ANALYSIS OF THE USE OF INOCULANT-BASED TECHNOLOGIES BY SMALLHOLDER FARMERS AND ITS EFFECT ON OUTPUT COMMERCIALIZATION: CASE OF FIELD BEAN FARMERS IN WESTERN KENYA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS

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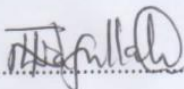
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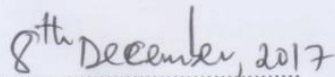
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Declaration

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

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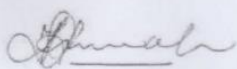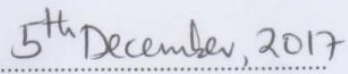
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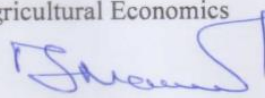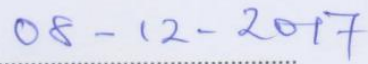
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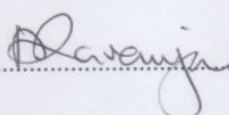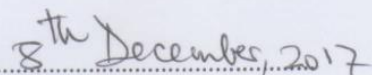
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DEDICATION

To my parents who have taught me that a good education is the key to success, my son, Austin and daughter Iris who have given me the reason to work hard each day and Charles, in strive for the ideal.

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ABSTRACT

Use of inoculant-based technologies in legume production has been practiced for over a century but in Africa, the technology is relatively new and especially to smallholder farmers. The introduction of these technologies has enabled increased legume productivity as well as increased soil fertility in other countries.

The inoculant-based technologies have been disseminated in Western Kenya by various organizations and projects including: Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa (SIMLESA) project through the Kenya Agricultural and Livestock Research Organization (KALRO)-Kakamega and Embu, Nitrogen 2 Africa (N2AFRICA), United States Department of Agriculture- National Institute of Food and Agriculture (USDA-NIFA), and Non-governmental organizations such as Appropriate Rural Development Agriculture Program (ARDAP). The dissemination targeted several counties including Bungoma, Busia and Kakamega. While past studies have assessed the adoption of inoculant technology as a single package, the effect of different inoculant- based technologies on bean yield remains unknown. There is also lack of information on the role inoculant-based technologies on bean output market participation.

This study examined the use and effect of inoculant-based technologies on smallholder field bean farm households in western Kenya. A multivariate probit (MVP) model was applied to assess factors affecting farmers' decision on use of alternative inoculant-based technologies. In

addition, a Tobit regression was estimated to assess the effect of the use of inoculant-based technologies on household output commercialization, measured by the share of sales, among project participating households and non-participating households. Data was collected from 248 farmers stratified by participation in projects that promote inoculant-based technologies. The information was collected in August and September 2014 and included farm and farmer characteristics; household endowment with physical, financial, social and human capital; market participation and institutional factors; field bean production and input usage; and farmer knowledge/awareness and information sources.

Descriptive results indicate that years of experience, total value of non-land assets and distance to the road significantly and positively affected adoption at 1percent, 5percent and 10percent error level respectively. Out of the five inoculant-based technologies demonstrated to farmers, only three were found to be widely adopted. These are: inoculant only, inoculant and farm yard manure and inoculant and fertilizer.

Results from the multivariate probit regression analysis showed that the distance to agricultural extension office, group membership, project participation, wealth (proxied by the total value of non-land assets), age and gender significantly affected the use of the inoculant-based technologies. The Tobit regression analysis results showed that transaction costs (proxied by the distance to group office and group and project participation), age, years of schooling, totals assets, access to information (proxied by extension visits) and total bean production area significantly influenced the commercialization of beans by the small holder farmers.

The findings of this study imply that use of inoculant-based technologies is influenced by asset endowment and hence the need to support the poorer farmer. Further, the finding that participation in groups increased output commercialization implies the need to encourage farmers to use these collective action schemes to reduce transaction costs that could reduce the benefits of using inoculant-based technologies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ALS   - Angular leaf spot

ARDAP   - Appropriate Rural Development Agriculture Program

ASAL   - Arid and semi-arid lands

BNF   - Biological nitrogen fixation

BRR   - Bean root rots

CIAT   - International Centre for Tropical Agriculture

CIMMYT   - Centro Internacional de Mejoramiento de Maíz y Trigo

FAO   - Food Agricultural Organization

GoK   - Government of Kenya

ICT   - Information, Communications and Technology

IFAD   - International Fund for Agricultural Development

KALRO   - Kenya Agricultural and Livestock Research Organization

KARI   - Kenya Agricultural Research Institute (Now KALRO)

KSC   - Kenya Seed Company

MoA   - Ministry of Agriculture

MVP   - Multivariate probit

N2Africa   - Nitrogen to Africa

NARO   - National Agricultural Research Organization (Uganda)

SIMLESA   - Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa

SPSS   - Statistical Package for Social Sciences

SSP   - Single supper phosphate

MT   - Metric tonnes

TSP   - Triple super phosphate

USDA-NIFA - United States Department of Agriculture- National Institute of Food and Agriculture

CHAPTER ONE

1. INTRODUCTION AND BACKGROUND INFORMATION

Over 70 percent of Kenya's land mass of 583,000 square kilometres is classified as arid and semi-arid lands (ASAL) which is characterized by low and unreliable rainfall (Makokha *et al* 2004). The livelihood of farmers in these areas depends on crops and livestock. In the ASALs, common bean is an important source of protein and calories in human diets (Laing *et. al,* 1984; Smithson *et. al.,* 1993; Katungi *et al.*, 2011) and is ranked second to maize as an important grain food crop (Mohajan, 2014; Katungi,2011). Kenya is currently the leading producer of common beans (henceforth referred to as beans) in Eastern Africa region with over 500,000 hectares (Ha) of land under the crop annually (FAOSTAT, 2015). On average, one decade ago, annual bean production amounted to 380,000 metric tonnes (MT) while total consumption is 450,000metric tonnes resulting in a 70,000metric tonnes deficit yearly, (MoA, 2009). Production has since increased to 529,265metric tonnes however there is still a deficit of 39,451metric tonnes (FAOSTAT, 2015). Beans are originally from Central and South America but can grow well in other regions of medium to higher elevations making Eastern African countries such as Ethiopia, Uganda, Rwanda, Tanzania and Kenya, suitable and well adapted for bean production. This is an important early maturing staple food in the semi-arid regions of these countries and globally.

In Kenya, the western region is one of the major bean production areas. The region is characterized by highly weathered and nutrient leached soils, mainly comprised of acrisols and ferralsols (Woomer and Muchena, 1996). Dry bean production which is dominated by small-scale farmers has been on the decline due to various biotic and abiotic constraints (Otsyula and Ajang, 1995). The biotic factors include bean root rots (BRR) and angular leaf spot (ALS) while

the abiotic factors are low soil fertility in form of low phosphorus and nitrogen and socioeconomic factors (MoA, 2009). Recent research on beans indicates that yields as high as four to five metric tonnes per hectare could be achieved with the Rose coco type variety of beans (Karanja *et al*, 2010).

Production of beans in Kenya is mainly concentrated around the highland and midland areas, with 33percent of the production taking place in the Rift Valley, Nyanza and Western Provinces each producing 22percent. Bean production in Eastern and Coastal regions remain constrained by adverse climatic conditions (Katungi *et al.*, 2009)

Even though Kenya is a leading producer of beans in the East Africa region, the declining soil fertility has led to reduced bean yield making Kenya to be a net importer of beans (MoA reports, 2009; Mutwoki *et al*., 2009). The limited use of purchased inputs as well as organic manures and bio-fertilizer, combined with increasing population pressure, has led to soil mining and declining soil fertility on declining land holding sizes (Doward *et al*, 2008) in most of the bean producing areas.

Tanzania, Uganda and Kenya have the highest area under bean cultivation as shown in Figure 1 below. Compared to other countries, Kenya and Uganda have very large differential between the land assigned to bean production and harvested and actual yield. With 1,030,435 hectares under cultivation in Kenya, the Kenya Seed company hybrid bean variety with an average yield of 1.8 metric tonnes per hectare, would yield 1,854,783 metric tonnes of beans as compared to the current production of 529,265metric tonnes under the same hectarage.
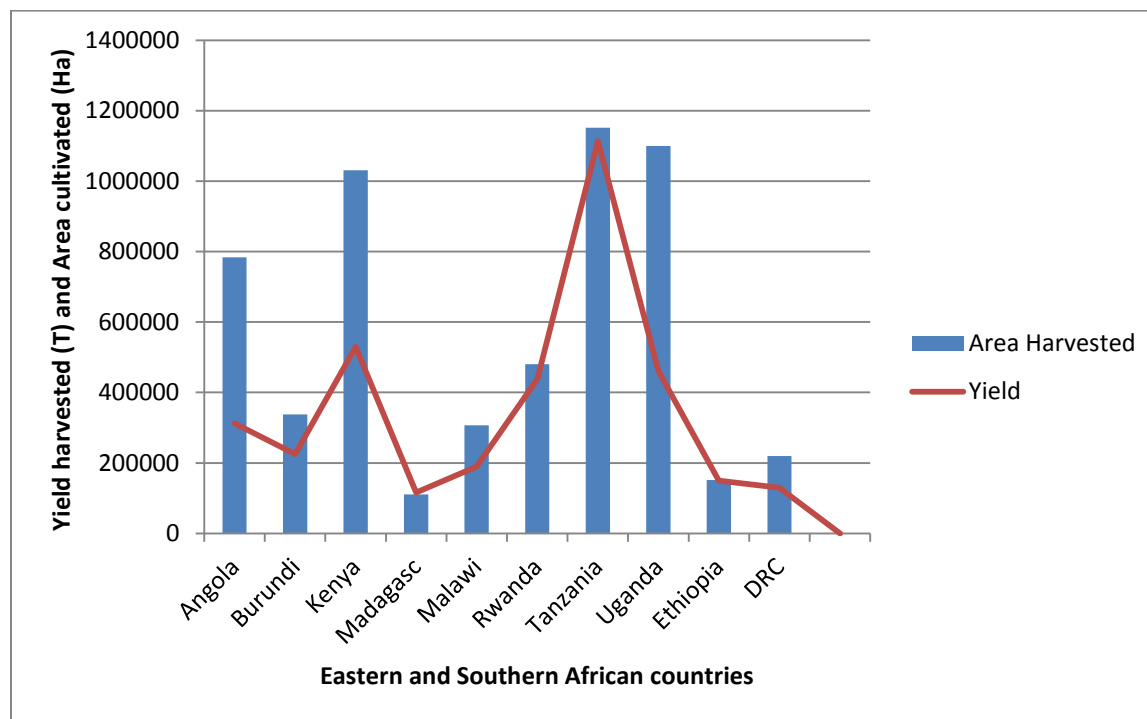
Source: FAOSTAT (2015)

Figure 1: Comparison of bean area production in Eastern, Central and Southern Africa.

