only treatment that gave a return to labor which is greater than 2.0, the minimum acceptable for most smallholder farming activities. The higher return to labor in the integration of manure and fertilizer could be due to the low labor required compared to the sole applications of either manure or tithonia. This higher economic return could be the result of manure being locally available on the farm, thus fewer costs associated with it and also due to the fact that this treatment had higher yields. These results indicate that the integration of manure with inorganic fertilizers is a more economically profitable investment amongst the smallholder farmers in Embu, County than the farmer's practice (control).

The above findings concur with those reported by several authors. For instance, a study in central Kenya by Adiel (2004) reported the highest BCR in tithonia (5.4), tithonia plus half rate mineral fertilizer (4.4), tithonia plus manure (4.2), manure plus mineral fertilizer (3.3), and mineral fertilizer (2.4). Benefit-cost ratios of 1.08 for tithonia plus mineral fertilizer, 1.04 for manure plus mineral fertilizer, and 0.87 for tithonia were reported by Kipsat *et al.* (2004) in their study with farmers in Vihiga, Western Kenya. Positive net benefits were also reported in trials conducted in Zimbabwe on manure and mineral fertilizers at different rates (Mutiro and Murwira, 2004). In these trials, sole manure had net benefits of USD 142 (KSh 9,996) while the control (no inputs) had a net benefit of USD 20.9 (KSh 1,463). Supplementing manure with N mineral fertilizers increased the net benefits to USD 244 (KSh 17,137) and USD 326 (KSh 22,817) at 20 and 40 kg N ha^{-1} respectively.

Similarly, evidence of positive returns was reported for biomass transfer (Place *et al.*, 2002; Nziguheba *et al.*, 2002). According to Mekuria and Waddington (2002), manure gave a higher net benefit than the control. Integrated mineral-organic systems increased net benefit and BCR of maize (Place *et al.*, 2002; Mucheru-Muna *et al.*, 2007). Singh *et al.* (2018); Mubarak and Singh (2011) reported a significant net benefit and BCR of rice and wheat on the use of a combination of NPK fertilizer plus farmyard manure over the control. Similarly, Mahanta *et al.* (2015) reported a significantly higher net benefit and BCR on garden pea and French beans on combining organic and inorganic fertilizer in comparison to the control.

5.1.3 Characteristics of adopters and non-adopters

The number of adopters increased over the six seasons from 28% to about 90%. Farmers adopted soybean incrementally (planted soybean to see how it will perform before planting more). The production and acreage under soybean also increased over the six seasons. These results agree with those by Keil *et al.* (2017) who found adopters of zero tillage on wheat farming to increase over time and Ogada *et al.* (2014) who found household adoption levels of fertilizer and improved maize varieties to increase over time from 2004 to 2007. At first, few farmers planted soybean and the numbers kept on increasing. This increase in acreage and production implies that the gap between demand and production of soybean in Kenya can be reduced. The study has shown that about 2.8 tonnes are produced annually by adopters in the region and this means that there is still a huge gap between production and demand. These results imply that more effort is needed to enhance the adoption and production of soybean to reduce this gap.

The explanation to this increment of adopters over the six seasons can be that adopters were aware of the benefits of soybeans and the perceived soybean to be of importance hence the increase of the numbers who planted soybean through the period. On the other hand, non-adopters were not aware of soybean and they had a negative perception and attitude towards it and hence their numbers kept on decreasing over the period.

The quantity and area planted with soybean by adopters kept on increasing while that of non-adopters remained constant. This could be attributed to adopters being aware of the benefits of soybean and that they perceived soybean to be profitable hence increasing their acreage under soybean. On the other hand, non-adopters probably did not perceive soybean to be profitable and not aware of its benefit and hence their acreage under soybean remained constant. The results of this study concur with those of Yigezu et al. (2018) who found the total area under zero tillage to increase from 15,000 ha in 2010/11 to 50,000 ha in 2014/15 in Syria and that by Keil *et al.* (2017) who found the area of wheat under zero tillage to increase consistently over time.

Soybean harvested by adopters increased consistently from MAM 2014 to OND 2016, while that of non-adopters remained constant. The explanation for this observation is that adopters' acreage under soybean kept on increasing and thus the production increased while that of the non-adopters remained constant making production to remain constant as well.