Beans are a major source of protein in household diets in Kenya. Despite the area under bean production being high, bean production output, has not been stable as demonstrated by Figure 2, Overall production of beans declined from 613,902 metric tonnes in 2012 to 529,265 metric tonnes in 2013, a 13.78 percent decline whilst the area under bean production declined by 2.69percent. No significant improvement in yield has been observed from the year 2009 to 2013. Local consumption, which is total production plus domestic supply mostly through imports, has however increased and is above the production output (FAOSTAT, 2015). The drop-in production was attributed to the excessive rains which were experienced during the short rain season, (MoA, 2009).
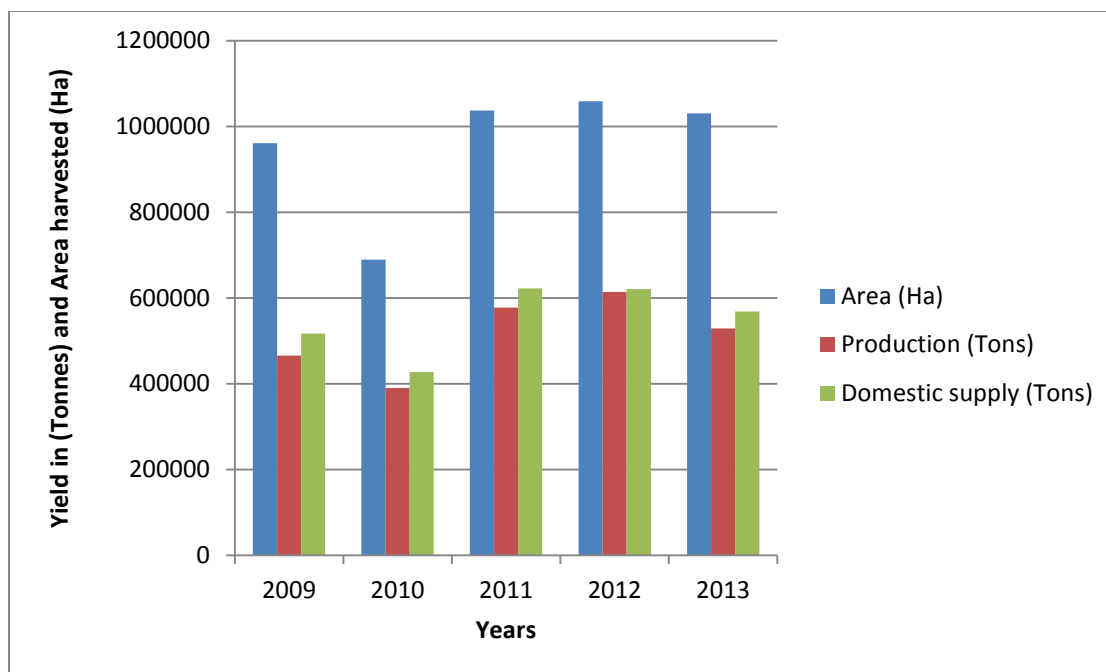
Source: FAOSTAT (2015)

Figure 2: Bean production area, yield and domestic supply trend in Kenya.

Farmers experience low bean yields because they tend to use 'own-saved' seed produced and recycled over years for bean production due to high cost of certified bean seed. Use of recycled seeds reduces bean cost of production, since they do not have to purchase certified seeds, but reduces the final yield harvested by the farmer. It also reduces the percentage of certified bean seed that is demanded and used by farmers. Lack of sufficient certified bean seed available for sale to farmers is also another constraint to improved bean yields (Katungi *et al*, 2009). This negatively imparts on bean yields as well as farmers using less vigorous and low yielding varieties of uncertified seeds (Karanja *et al*, 2010).

One of the strategies that aimed at arresting the low yields of beans in Kenya is the use of inoculant-based technologies. These are a suite of technologies that are provided to farmers, alongside inoculated beans, with the aim of boosting yields of leguminous crops. The technologies usually have a legume inoculant, but may be a combination of: the legume inoculant and straight phosphate fertilizers; farm yard manure and agricultural lime or biochar and special fertilizer blends. In addition, farmers are offered training and extension services. These inoculant-based technologies were promoted by research organization and projects namely Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa (SIMLESA) run under Kenya Agricultural Livestock research Organization (KALRO), United States Department of Agriculture- National Institute of Food and Agriculture (USDA-NIFA), Nitrogen 2 Africa (N2AFRICA) and Non-governmental organizations such as Appropriate Rural Development Agriculture Program (ARDAP) in many parts of Western Kenya. Nonetheless, some parts of the region have not yet adopted them, with a majority still producing beans using traditional methods which do not include the use of certified seed and other external inputs (e.g., fertilizers and *Rhizobia,* legume inoculant) (Karanja *et al*, 2010).

Most beans are produced by smallholder farmers, with yield ranging from 0.14 to 0.77 t/ha (Kapkiyai *et. al.,* 1998). The national average yield is 0.50 t/ha (Ssali, 1988), compared to the potential yield of 1.8t/ha, Kenya Seed Company (KSC), 2015. The rising cost of bio-fertilizers and fertilizer and smallholder farmers' belief that it is unprofitable to use improved inputs in beans also contribute to the low yields.

Five different inoculant-based technologies were therefore introduced to smallholder farmers in 2009, and have since been disseminated with the aim of addressing the problem of declining soil fertility among legume producing households. These technologies included the bean inoculant, biochar, lime, farm yard manure, and inorganic fertilizer and were promoted by the project in various combinations as listed below:

1.   Inoculation only

2.   Biochar + Inoculant

3.   Lime +Inoculant

4.   Inoculant + Farm yard manure

5.   Inoculant + Fertilizer (Sympal, a legume fertilizer blend; DAP; NPK, other)

Farmers were free to choose the combination that suited them and that they could afford.

1.1.   Statement of the problem

Overall production of beans has declined by 16 percent while the area under production declined significantly by 28 percent (MoA, 2009). Several factors have been attributed to it especially the low use of inputs. Despite the release of new varieties, increased importation of certified bean seed, and the promotion of various agricultural technologies, that are geared towards increasing the output of beans among smallholder farms, bean yields have remained quite low. This has been attributed to poor rain distribution and pest damage (MoA, 2009). Declining soil fertility has been the major concern for the low productivity and especially of beans over the years (Otsyula and Ajang, 1995). This has led to Kenya being a net importer of beans (Katungi *et al*., 2010). In response to this problem, the SIMLESA, KALRO, USDA-NIFA and N2Africa projects were initiated in between 2009 to promote the use of inoculant-based technologies to improve

the yield of legumes which included beans in Western Kenya. The patterns of adoption and the resulting outputs and outcomes, however, are not known precisely.

Mutuma (2014) undertook an assessment study focusing on the adoption of BIOFIX[®], a legume inoculation technology, comprising of the legume inoculation technology only on the soybean crop. The study specifically examined how farmers perceive the biological nitrogen fixation (BNF) inoculant, factors that drive its use and profitability. The results showed considerable increase in yields and profitability among households that used the legume inoculation technology to grow soybean (Mutuma, 2014). Mutuma (ibid) however used the Logit regression technique to assess the adoption process and focused on one technology only, namely the use of BIOFIX[®], and did not consider the other combinations of the inoculant-based technologies namely: Inoculation only, Biochar + Inoculant, Lime +Inoculant, Inoculant + Farm yard manure and Inoculant + Fertilizer (Sympal, a legume fertilizer blend; DAP; NPK, other), that were provided to the farmers. Analyzing adoption of the five-separate inoculant- based technologies above as a single composite technology fails to account for the possible correlation in decision to adopt the different inoculant-based technologies and hence may result in biased estimates of the coefficients. Indeed, Otieno *et al*., (2011) and Timu *et al* (2014) argue that decision to adopt one specific technology (a crop variety in their case) where there are other options tends to be correlated and/or interdependent with the decision to adopt the remaining ones. It is therefore expected that decision to adopt the BIOFIX[®] (the legume inoculant technology) is likely to be correlated with the decision to adopt the other inoculant-based technologies, making the estimated coefficients from a model such as that of Mutuma (ibid) biased.

A previous study by Mutuma (2014) used gross margin analysis to analyze the profitability of soybean enterprise by assessing returns to farmers who use inoculant on soybean production and those who do not. His study however, did not assess whether increased yields realized by farmers who applied BIOFIX® increased participation in output markets. Furthermore, Mutuma (2014), did not factor into the analysis the use of the three inoculant-based technologies that were offered to farmers when calculating BIOFIX® profitability using gross margin analysis. Currently there is no report of a study conducted to assess the effect of multiple inoculant-based technologies on bean output commercialization on smallholder farms

1.2. Objectives and hypotheses

The purpose of this study is to analyze the use and effect of inoculant-based technologies on smallholder field bean farm households in western Kenya.

1.2.1. Specific objectives:

i)   To analyze factors affecting farmers' decision to use alternative inoculant-based technologies.

ii)   To assess the effect of participation in a project that promotes the use of inoculant-based technologies on household field bean commercialization.

1.2.2. Hypotheses

The hypotheses to be tested are:

i)   Farmers' decision to use inoculant-based technologies is not affected by participation in a project that promotes the use of inoculant-based technologies.

ii)   Participation in a project promoting inoculant-based technologies does not affect the share of field beans marketed/sold by farmers.

1.3.   Justification

There are 1.4 billion poor people in Africa living on less than US$1.25 a day. One billion of them live in rural areas where agriculture is their main source of livelihood. Smallholders manage over 80 percent of the world's estimated 500 million small farms and provide over 80 percent of the food consumed in a large part of the developing world, contributing significantly to poverty reduction and food security. Increasing fragmentation of landholdings, coupled with reduced investment support and marginalization of small farms in economic and development policy, threaten this contribution, leaving many smallholders vulnerable (IFAD, 2013). Smallholder commercialization could be the strength of the linkage between farm households and markets at a given point in time. This household-to-market linkage could relate to output or input markets either in selling, buying or both. Alternatively, smallholder commercialization could also be a dynamic process: at what speed the proportion of outputs sold and inputs purchased are changing over time at household level (Jaleta *et al*, 2009)

At the farm household level commercialization is measured simply by the total value of sales as a proportion of the total value of agricultural output (Gebre-Ab, 2003). A study by Wiggins *et al* 2013, under the Future Agriculture Consortium, on smallholder commercialization showed that technical interventions, such as the use of inoculant-based technologies – which is the focus of this study, provide incentive for smallholder farmers to increase their output commercialization.