5.1.4 Factors affecting the adoption of soybean in the central highlands of Kenya

Age of the household head negatively influenced the decision to adopt soybean. Farmers' age has been found to increase as well as decrease the probability of adoption. A young population is more likely to provide more labor because the younger population is more energetic than an older population and more knowledgeable (Martey *et al*., 2014). The age factor can have both a positive and negative effect. For example, Mugwe *et al*. (2008) found that younger population adopted ISFM technologies. Additionally, Younger farmers have the time to experiment with new strategies as opposed to older farmers.

In a study by Letaa *et al.* (2015) in Tanzania, farmers' age was found to negatively influence common bean adoption, while a study by Grabowski *et al.* (2016) in Zambia reported farmer's age to positively influence the adoption of cotton, where adopters were more advanced in age. The negative influence of the household head age on the decision to take up soybean in the current study could be due to young farmers having a tendency to be more innovative due to their longer planning horizons (Akinola *et al.*, 2010). It may be also that older farmers are more risk-averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of trying crops like soybean (Akinola *et al.,* 2011). This may also be because younger farmers are often better exposed to trying new innovations and have lower risk aversion and they 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). The negative influence of age on adoption in the current study is consistent with the findings of Nguyen-van *et al.* (2017) in Vietnam who found age to negatively influence the adoption of tea varieties. The importance of age in influencing (negatively) adoption is also in agreement with several other studies, for example, Ogada *et al.* (2014) in Kenya; Owombo and Idumah (2015) in Nigeria; Salifu and Salifu (2015) and Wongnaa *et al.* (2018) in Ghana.

The total farm size positively influenced the adoption of soybean. This implies that the adoption of soybean increased with an increase in farm size. Farmers who own and cultivate larger farms are more likely to spend more on conservation as it is associated with greater wealth and increased availability of capital, which makes investment more feasible. The positive influence of farm size on the adoption of soybean can be attributed to farmers with large farms diversifying crop production and trying new crops in their farms. This finding agrees with previous studies Bamire *et al.* (2010); Odoemenem and Obinne (2010) which found farm size to have a positive and significant influence on the utilization of improved cereal production technologies. The study also agrees with studies by Challa and Tilahum (2014); Owombo and Idumah (2015); Saliu *et al.* (2016) and Wongnaa *et al.* (2018) who found farm size to positively influence the adoption of agricultural technologies. The findings, however, disagrees with those by Jaleta *et al.* (2013) and Aidoo *et al.* (2014) who found farm size to negatively affect the adoption of maize production technologies.

Membership of farmer groups positively influenced the adoption of soybean. This implies that households belonging to farmer groups are likely to be more knowledgeable than households that do not belong to any group. This could be because the farmers in groups share their experiences and challenges hence fostering a positive way forward. Moreover, groups could be effective in persuading farmers to try new technologies and encourages the sharing of knowledge and experiences among members. Membership of an organization provides valuable learning and collective bargaining opportunity for farmers (Odendo *et al.,* 2009). Groups provide a means of collective action by farmers, providing resources such as credit, labor, and information (Odendo *et al.,* 2009).

Membership of farmer groups also enables individuals to have access to capacity building efforts such as training and study tours and to information pertaining to new agricultural technologies. Stringer *et al.* (2009), notes that group membership increases the information which also improves its access and adoption. These results are in agreement with previous studies by Matata *et al.* (2010) who found that farmers who did not adopt improved fallow were non-members in farmer groups and hence groups were needed in order to improve farmers' awareness and knowledge on improved fallow. The findings are consistent with those of Sisay *et al.* (2015) and Ahmed (2015), who observed that membership in a group had a positive influence on IMVs adoption in Ethiopia. Also, Ugwumba and Okechukwu (2014) and Ojo and Ogunyemi (2014) found similar results in Nigeria and Mmbando and Baiyegunhi (2016) in Tanzania.