A study by Mutuma (2014) showed the benefits of smallholder soybean farming by using gross margin to assess the profitability of growing soybean using BIOFIX®, a legume inoculant. It also proved the benefits accrued from being in an organization and provision of marketing channels for farmers growing soybean. His study however did not take into consideration the possible correlation in farmers' decision to adopt the different packages with, if it so happens, can result in imprecise estimates of the effects of using such technologies. At the same time, his study lumped all the inoculant technologies together into one called BIOFIX. The current study however examines the different packages that collectively form "inoculant-based technologies" thus allowing for greater learning and provides more information that can be used to guide policy on the promotion of such technologies.

2. LITERATURE REVIEW

2.1. The concept of Technology adoption

Technology plays a vital role in any country's agricultural and economic growth. Technology arises from an innovation which is an idea, object or practice perceived as new (Nair *et al*, 2004). Adoption is therefore a mental process of first hearing about the innovation and deciding to make full use of that new idea (Rogers and Shoemakers, 1971; Rogers and Shoemakers, 1983; Evans, 1988). Rogers (2003) defines adoption as a slow process through which a person first hears the process and eventually decides to learn it and master it through, hence adoption. In any given adoption technology, there are different categories of adopters as shown in Figure 3.
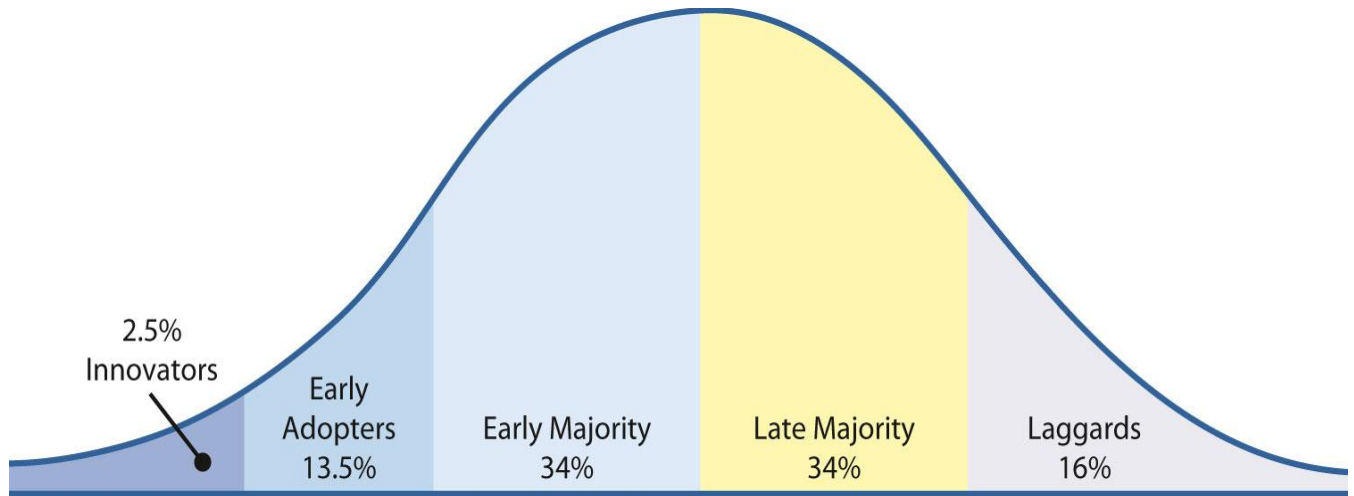
Figure 3: Innovation Adoption Lifecyle

Source: Rogers (2003)

Figure 3, above, shows innovators as those who are willing to experience the technology and are prepared to cope with unprofitable and unsuccessful innovations, and a certain level of uncertainty about the innovation. These are mostly educated and have complex technical

knowledge. The early adopters more likely to hold leadership roles in the social system, other members come to them to get advice or information about the innovation. They take up a more leadership role and put their stamp of approval on a new idea by adopting it. Although early majority have a good interaction with other members of the social system, they do not have the leadership role that early adopters have. However, their interpersonal networks are still important in the innovation-diffusion process. Their decision takes longer than the innovators and early adopters and they are neither the first nor the last to adopt the technology. The late majority includes one-third of all members of the social system who wait until most of their peers adopt the innovation. Although they are skeptical about the innovation and its outcomes, economic necessity and peer pressure may lead them to the adoption of the innovation. Close networks with peers convince this group to feel safe to adopt new technologies. Laggards have the traditional view and they are more skeptical about innovations and change agents than the late majority, (Rogers, 2003). Katungi (2011) further discusses the adoption cycle as variation in an adoption technology which is a function of the economic unit, the technology attributes and location or region. It is therefore defined as technology adoption if there is continued full use of a technology in the long run.

Feder *et al.*, (1985), argued that sociological definitions of adoption are usually inadequate for rigorous theoretical and empirical analysis due to their imprecision and failure to distinguish individual or farm level adoption from aggregate adoption. Innovation is perceived by economists as a technology with uncertain impacts on production; therefore, farmers reduce this uncertainty over time by acquiring experience, modifying the innovation and becoming more efficient in its application. Economists define adoption at the farm level as the degree of use of a

technology in the long-run equilibrium when a farmer has full information about the technology and its potential. At this level, each individual farm chooses to either use or not use the technology depending on the information provided. The second level which is aggregate adoption, gives the level of use of a specific new technology in each geographical area or population. Its focus is comparison across geographic regions and uses the proportion of farmers applying new technology in different regions (Hintze *et al*, 2002)

2.2. Socio-economic and institutional factors influencing technology adoption

Previous studies show that age, education, household size, distant to the nearest market, farmer's experience, land size and size of family directly influence the rate of adoption of any farm household. Access and frequency of extension contact and the attribute of the technology in terms of productivity were significant contributors to adoption of new agricultural technologies among farmers. Good marketing systems, group membership and access to credit are needed to increase the adoption rate and/or intensity of agricultural technologies as well. Attributes including cost of the technology package directly influenced the decision of farmers to adopt a given agricultural innovation. Group membership plays an important role in not only technology diffusion but adoption and adaptation (Hintze *et al*, 2002; Doss, 2003; Saka and Lawal, 2009; Otieno *et al*, 2011; Timu *et al* 2012; Mutuma, 2014). A study by Omonona *et al*. (2005) on adoption of improved cassava varieties in Edo State, Nigeria showed that sex, age, access to extension agent, access to inputs and crop yield were significant variables positively influencing adoption of improved cassava varieties.

2.3. Assessing the factors affecting use of alternative inoculant-based technologies

Adesina *et al*., (1995) used a Tobit model to estimate the effect of technology attributes on adoption of sorghum varieties in Burkina Faso and Guinea. The results revealed that attributes such as the ease of making sorghum paste and drought resistance under poor soil conditions were highly significant compared to yield and resistance to *Striga,* which the sorghum varieties were bred for. The findings concluded that farmers' subjective preferences to new agricultural technologies are important for any adoption behavior (ibid).

Saka and Lawal (2009) employed an adoption index, logit model and stochastic frontier model to assess the adoption status, its determinants and impact on farmers' rice productivity, respectively in Northwest Nigeria. Results from the logit model showed that adoption of new improved rice varieties was significant for size of the farm at 10 percent level, yield of the rice variety at 5 percent level and frequency of extension contact at 5 percent level while the stochastic frontier results was significant at 10 percent level for high yield of the new improved varieties.

The study by Otieno *et al* (2011) used multivariate probit regression analysis to analyze the effect of varietal attributes on the adoption of pigeon pea varieties and then used Poisson regression to assess the effect of varietal attributes on the number of pigeon pea varieties adopted by farmers. The findings on intensity of adoption of pigeon pea varieties indicated that high yield and early maturity traits were not significant. Drought tolerance, pest resistance, ease of cooking and the ability of the variety to fetch a price premium were significant. Drought tolerance was the highly significant for the adoption parameter at 5 percent level.

14

Timu *et al* (2014) examined the effect of variety attributes on adoption of improved sorghum varieties in Kenya using the multivariate probit. Results were significant for high yield, pest resistance, brewing qualities, ease of cooking and ability to yield a price premium. However, the decision to adopt one variety was correlated to other variety attributes.

In assessing the perceptions of farmers toward the use and profitability of BIOFIX®, legume inoculant, Mutuma, (2014) used the Logit to estimate the adoption of inoculant using one technology presented to farmers. Results were significant for farmer contact with organization promoting the inoculant.

Little is however known on the influence of such factors on the use of inoculant-based technology in bean production. The current study therefore seeks to investigate the socio-economic factors such as market, institutional and policy factors, farm and farmers characteristics and capital endowments on the influence of adoption of these technologies.

2.4.   Use of soil amendments and their effect in adoption of inoculant-based technologies

Soil amendments are materials that are worked into topsoil to enhance good soil properties hence promote healthy plant growth. They function in a number of ways for example; they may change the *pH* of soil or supply nutrients (Abegunrin *et al.*, 2013). Whiting *et al.*, (2013) defines soil amendments as any materials that are added to the soil to improve its physical properties such as water retention, permeability, water infiltration, drainage, aeration and structure. The goal is for provision of a better environment for plant roots. Most of Kenyan soils are acidic due to use of

chemical fertilizers such as DAP (Gachene and Kimaru, 2003). Acidic soils cause poor plant growth resulting from aluminum (Al^{+3}) and manganese toxicity (Mn^{+2}) or deficiency of essential nutrients like phosphorus, calcium and magnesium. Restoring, maintaining and improving fertility of this soil is major priorities as a demand of food and raw materials are increasing rapidly (Bekere *et al.*, 2013). Efforts have therefore been made to utilize locally available materials to assist in increasing soil pH and therefore improve soil conditions with new agricultural technologies such as inoculant-based technologies. It is these efforts that will assist in improving soil fertility and in achieving long term food security and improve farmers' standard of living, while mitigating environmental degradation (Hale *et al.*, 2013). Biochar, farmyard manure and lime are some of the soil amendments that have been used in Kenya to improve the performance of inoculant- based technology and its adoption by improving the soil structure hence provide for better inoculant performance and soil nutrients uptake by plants (Bekere *et al*, 2013).

2.4.1. Lime

Lime has been used over the years to amend soils that have low *pH* therefore improving the production of crops in acidic soils by raising the soil pH. It raises the soil *pH* by displacement of hydrogen (H^+), ferric (Fe^{2+}), aluminum (Al^{3+}), manganese (Mn^{4+}) and copper (Cu^{2+}) ions from the soil's adsorption site (Onwonga *et al*., 2010). More than increasing soil pH, it also supplies significant amounts of *Calcium* and *Magnesium*, depending on the type. Indirect effects of lime include increased availability of *Phosphorus*, *Molybdenum* and *Boron*, and therefore more favorable conditions for microbial mediated reactions such as nitrogen fixation and nitrification, and in some cases improved soil structure (Young *et al*., 2008). Western Kenya soils are

characterized by high soil acidity that impedes the growth of crops such as maize and beans due to reduced soil microbial activity (Akinrinde *et al.*, 2006; Gachene and Kimaru, 2003; Young *et al.*, 2008). The use of lime and *Bradyrhizobia spp* at the same time improves yield and its attributes than using the later alone in acidic soil (Bekere, 2013).

Kisinyo *et al* (2012) in assessing the effects of lime, phosphorus and rhizobia on *Sesbania sesban*, an animal tree legume forage, performance in Western Kenyan acidic soils showed that the use of lime, phosphorus based fertilizer, rhizobia inoculation can reduce the effect of Aluminium toxicity on *Sesbania sesban* establishment and growth. This is due to lowering of the soil pH by lime therefore increasing the performance of rhizobia inoculation on *Sesbania sesban*.

Verde *et al* (2013), showed the effect of lime application in increasing soybean yields in the central highlands of Kenya. Results from the study indicate that the use of lime in various combination of either inorganic or organic fertilizer had significant effect in uptake of nutrients such as magnesium and potassium as well as calcium in sole lime application on the soil. Lime increases the soil pH from the low (acidic) level to favorable levels for soybean production. The current study therefore examines the adoption of inoculant-based technologies that contain lime as a package to farmers.

2.4.2. Biochar

Biochar, commonly known as charcoal or *agrichar*, is a carbon (C) rich product derived from the pyrolysis of organic material at relatively lower temperatures of less than 700 degrees Celsius ($<700\ °C$). The normal charcoal making process uses over 1000 degrees Celsius (^{o}C) and up to

2700°C. (Lehmann and Joseph, 2009). Biochar stores carbon for long time, ameliorates degraded soils and reduces soil acidity for better crop production (ibid, 2012). It improves crop yield when applied as a soil amendment (Major *et al.*, 2010). Biochar application improves crop productivity through enhancing water holding capacity, cation exchange capacity (*CEC*), adsorption of plant nutrients and creates suitable condition for soil micro-organisms (Glaser *et al.*, 2002; Sohi *et al.*, 2009; Lehmann *et al.*, 2011).

Soil amendment with biochar is evaluated globally as a means to improve soil fertility and to mitigate climate change. It is clear, however, that sorption phenomena, pH and physical properties of biochar such as pore structure, surface area and mineral matter play important roles in determining how different biochar affect soil biota (Lehmann *et al*, 2011). Results from the investigations on the role of biochar on acid soil reclamation and yield of Teff in North-western Ethiopia show that the use of Biochar increased soil *pH*, *CEC*, available *P* and organic carbon and significantly increased yield of Teff (Abewa *et al.*, 2013). The alkalinity of most biochar can be beneficial to acidic soils, acting as a liming agent to increase pH, and decrease exchangeable *Aluminium ions* (Chan *et al.*, 2007, 2008; Major *et al.*, 2010). Just as any effect on improving soil pH, an improvement due to the use of Biochar is important in crop production due to increase nutrient absorption and potential yield of any crop.

Studies have also shown an increase in microbial activity where biochar was used. It is therefore being examined as a potential carrier for inoculant- based technologies. There are indications that biochar is an excellent support material for Rhizobium inoculants (Pandher *et al*. 1993; Lal and Mishra 1998).

Results from a study by Rondon *et al.*, 2007, showed an increase of biological nitrogen fixation, (BNF), by common beans with biochar additions and with a combination of effective rhizobium strains. The results demonstrated increased nitrogen through BNF into agro-systems with highly weathered and acidic soils by applications of biochar. This has led to further evaluation of biochar not only as a soil amendment in legume production but also as a future carrier material for inoculants. Detailed studies, however, on the relationship of biochar and BNF have not been published

2.4.3. Farm Yard Manure

Application of farm yard manure (FYM) has been shown, through research, to have significant impact on the chemical, physical and biological properties of the soil due to increased soil organic matter (Shirani *et al*., 2002; Liang *et al*., 2011; Bakayoko *et al*., 2009). Smallholder farmers in Central Highlands of Kenya have used manure as fertilizer to increase crop production, and have been shown to be an alternative for improving crop yields (Mugwe *et al*., 2007). Manure however, has different nutrient value depending on the types of animal, food rations, manure collection, storage, application and climate (Risse *et al*., 2008)

A study by Muthomi *et al*., (2007), showed the effect of FYM, rhizobia inoculant and fertilizer on various legumes. No significant effect on nodulation where FYM was used was seen, however, a higher number of nodules were experienced where FYM was used than in the control experiment. The study however did not find any significant effect on the use of FYM on yield of the legumes (common beans, green grams, lablab and lima beans) as well as grain and shoot dry matters.

In evaluation of the effects of farm yard manure, lime and mineral Phosphorus (P) fertilizer on soybean yields and soil fertility in a humic nitisol in the Central Highlands of Kenya, Verde *et al*., (2013), reported an increase in Nitrogen (N) mineralization. Possible assumption was that the N was obtained from the farm yard manure. An increase of micro-organisms was also observed due to reduced soil pH which favored the N mineralization, a contribution to the soil nitrogen quantity. Another effect of manure in this study is the positive effect on yield, growth and development of soybean due to increased nutrients and water uptake.

While most of the studies have shown that the use of lime, farm yard manure and biochar increase the functioning of inoculants, no study has been done to show the effect of using the soil amendments in combination with inoculant hence inoculant-based technologies. No adoption study has also been conducted for inoculant-based technologies in combination with soil amendment technologies. The current study therefore seeks to carry out the adoption of these technologies by using socio- economic factors that affect and influence adoption among smallholder farmers.

2.4.4. Assessing the effect of using inoculant –based technologies on household output commercialization

The theory of the firm is the study of how firms allocate their scarce resources among alternative uses in the pursuit of profit maximization. On the other hand, a producer will pick a production package or inputs that minimize his/ her cost as well as potentially maximize his profits, (Varian, 1997:49). A producer will use his/ her rationality to pick a bundle of inputs that are affordable but not the most preferred bundle, therefore minimizing cost.

A previous study by Mutuma (2014) used gross margin analysis to analyze the profitability of soybean enterprise by assessing returns to farmers who use inoculant on soybean production and those who do not. His study however, did not assess whether increased yields realized by farmers who applied BIOFIX® increased participation in output markets. Furthermore, Mutuma (2014), did not factor into the analysis the use of the three inoculant-based technologies that were offered to farmers when calculating BIOFIX® profitability using gross margin analysis. By viewing the farmer as a firm and a producer, we are able to assess why he/she will choose a given inoculant-based technology thus assess the effect of the given technology over others on the yield consequently on the household output commercialization. Currently there is no report of a study conducted to assess the effect of multiple inoculant-based technologies on bean output commercialization on smallholder farms

CHAPTER THREE

3.   METHODOLOGY

3.1.   Theoretical framework

This study is based on the theory of the firm. Agricultural households combine two fundamental units of microeconomic analysis, the household as a consumption unit and the firm as a production unit. When the household is a price taker in all markets, for all commodities which it both produces and consumes, optimal household production can be determined independent of leisure and consumption choices. Therefore, given the maximum income level derived from profit-maximizing production, family labor supply and commodity consumption decisions can be made (Singh *et al*, 1986). In focusing on farm production and on productivity change, the unit of analysis is the firm and the economic motivation is that of cost minimization or profit maximization subject to constraints (Evenson *et al,* 1986). The household as a firm (producer) is therefore assumed to seek to minimize the cost of producing beans using the inoculant-based technologies subject to specific constraints, that is a given output level. In this study, the household is dealing with a single output problem, and has to choose a least cost input package for bean production. The farmer problem can thus be presented as:

$$\text{minimize C } (\mathbf{WX}) \tag{1}$$

Subject to a production function specified as:

$$f(X, T) \geq \mathbf{q} \tag{2}$$

Where **C** is the total cost function; **W** is the fixed cost of the input bundle while **X i**s a cost associated with acquisition of the inoculant-based technology pack. Prices are strictly positive

hence $X \geq 0$, q is the output of bean and **T** is the total labor requirement comprising family labor

(**l**) and hired labor (**h**).

The farmer's optimization problem therefore is to choose **X** to minimize the cost of production

subject to the production function and a specified quantity of output $\mathbf{q^o}$. That is:

$$\text{Min } C(W_iX_i) \qquad (3)$$

s.t.

$$f(X_i) = q \qquad (4)$$

Where $i = 1, 2, 3...$ n represents the inoculant-based technologies available and which a farmer

will choose from, for bean production

$$q \geq q^o \qquad (5)$$

$$T \geq l + h \qquad (6)$$

Equation (5) shows that the bean output constraint which need not hold exactly, whereas

equation (6) shows that the family labor and the hired labor together should at least equal the

total effective labor requirement.

The Lagrangian expression associated with the cost-minimization is:

$$L = X_i + \lambda_1 [f (X_i - q) + \lambda_2 (T - l - h)] \qquad (7)$$

Where L is the cost minimization level of bean production. The first order conditions are
differentiated with respect to X_i variables and the Lagrangian multipliers λ_1 and λ_2 :

$$X_i: Wx_i - \lambda_1 \left(\frac{\partial q}{\partial x_i}\right) - \lambda_2 \left(\frac{\partial l}{\partial x_i} - \frac{\partial h}{\partial x_i}\right) = 0 \qquad (8)$$

$$\lambda_1: f(X_i) - q = 0 \tag{9}$$

$$\lambda_2: T - l - h = 0 \tag{10}$$

The Lagrange multiplier λ_1 represents the marginal value of output, whereas λ_2 is the marginal cost of labor or the additional cost associated with an additional unit increase in labour.