Attendance of training on soybean positively influenced the adoption of soybean. This implies that adoption will increase with an increase in training on soybean. The more trained the households were the more knowledgeable they were likely to be in soybean production. The results agree with those of Pierre-André *et al.* (2010) who found that through training the farmers acquired knowledge that led to increased agricultural production and income from their farms. Similarly, Wongnaa *et al.* (2018) found that training by extension agents improved the level of adoption of improved seeds. Training is a vehicle by which profitable and resource-conserving land management is locally promoted and widely adopted. Training also addresses the challenges of lack of knowledge by creating awareness. The results of this study agree with those by Yirga *et al.* (2015); Owombo and Idumah (2015) and Ghimire *et al.* (2015) who found the positive influence of training through the extension on the adoption of agricultural technologies.

5.2 Conclusion

The first objective of the study was to determine the effect of organic and inorganic fertilizers on grain yield of soybean under on-farm conditions. The result showed that a combination of manure plus fertilizer and a combination of tithonia plus fertilizer had a significantly higher soybean grain yield than farmer practice (control) in both seasons. However, the yield of these treatments was not significantly different from other treatments. Application of single organics or inorganic fertilizer gave statistically similar yields to the control. In LR 2016 manure gave statistically higher yields than the control and this can be attributed to the use of well-decomposed manure which released nutrients immediately to the crop. These results imply that farmers should be integrating organic and inorganic fertilizers in soybean farming in Embu County.

The second objective aimed at comparing the economic benefits of soybean under organic and inorganic fertilizers. The results showed that manure and fertilizer was the only treatment which had a significantly higher net benefit and return to labor than the control in both seasons. This treatment was also the only one with a return to labor which was great than 2.0, the minimum acceptable for most smallholder farming activities. This implies that manure and fertilizer treatment was affordable, economical and with the highest net benefit compared to the control and hence it can be concluded that smallholder farmers in Embu County need to be integrating manure and fertilizer in soybean farming for maximum economic returns.

The third objective sought to determine the factors affecting the decision to adopt soybean in the Central Highlands of Kenya. The results showed that the factors that significantly influenced the decision to adopt or not to adopt soybean were: age of household size (negatively), total farm size (positively), membership of farmer group (positively) and attendance of training (positively). These results imply that younger farmers are more likely to adopt soybean than older farmers and farmers with bigger land sizes are more likely to adopt soybean than farmers with small land sizes. Further, farmers who are in a farmer group and have been trained on soybean have a higher probability of adopting soybean. The implication of these results is that the adoption of soybean could be enhanced by targeting younger families, farmers with bigger farms sizes than those with small farm sizes. Adoption of soybean can also be increased by training farmers on soybean production and encouraging them to join farmer groups where they can learn from each other.

5.3 Recommendations

Combining manure and fertilizer led to a significantly higher soybean yield than the control. Therefore, farmers in Embu County should be integrating organic and inorganic fertilizers in soybean farming.

Manure and fertilizer gave a significantly higher net benefit and return to labor than the control treatment and it is the only treatment that gave a return to labor which is greater than 2.0. This implies that the integration of manure and fertilizer should be promoted in order to realize maximum economic returns from soybean farming in Embu County.

To increase adoption of soybean, young household heads and household heads with bigger farm sizes should be targeted, increase training for farmers on soybean production and encouraging farmers to join farmer groups.

Further studies should be carried out to carefully monitor and assess how farmers continue planting and adapting soybean in the central highlands of Kenya, as this is a part of the adoption process.

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APPENDICES

Appendix 5.1: QUESTIONNAIRE

STUDY OF ADOPTION OF SOYBEANS QUESTIONNAIRE

The objective of this exercise is to evaluate the adoption of soybeans in the central highlands of Kenya.