The second order sufficient condition for cost minimization requires that the determinant of the Bordered Hessian be negative. The Bordered Hessian comprises the second partial derivatives of the Lagrangian expression with respect to X_i, λ_1 and λ_2

Assuming that the second order sufficient condition is satisfied, the first order condition equations can be solved for $X_i{}^*$ yielding the conditional factor demand equations as functions of output $\mathbf{q^o}$, input bundle price $\mathbf{W}$ and the cost associated with acquisition of the inoculant-based technology pack $\mathbf{X,}$

$$X_i{}^* = X_i{}^*(\text{w}, q, x) \tag{11}$$

Equation (11) above also gives the input demand function which is, in this study, the demand function for the inoculant-based technology. It is therefore an adoption function for inoculant-based technologies.

3.2.   Conceptual framework

The conceptual framework shows the link between the socio-economic factors that influence the use and/or adoption and adaptation of inoculant-based technologies consequently affecting the quantities of output produced by the farmers and hence and the percentage the farmers allocate to consumption and sales. The share of output sold is referred to in this study as the output commercialized hence the term used output commercialization. Assessment of the use inoculant-based legume technologies and the effect of adoption of these technologies on the share of beans sold is important in guiding efforts aimed at promoting these technologies.
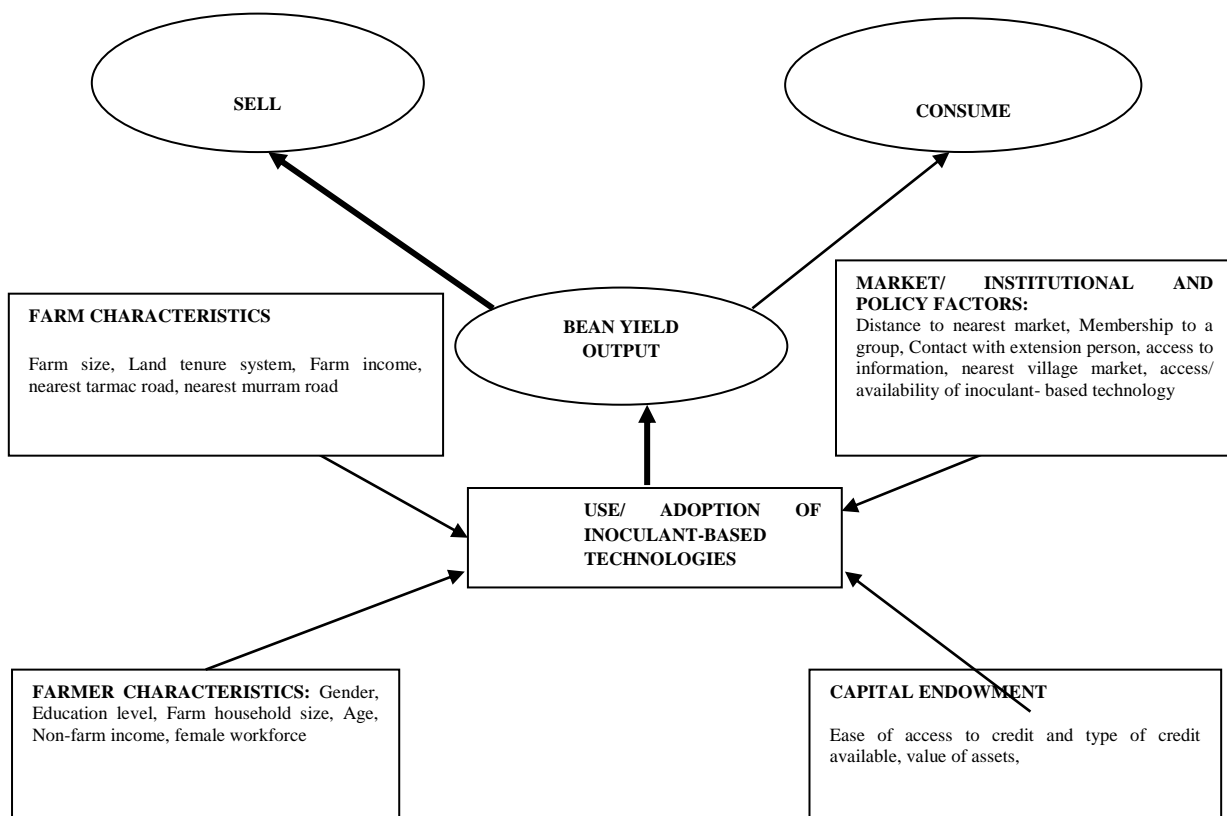
Figure 4: Conceptual Framework

Source: Author's conceptualization

3.3. Empirical model

3.3.1. Assessing the factors affecting the use alternative inoculant-based technologies

Different models have been used to assess adoption over the years. The most common being the linear probability model (LPM), Logit, Tobit and recent studies using the Poison and multivariate probit (MVP) regression models (Green, 2003; Gujarati, 2003; Otieno, 2010 and Timu *et al*, 2014)

According to Gujarati (2003), probability models for qualitative studies with a binary response variable include linear probability model (LPM), the Logit model or the probit model. Although LPM yields unbiased estimates, it has heteroscedastic variances of the error terms. The R^2 value as a measure of goodness of fit is also questionable since it either is lower than or exceeds the range of 0.2-0.6 that is given for any practical applications (ibid). LPM also produces predicted probabilities that are less than zero or greater than one, violating probability limits, implying that the constant marginal effect of each explanatory variable appears in their original form, and therefore contains heteroskedasticity. These limitations of the LPM can be overcome by using more sophisticated binary response models (Wooldridge, 2004). In adoption studies, a negative or positive response towards new agricultural technologies was observed to either adopt or not to adopt the technology with a binary response with either a 'Yes or 1' for adoption and 'No or 0' for non-adoption. Binary response models such as the probit and the logit, which are derived from an underlying latent variable model satisfy the classical linear model assumptions.

The probit is favored for regression analysis due to the assumptions of the normal distribution of the error term (*e*) (Wooldridge, 2004). In cases where the dependent variable is binary, the linear

probability model (LPM), probit or Logit can be used. However, the logit has slightly flatter tails and easily available in computer programs which makes it a more ideal model to be used compared to the probit, however, the logit model would yield biased and inefficient estimates due to the various inoculant-based technologies presented. The Poisson model could have been used however this regression model however it is specifically suited for count data (Gujarati, 2003; Greene, 2003; Wooldridge, 2004 and Otieno 2010)

The current study therefore, uses the MVP regression model to analyze the use of three inoculant-based technologies among smallholder bean farmers in Western Kenya. Five inoculant-based technologies were originally showcased to the farmers. However, only three as listed below were entered the MVP as two i.e. Biochar + Inoculant and Inoculant +farm yard manure did not yield significant data that could be analyzed in the MVP. The MVP is a natural extension of the probit model that allows for more than one equation, with correlated disturbances, in the same spirit as the seemingly unrelated regressions model.

The general multivariate probit regression model is specified as follows:

$$Y_{ij}^* = \beta_i X_i + \mu_i \tag{12}$$

Where Y_{ij} for $j = 1, 2, \ldots, n$ represents an unobserved latent variable of the inoculant-based technologies j used by farmer i; X is a 1 x k vector of observed variables that affect the inoculant-based technology adoption decision; β is a k x 1vector of unknown parameters to be estimated; and ε is a vector of stochastic (error) terms. Each Y_{ij} is a binary variable representing the adoption decision by farmers. Equation (11), written as $X_i^* = X_i^*(w, q, x)$, which is the

input demand function, is therefore specified in Equation (12). The yielding conditional factor demand equations, will influence the choice of inoculant-based technology adopted, j =1, 2, 3 …n and utilized by farmers:

1.   Inoculation only

2.   Inoculant + Farm Yard Manure

3.   Inoculant + Fertilizer (Sympal, a legume fertilizer blend; DAP; NPK, other)

The composite equation is therefore written as:

$$\left\{ \begin{array}{l} Y_1^* = \beta_1 X_i + \mathcal{E}_1 Y_! = 1 \ \text{if} \ Y_1^* > 0 \ and Y_1 = 0 \\[2ex] Y_2^* = \beta_2 X_2 + \mathcal{E}_2 Y_2 = 1 \ \text{if} \ Y_2^* > 0 \ and Y_2 = 0 \\[2ex] Y_3^* = \beta_3 X_3 + \mathcal{E}_3 Y_3 = 1 \ \text{if} \ Y_3^* > 0 \ and Y_3 = 0 \end{array} \right\} \qquad (13)$$

This system of equations is jointly estimated using maximum likelihood method.

The decision to use inoculant- based technologies is hypothesized to be dependent on farmers' characteristics, farm characteristics, institutional and policy variables and capital endowment. The dependent and the explanatory variables used in the estimation of MVP regression model are presented in Table 1, along with their definitions and hypothesized directions of effect based on the existing literature.

Table 1: Description of variables to be included in the MVP regression model

Dependent Variable	Description	
Y_{ij}^*	Y_{ij} takes the value of 1 if farmer i uses inoculant j, and 0 otherwise.	
Independent variables **i) Farmer Characteristics**		
		Hypothesized sign
Lnage	Natural log of age of the household head (Years)	+/-
Gender	Gender of the household head (1=Male, 0= Otherwise)	+/-
Lnyrsofschl	Number of years of formal school (count)	+
Inotecexp	Years of experience in growing beans using the chosen inoculant-based technology (j)	+
householdsize	The number of individuals in the household above 18 years	+/-
ii) Farm Characteristics		
Bnland	Total land size, in acres, under bean production, whether mono or intercropped (i.e., where intercropped it was based on share of land covered by beans)	+
Distrd	Distance to the nearest paved earth road (Kilometers)	-
Dinosource	Distance to the nearest inoculant acquisition source	-
Dcoop	Distance to the nearest cooperative or group office (Kilometers)	-
Distmkt	Distance to the nearest village market (Kilometers)	-
Llnlasset	Natural log of value of non-land assets bringing in income other than farming income)	+
Lntassets	Natural log of value of total assets (defined as value of assets owned by the household but not land e.g. livestock, household/ physical assets e.g. TV, bicycles in Kenya Shillings)	+
iii) Institutional and policy variables		
grpart	Farmer belongs to a group/ association (1= Yes and 0=No)	+
dagricrxt,	Distance in kilometers to the nearest agricultural extension office that gives information on bean production (Interaction with the farmers group office, agro-dealer and/or government extension office were used as proxies to access of information)	+

Propart	Farmer participated in inoculant-based technology promoting project (1= Yes, 0= Otherwise). Farmers who were not in the project but used either one of the inoculant-based technologies to grow their beans, were categorized as adopters	+
Extvisit	Number of extension visits in the 2013cropping season	+
iv) Capital endowment		
creditaccess	Access to loans or funds that offer loans for purchase of inputs (Access= 1, 0=Otherwise) Consideration was given for banks, MFIs, merry-go-rounds (*chamas*) and farmers SACCOs	+
bnshare	Total bean marketed or sold by farmers ((1=Yes, 0=otherwise)	+

The implicit general form of the empirical model is specified as follows:

Yij = f (lnage, gender, lnyrsofschl, llnlasset, inotecexp, householdsize, distrd, distmkt, lntassets, grpart, propart, extvisit, dagricrxt, creditaccess) +ε.