Your participation is voluntary, but it is very important because you represent many other people in this County. There are no wrong and right answers to these questions. I would like to assure you that your answers will be handled with strict confidentiality. The interview will take about 30 Minutes - 1 hour

Section 1: General

1. Name of interviewer: ____
2. Date of interview: ____
3. Start time of interview: ____
4. GPS coordinates____________________________________

Section 2: Identification of household and study site

1	Name of the respondent	
2	Name of the household head	
3	County	
4	Sub-county	
4	Division	
5	Location	
6	Sub-location	
7	Village	
8	Phone Number of the respondent	

Section 3: Demographic characteristics

1	If the respondent is not a household head give the relationship of the respondent to the household head	1=Spouse 2=Son 3=Daughter 4=Relative 5=Other (specify)	
2	Age of the household head? ____________________		Actual age (yrs)
3	Gender of Household head	1=Male 2=Female	
4	Marital status of Household head	1=Single 2= Married 3=Widowed 4=Divorced	
5	The main occupation of the Household head	1=Farming 2=Off-farm business 3=Employed 4=Other (specify)	Give details if possible
6	The education level of Household head	1=No education 2= Lower Primary education 3=Upper primary education 4=Secondary education 5=Tertiary education	
7	Household size? Males________ Females________		Numbers
8	How many years of farming experience of the HH?		
9	How many HH members contribute to farming activities?	Males_______ Females________	
10	Do you sometimes hire in farm labor?	1=Yes 2=No	

Section 4: Farm characteristics

1	Does your household own land?	1=Yes 2=No	
2	If yes, what is your total farm size in acres	?___________acres	
3	What area is under cultivation?	_______acres	
4	What is the area under annual crop?	_______acres	

5	What is the area under homestead?	______acres	
6	What is the area under grazing/fallow land?	______acres	
7	How did you obtain the land?	1=Inherited 2=Purchased 3=Rented 4=Others (specify)	______acres (size for each)
8	Have you rented in land for cultivation of soybean in the last 5 years?	1=Yes 2=No	
9	If yes give acreage of the most recent	________acres	
10	Do you perceive soybean profitable?	1=Yes 2=No	
	If Yes, compared with other legumes do you think Soybean is more profitable		Probe, indicate the type of legume compared with

Section 5: Belonging to a group

1	Do you belong to a farmer group (yes/no)		
2	If yes, how many farmer groups are you a member?		Give names of the groups
3	How many members in each group?		
4	When did you join the above-mentioned farmer groups?		Give year

Section 6: Soybean production

1. Do you/have you ever planted soybean? Yes/No
2. If yes,

Season and year	Did you plant soybean in the following season Yes/No	Source of the seed **<u>Codes A:</u>**	Amount of seeds received	How much was planted (kg)	How much area (acres)	Inputs applied **Code B**	How much harvested(kg)
MAM 2014							
OND 2014							

MAM 2015							
OND 2015							
MAM 2016							
OND 2016							
		Code A 1=Extension/government , 2=KU, 5=farmer/neighbor, 3=Market, 4=own/recycled seeds, 5=SoCo project, 6= other, specify____			**Code B** 1=Manure, 2=Tithonia, 3=Chemical fertilizer, 4=Organic & chemical combined, 5=None		

Section 7: Participation in Training

Have you attended training(s)?

	Which topic have you been trained on?	**How many times in the last 3 years?**	**The venue of the training**	**When was the most recent? (Season and Year)**	**Do you apply the knowledge gained? Score level of application**	**Who trained you?**
1						
2						
3						
	1=Agronomy of soy and climbing beans, 2=soil fertility (ISFM) 3=Processing and utilization of beans, 4=Group dynamics, 5=Marketing, 6=Financial literacy, 7=Post harvest handling 8=other	Number of times	The specific site where the training took place (mother demos; kamujine, kigogo, Ngenge) OR Baby demos	Season and year	*On a scale of 1 to 5 one being the lowest while 5 the best*	*1=KU, 2=MoA, 3=FCI, 4=NGO, 5=KARI, 6=Agro-dealers/stockists, 7=Fellow farmers 8=Other specify*

Section 8: Availability of credit

1	Do you sometimes need credit for agricultural enterprises?		
2	Are there credit and savings facilities in the area for agricultural enterprise?		1= Yes; 0= No
3	Did you need credit in the last 2 years for agricultural enterprise?		1= Yes 0= No
4	If yes, did you access/get it?		1= Yes 0= No
5	If no why?	______________________________	
6	What is your main source of credit?		

Source of credit

1. Banks
2. Saccos
3. Commercial villages
4. Table banking

Thank you very much for your time.

Do you have any question?
Yes/No____
____

If Yes,
Question____
____

Answer
given____
____

End time of interview_______________

Enumerator's Remarks
____