The variable *propart* is used to test hypothesis one using the MVP regression model. The null and alternative hypotheses are stated as below:

  i.   Null hypothesis: Farmers' decision to use inoculant-based technologies is not affected by participation in a project that promotes the use of inoculant-based technologies.

 ii.   Alternative hypothesis: Farmers' decision to use inoculant-based technologies is affected by participation in a project that promotes the use of inoculant-based technologies.

3.4.   Assessing the effect of using inoculant-based technologies on household output commercialization

Agricultural commercialization can broadly be looked at from two perspectives: a rise in the share of marketed output; or of purchased inputs per unit of output (de Janvry *et al.*, 2000;

Otieno et al, 2009). Agricultural commercialization can occur on the output side of production with increased marketed surplus. Commercialization is measured, in this study, as a ratio of the value of bean sales to the total value of production of beans (ibid). The Tobit regression model is used to assess the effect of the use of inoculant-based technologies on household output commercialization. A Tobit model is usually applied to outcome variables that are roughly continuous over positive values but have a positive probability of being zero. In this study, the share of beans sold can assume a zero value (no sales) or non-zero values (sales occurred).

Following Greene (2003), the Tobit model used in this study can be specified as follows:

$$y_i^* = \beta_i \chi_i + \mu_i \qquad\qquad (14)$$

Where

$$y_i = y_i^* \text{ if } y_i^* \geq 0$$

Where y_i^* is the share (percent) of output of beans that is sold by a farmer i, given X_i, the vector of explanatory variables, β_i is a vector of parameters to be estimated, and μ is the error term. The model is estimated using maximum likelihood technique.

The implicit form of the Tobit model estimated in this study is specified as:

Share of bean output sold= f (lnage, gender, lnyrsofschl, llnlasset, inotecexp, householdsize, bnland, distrd, lntassets, grpart, propart, extvisit, creditaccess) +ε.

The variable *propart* is used to test the second hypothesis. Participation in the project assumes that the farmer used an inoculant-based technology, which is, in turn, assumed to increase the

volume of production and consequently marketable surplus. The null and alternative hypotheses tested are stated as:

i. Null hypothesis: Participation in a project promoting inoculant-based technologies does not affect the share of bean output marketed/sold by farmers

ii. Alternative hypothesis: Participation in a project promoting inoculant-based technologies affects the share of bean output marketed/sold by farmers

The variables used in the Tobit regression model are as defined in Table 1 above.

The share of bean output sold was calculated as a percentage of total sales to the total production by the farmer. Farmers who did not participate in the sale of bean were censored at zero by the regression model.

3.5.   Research design, sampling and data collection procedure

The survey was conducted in two stages. Initial pre-survey was done to obtain an understanding of the production and marketing of beans in the survey areas. During the exploratory survey, discussions were held with different stakeholders including county directors of agriculture, district agricultural officers, group contact persons and extension staff working directly with farmers. The results obtained were used to guide the selection of the sites and designing the sampling frame. The pre-survey was conducted between 25th and 28th February 2014.

The second stage was the actual data collection. A total 248 farmers, both adopters and non-adopters, were interviewed in this study. The farmers were drawn from Bungoma, Busia and Kakamega counties. Bumula, North Teso and Kakamega South sub-counties were purposively selected as this is where the inoculant-based technology project was implemented. Three

32

divisions, one from each sub-county that participated in the inoculant-based project were purposively selected based on the extent of use of the inoculant-based technologies. Information on the extent of use of inoculant-based technologies was obtained from the key informants and project staff. The divisions selected were Bumula, Angurai and Ikolomani North. Next, in each division, three locations where the project was implemented were purposively selected. These were: Moding, Kolanya and Katakwa locations in Angurai division, North Teso sub-county; Shisere location in Ikolomani North Division, Kakamega South sub-county and Kimaeti in Bumula Division, Bumula sub-county. The locations were selected based on where the project conducted the training and demonstrated the use of the inoculant-based technologies on bean production in the region. The sub-locations were then purposive selected to yield Mutaho sub-location in Shisere location; Nakwana and Siombe sub-locations in Kimaeti location; and Apokor, Kolanya, Aloete, Rwatama and Katelepai sub-locations in Moding, Kolanya and Katakwa locations respectively.

A total of 31 villages were eventually selected using probability proportionate to size (PPS). This was guided by the total number of villages found in each purposively selected sub-locations. In each village, a list of farm households growing beans and participating in the inoculant-based technology project and another list of farmers growing beans but not participating in the project was drawn with the help of the farmer group contact persons and village heads, giving rise to a stratified sample. Lastly, a random sample of adopters and non-adopters of inoculant-based technologies was selected from the two lists. An equal number of participants and non-participants were randomly drawn from the two (2) lists to participate in the survey. This process

gave rise to a total of 248 farmers. The determination of the size of sample was guided by Fink and Kosecoff (1998).

The data was collected using pre-tested questionnaires from 20th August to 2nd September 2014. Information collected included those on farm and farmer characteristics, institutional, market and policy variables, capital endowment and household participation in bean markets.

3.6.   Sample size determination

Following Fink and Kosecoff (1998) the size of survey sample size was determined using the formula:

$$n = \left(\frac{Z}{e}\right)^2 pq \tag{15}$$

Where:

N= Calculated sample size

Z= Standard limit depending upon confidence level. In this case 1.96 corresponding to 5percent level

e = Sampling error in this case 0.05

p = the proportion of adopters which is assumed to be 0.2 (A study by Jack, 2013, confirms the adoption of agricultural technologies, in this case maize, in Sub-Saharan Africa at 17 percent, an estimate of 20 percent rate of adoption was used for this study)

q = 1-p

Therefore:

$$n = \left(\frac{1.96}{0.05}\right) 2(0.2)(0.8) = 245.8624 \tag{16}$$

Hence according the above formula no less than 246 needed to be sampled. The sample size of 248 was therefore used in this study.

The data collected was coded and entered using the Statistical Package for Social Sciences (SPSS). Descriptive analysis was done using SPSS while regression analyses were done using STATA.

3.7. Description of the study area

This study focused on three counties in Western Kenya namely; Bungoma, Kakamega and North Teso where the N2Africa project promoted the inoculant-based technologies

Figure 5: Map of Bungoma, Kakamega and Busia Counties

Source: http://www.opendata.go.ke and http://www.investmentkenya.com

Bungoma County is in Western Kenya along the border with Uganda, and borders Busia, Kakamega and Trans-Nzoia Counties. It has an area of 3,032.2 square kilometres and lies on Latitude 0^0 35'N and Longitude 34^0 35'E. Temperatures range from a minimum 15 to 20 °C to a maximum of 22 to 30 °C. It has two rainy seasons with average rainfall from 1200mm to 1800mm per annum. It has a population of 1,375,063. Agriculture is the main economic activity in this county with sugar cane and maize farming being major crops grown and accounting to a part of the county's income. Other crops grown by most households are beans, groundnuts, coffee and horticultural crops (especially onions and tomatoes). The county also has good livestock breeds that have seen the growth of beef and dairy industries.

Kakamega County is located in Western Kenya bordering Bungoma to the North, Trans-Nzoia to the North East, Uasin Gishu and Nandi Counties to the East, Vihiga to the South, Siaya to the South West and Busia to the West. It has an area of 3,224.9 Square kilometres. It lies on Latitude: 0° 17' 08" N and Longitude: 34° 45' 19" E and has temperatures range from a minimum of 10.3°C to a maximum of 30.8°C with an average of 20.5°C. The rainfall ranges between 1,250 and 1,750 mm per annum. It has a population of 1,660,651 with the number of Households being 398,709. The major economic activities are farming. Crops grow include maize, beans and horticultural crops. The major cash crop is Sugarcane.

North Teso County has an area of 261 square kilometres with a population of 117,947 and 23,432households. It lies on Latitude 0° 36' 25.2" (0.607°) North and Longitude 34° 16' 33.6" (34.276°) East. The average is elevation 1,208 meters (3,963 feet) above sea level. The major economic activity is farming. Crops grow include maize, beans, sweet potatoes, soybeans,

groundnuts and onions with a few horticultural crops. The major cash crop grown on a smaller

scale is coffee.

CHAPTER 4

4. RESULTS AND DISCUSSIONS

This chapter is divided into two main sections; the first section is based on description of the participating households, farm and farmer characteristics, institutional, market and policy variables and capital endowment. The section further discusses and gives a breakdown of the importance of beans in the family household. It also highlights the awareness of soil amendments. Section two discusses the results of the two econometric models used to address the objectives of the study.

4.1. Socio-economic characterization of the population

Figures 6 and 7 present the percentages of survey respondents that used the various inoculant-based technologies in year 2012 and 2013. They show that 44.4percent and 39.9 percent of the respondents used inoculant-based technologies in 2012 and 2013, respectively. This is because of the cost of the packages presented to farmers was higher in 2013 than the previous year 2012. Accessibility of inoculant-based technologies through the participating project groups enabled distribution and ease access of these technologies by farmers in 2012 as compared to 2013 where they were required to purchase from their nearest agro-input dealers. The number of farmers using biochar and inoculant remained constant during both years indicating no adoption of the use of biochar among farmers. Farmers might have found it a challenge to obtain the biochar or even too tedious to make their own biochar for farm utilization. Just like lime, biochar is required in large quantities to be effective in soil amendment programs.
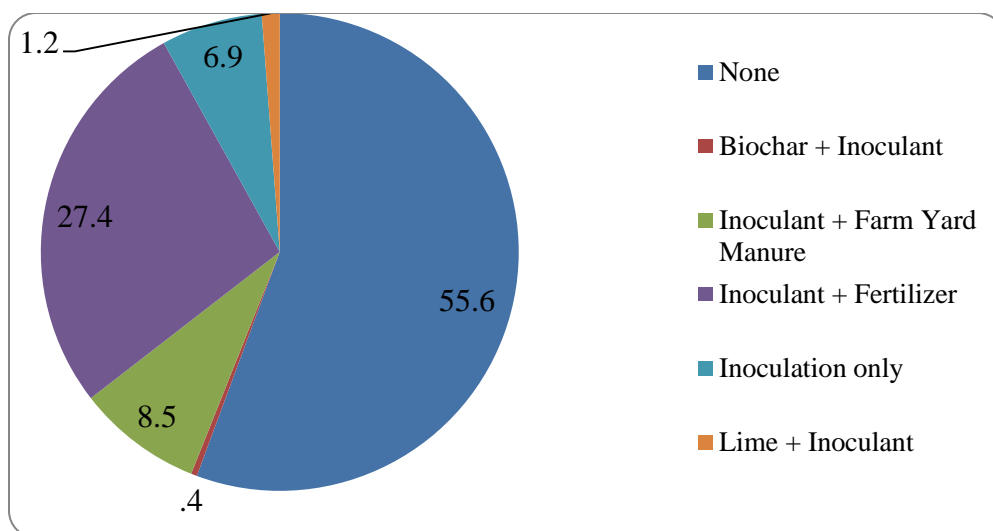
Figure 6: Proportion of farmers using inoculant-based technologies used in 2012, % of total responses
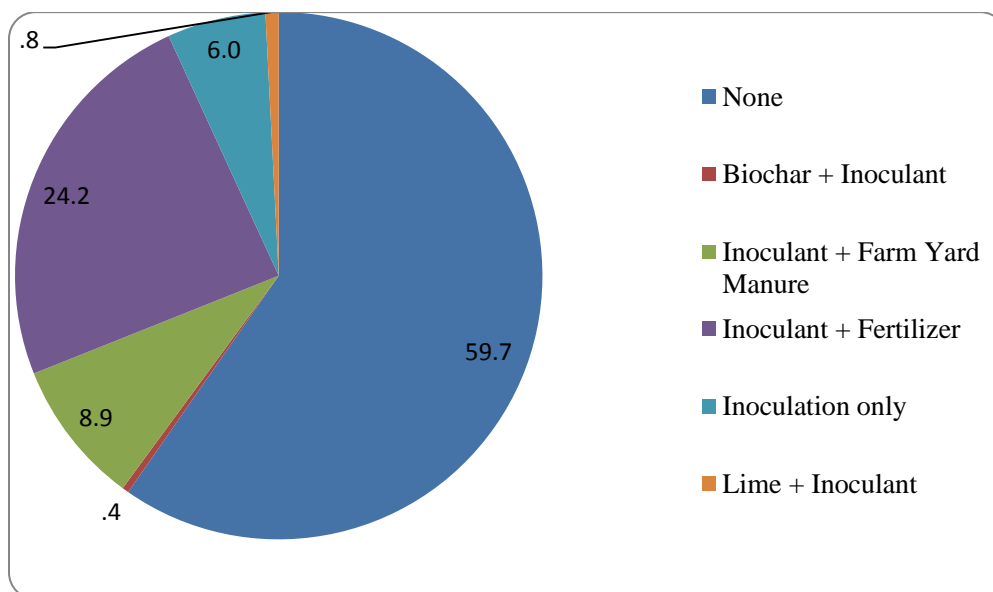
Figure 7: Proportion of farmers using inoculant-based technologies used in 2013, % of total responses

Results of the socio-economic characterization of the survey respondents of adopters and non-adopters are presented Table 2 below. The average age of adopters was 46 years while that of

non-adopters was 48years. The average years in formal school for the adopters was 9.30 years and 9.72 years for the non-adopters.

Adopters had an average household size of 4.02 while non-adopters had an average of 3.89 for members above 18 years. Larger family sizes increase the need for adoption of new agricultural technologies due to increased pressure to be food secure therefore improving their food security through adoption of new agricultural technologies that increase output. They also have more labor to use which is associated with adoption of new technologies such as weeding, proper cultivation and harvesting (Arene, 1994; Adeoti, 2009; Sulo *et al*, 2012 and Mutuma, 2014). The average years of experience in inoculant was 2.56 years for the adopters and 0.45 years for non-adopters and had a significant p-value.

Table 2: Farm and farmers' characteristics of the survey respondents

Variable	Adopters		Non-Adopters		Pooled data		Test of means	
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev	t-statistic	p-value
lnage	46.150	13.130	48.960	14.020	47.840	13.720	1.610	0.110
lnyrsofschl	9.303	3.376	9.718	3.009	9.552	3.161	-0.990	0.320
householdsize	4.020	2.352	3.886	2.361	3.940	2.353	0.440	0.660
bnshare	23.19	15.94	28.00	26.00	26.06	22.57	18.18	0.000***
inotecexp	2.556	2.158	0.446	1.254	1.288	1.965	8.792	0.000*
distmkt	3.242	4.124	2.823	2.292	2.990	3.152	0.920	0.360
distrd	0.960	10.113	1.321	1.811	0.777	6.557	-1.920	0.060*
dinosource	3.488	11.719	1.298	14.756	2.172	13.642	1.298	0.200
dcoop	2.498	3.362	2.248	6.977	2.348	5.802	0.377	0.710
dagricrxt	4.444	15.873	4.293	12.784	4.353	14.067	0.079	0.940
bnland	3.672	2.689	3.476	3.103	3.554	2.941	0.529	0.600
lntassets	469.183	541.975	409.400	578.768	433.265	564.018	0.828	0.410
llnlasset	136.659	194.801	81.788	117.297	103.692	155.001	2.516	0.010**

***, ** and * indicate significance at 1 percent, 5 percent and 10 percent levels respectively

Experience and use of any new agricultural innovation, increases the chance of adoption by any given farmer, (Rao and Rao, 1996).

The mean share of field beans sold by project participants was 23 percent while non-project participants sold 28 percent of their total production. The overall mean share of sales for the whole sample was 26 percent. Notably, these results indicate that non-participants sold significantly higher number of beans than the project participants. This is probably because the mainly targeted farmers who had low yields and very low household production. The increased yield from using inoculant based technologies could probably therefore have been accompanied by increased household consumption.

Distance to the road was used as a proxy to access to information, and could also reflect transaction costs of input access, and significant at 10 percent and with a negative coefficient as expected. Results indicate that the distance to the road was, on average, 0.96 kilometres for adopters and 1.32 kilometres for the non-adopters. Distance to main road has been used a proxy for information access (Otieno, 2011; Mutuma, 2014 and Timu, 2014). The average distance to the nearest market was 3.24 kilometres for adopters and 2.82 kilometres for non-adopters, while distance to the nearest source of inoculant-based technology is 3.49 kilometres for the adopters and 1.30 kilometres for the non-adopters. Thus, non- adopters were on average nearer to the markets than the adopters. Other factors such as total value of non-land asset, a proxy for wealth, and lack of experience in using inoculant-based technologies could have been the reason for lack of adoption by this category of farmers.

Table 2 above also shows the total value of non-land assets owned by project participants and non-participants. It shows that adopters had statistically significantly higher (at 5percent level) endowment of non-land assets than their counterparts. The difference in the value of non-land assets between adopters and non-adopters was $54.87 and is also statistically significant. This indicates that the former had higher purchasing power, which in turn can influence the rate of adoption (Doss *et al*, 2003; Shiferaw *et. al*, 2009).

Table 3 below shows that 83 percent of adopters and non-adopters were males, 98 percent of adopters and 56 percent of non-adopters had group membership while 44 percent of adopters and 30 percent of non-adopters could access credit.

Table 3: Characteristics and capital endowment of adopters and non-adopters of inoculant-based technologies, percentage (%)

	Adopters (n=99)	Non-Adopters (n=149)
Gender	82.82	83.22
Group participation	97.98	55.70
Credit access	44.44	30.20
Farmer sold beans	77.78	74.50
Extension visit	60.61	29.53

The results further show that non-adopters had less access credit that their counterparts. While 78 percent of adopters participated in the bean market only 75 percent of non-adopters participated indicating a higher percentage of market participation by adopters. About 61 percent of adopters had extension visits as compared to non-adopters.

Data collected in this study however showed that only 50.4 percent of the farming population were aware of the soil amendment technologies such as lime, farm-yard manure and biochar while only 69.4 percent were willing to try their use. At the same time, more that 95 percent of those who were not aware of these technologies cited lack of information regarding the technologies.

4.2. Factors affecting farmers' decision to use alternative inoculant-based technologies

Only three out of the five inoculant-based technologies presented to farmers were entered the MVP as two i.e. Biochar + Inoculant and Inoculant +farm yard manure did not yield significant data that could be analyzed in the regression model. The results of the MVP regression model estimated to assess the factors affecting farmers' decision to use inoculant-based technologies and the Wald test are presented in this section.

Table 4 below shows the overall results of the Wald test, significant at 5 percent indicating that the multivariate probit regression model is significant overall. The Likelihood ratio test of rho (ρ) is significant at 5percent (p-value = 0.0207). This finding indicates, as earlier argued, that the multivariate probit regression model specification fits the data better than a simple probit

regression model. Indeed, the correlation coefficients between two of the inoculant-based packages, inoculation and farm yard manure and inoculation and fertilizer are significant at 5 percent. These findings thus confirm that using the logit or probit regression model to assess drivers of use of inoculant-based technologies on smallholder bean farmers would have yielded biased and inefficient estimates.

Table 4: Results of the Wald test of presence of correlation in the decision to adopt different inoculant-based technology packages

Table of p-values of test of simultaneous decision making by farmers to adopt different inoculant-based technologies where 1= Inoculation only, 2= Inoculation and Farm Yard Manure (FYM) and 3= Inoculation and fertilizer

	Coeff.	p-value		Coeff.	p-value
/atrho21	0.0735	0.765	rho21	0.0734	0.764
/atrho31	-0.4746	0.028*	rho31	-0.4419	0.011**
/atrho32	-0.2836	0.059*	rho32	-0.2763	0.047**

Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi^2 (3) = 9.75916 Prob> chi^2 = 0.0207

A multivariate probit regression model was therefore used, because it explicitly takes into account joint adoption decisions made by farmers with regard to the inoculant-based technology packages to use. The estimated multivariate probit regression model results are represented in Table 5 below.

Table 5: Factors affecting adoption of inoculant-technology packages: Results of MVP model

	Inoculation only		Inoculation and farm yard manure		Inoculation and fertilizer	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
gender	-0.168	0.704	8.099	0.000***	-0.516	0.072*
Householdsize	0.084	0.220	0.006	0.939	-0.016	0.749
Inotecexp	0.049	0.533	0.041	0.533	0.044	0.476
Distmkt	0.024	0.456	-0.091	0.124	0.035	0.241
Distrd	-0.066	0.557	-0.590	0.012**	-0.029	0.694
Dcoop	-0.019	0.703	0.162	0.028**	-0.028	0.463
Dagricext	-0.025	0.000***	0.005	0.412	0.016	0.192
Grpart	2.076	0.014**	-1.615	0.069*	-0.015	0.976
Propart	4.667	0.000***	6.366	0.000***	1.529	0.000***
Creditaccess	-0.307	0.340	0.428	0.203	0.258	0.284
Lnnlasset	0.096	0.536	-0.267	0.073*	-0.041	0.720
Lntassets	-0.248	0.172	0.244	0.125	0.081	0.438
Lnage	0.322	0.568	-0.629	0.229	-0.771	0.088*
Lnyrsofschl	0.188	0.603	-0.271	0.607	-0.535	0.119
Cons	-8.064	0.000***	-10.925	0.001***	2.237	0.330

Notes: N=207; Log pseudo likelihood = -147.44052; Wald Chi^2 (χ^2) (45) = 2828.51 Prob> chi2 = 0.000
Joint hypothesis test for inoculant-technology packages variables: Wald χ^2 (45) = 2828.51; Prob> χ^2 = 0.0000
***, ** and * indicate significance at 1percent, 5percent and 10percent levels respectively.

Variables used in the above table have been described in Table

4.2.1. Adoption of inoculation only package

Table 5 above shows that the main factors affecting the decision to adopt inoculation only package in the estimated model are distance to agricultural extension office, participation in a farmer group and project participation. Distance to extension is negative and significant at 1% indicating that longer distances to agricultural office reduces the likelihood of adopting this package. This variable was used as a proxy for access to accessing agricultural information, hence the sign is as expected. Indeed, it corroborates the findings of past studies (Otieno, 2011; Mutuma, 2014 and Timu, 2014) that have suggested that poor access to information about the technology reduces its adoption. Results also show that member to a group and project participation were significant at 5percent and 1percent, respectively, and both have positive coefficients. Thus, membership to a farmer group and project participation both increase the likelihood of inoculant only package. These signs are also as expected.

4.2.2. Adoption of inoculation and farm yard manure package

Result show that gender plays a key role in the adoption of this package. Its coefficient is positive and highly significant. The finding suggests that being a male farmer plays a significant role in the likelihood of the adoption of this package. This finding may be related to the fact that male farmers tend to be more likely to have equity capital (i.e., money) with which to purchase external inputs such as an inoculant than female farmers. Distance to the road is also significant at 5percent level, and as expected, has a negative coefficient. The negative sign suggests that farmers who are further away from the main road are less likely to adopt this technology package that their counterparts. It signals the existence of high transaction costs. In addition, distance to the group office is also negative, as expected, and significant at 5percent level. This variable was

used a proxy for access of information about inoculation technologies. This finding therefore indicates that the likelihood of adoption of inoculant and farmyard manure decreases as access to information decreases.

Results further show that group membership and project participation are significant at 10 percent and 1percent, respectively. However, for this package, contrary to expectations, group participation had a negative coefficient. Off-farm income is also significant at 10percent but has negative sign, indicating that increase in off-farm income is likely to reduce the use of inoculation and farm-yard manure as a technology package. Considering that demand for technology is derived from demand for beans, this finding may be related to the fact that households are likely to shift their consumption away from beans as off-farm (i.e., employment) income increases. Indeed, Doss *et al.* (2003) argue that as purchasing power increased farmers seek alternative sources of protein, with may in turn signal that beans is considered an inferior product.

4.2.3. Adoption of inoculation and fertilizer package

The results of this package are presented in the last 2 columns of Table 5. It shows that project participation significantly (at 1percent level) increases the likelihood of adopting this package of inputs. Gender and age of the respondent were also significant at 10percent, but both had negative coefficients. This suggests that being a male reduces the likelihood of adopting the inoculant-based technology package. The finding that male respondents are less likely to adopt this package could be true since beans are often considered a ''woman's'' crop. The finding relating to age, on the other hand, suggests that older farmers are less likely to adopt this package

of the technology and is in line with past studies that find negative relationship between age and technology adoption (Marenya, 2007; Otieno, 2011; Mutuma, 2014 and Timu, 2014)

The MVP results shows a strong negative link between project participation and use of inoculant based technology (p- value of 0.000). This implies that projects, that promote use of new agricultural technologies are important in facilitating adoption. The null hypothesis that states farmers' decision to use inoculant-based technologies is not affected by participation in a project that promotes the use of inoculant-based technologies is therefore rejected at 1 percent level in favor of the alternative hypothesis. This means that farmers' decision to use and/or adopt inoculant-based technologies is affected by participation in a project that promotes the use of inoculant-based technologies

4.3.   Effect of the use of inoculant-based technologies on output commercialization

Table 6 below show the percentage of farmers that participated in bean trade. It shows that only 188 out of the 248 respondents participated in the market for field beans during the period covered by the study

Table 6: Percentage of farmers participating in the market as bean sellers

	Percentage of farmers
Non-adopters (n=149)	74.50
Adopters (n=99)	77.78

The   results   of   the   Tobit   regression   analysis   are   presented   in   Table   7   below.

Table 7: Factors affecting the share of beans sold by the household: results of Tobit regression

		Number of obs	= 248
		F (11, 237)	= 4.16
		Prob > F	= 0.0000
Log pseudolikelihood= -123.02075		Pseudo R^2	= 0.143

Beanshare	Coef.	p-value
Gender	0.020	0.753
Householdsize	0.008	0.468
Inotecexp	0.015	0.310
Distmkt	0.011	0.037**
Dcoop	-0.019	0.032**
Grpart	0.240	0.002***
Propart	-0.037	0.589
Creditaccess	-0.019	0.690
Extvisit	0.105	0.029**
Lnage	-0.215	0.022**
Bnland	0.162	0.011**
_cons	0.876	0.016**

/sigma	0.346	
Obs.summary:	60 left- censored observations at beanshare<=0	
	188 Uncensored observations	
	0 right- censored observations	

Note: ***, ** and * indicate significance at 1percent, 5percent and 10percent levels respectively

Variables used in the above table have been described in Table 1

The results show that distance to the market/ inoculant source and cooperative (group) office was significant at 5percent. While the coefficient for the distance to market was positive and unexpected, the coefficient of the distance to the group office was negative as expected. The finding means that an increase in distance to the group office by one percent reduces the share of beans sold by 2.3 percent, other things being constant.

Group participation increases the share of beans sold, and was significant at 1percent. Specifically, being a group participant increased the share of beans sold by 24 percent, other things being constant. This finding is in line with past studies which have suggested that group participation enables farmers to reduce the transaction costs hence increase their extent of participation in the field bean market (Heltberg and Tarp, 2002 and Benfica *et al*., 2006)

Contrary to expectations, however, project participation was not significant and had a negative coefficient. This could be attributed to the fact that the projects provided free inputs enough to plant only very small areas of land which, even though could increase yield, was not sufficient to generate significant surpluses for sale. Increased production could therefore have ended up being consumed by the household. This is unlike in group participation where group members are more geared towards income generation hence banded together to utilize their groups for market participation to obtain better prices of input and output (Heltberg and Tarp, 2002 and Benfica *et al*., 2006)

Extension visit was positive and significant at 5 percent as expected. The findings show that respondents who received and extension visit had, other things equal, had 10.5 percent more

sales than their counterparts who did not. Extension plays a big role, not just in giving the farmer information on how to produce but also information about markets, when to sell and where.

Age was also significant at 5 percent but, as before, had a negative coefficient. This finding is in line with past studies (Marenya et al, 2007; Otieno, 2011; Timu *et al*, 2014; and Mutuma, 2014). As expected therefore, there is a 21.5% decrease in the rate of adoption as the farmer's age increases. Lastly, the results further show, as expected, that increase in total area under field bean production area significantly increase (at 5percent level) the share of beans sold. Indeed, an increase in area by one acre increase the share of beans sold 16.2 percent, *ceteris paribus*.

The second hypothesis of this study was tested using the coefficient of the variable *propart*. As shown by the results, this coefficient has a p-value of 0.589 hence was insignificant even at 10percent level. Thus, the second hypothesis that adoption of inoculant-based technologies does not affect the share of output marketed/sold by farmers is not rejected. This means that the share of beans sold is not affected by the participation in the project. Participation in commercial bean market therefore is influenced by other socio-economic factors and not participation in inoculant-based technology promoting projects. Results showcased significant results that positively influenced market participation through group participation, distance to the market, distance to source of inoculant-based technology and extension visits.

CHAPTER 5

5. SUMMARY CONCLUSIONS AND POLICY IMPLICATIONS

5.1. Summary and conclusions

This study analyzed the use of inoculant-based technologies on smallholder field beans production and the effect of participation in the project on share of beans sold by farm households. The study focused on western Kenya. Primary data was collected from 248 farmers stratified by participation in inoculant-based technology projects.

This study found that only three of the five packages of inoculant-based technologies were widely used. These were: inoculation only, inoculation and farm yard manure and inoculation and fertilizer. Two of the inoculant-based technology packages, that is inoculation and lime and inoculation and biochar, did not yield significant data to be used in the MVP model therefore were dropped from the regression analysis. Majority of farmers were aware of but had not used the soil amendment technologies such as biochar and lime. Results of the multivariate probit (MVP) regression model estimated to examine the factors affecting the decision to use alternative inoculant-based technologies showed different factors significantly affect the likelihood of adopting the various technological packages which included gender, distance to the road, distance to nearest cooperative office, distance to agricultural extension office, group participation, project participation, age and total non-land assets

This study hypothesized that farmers' participation in a project that promotes the use of inoculant-based technologies has an effect on the adoption of such technologies. As, hypothesized, the results of this study indeed found that farmers who participated in projects promoting inoculant-based technologies were motivated to adopt these packages. This therefore led to the rejection of null hypothesis that farmers' decision to use inoculant-based technologies is not affected by participation in a project that promotes the use of inoculant-based technologies. Results further indicated that distance to agricultural extension office, group membership, off-farm income, age and gender significantly affected adoption of the inoculant-based technologies.

A Tobit regression model was used to assess the effect of using inoculant-based technologies on household output commercialization. It specifically tested the hypothesis that use of inoculant-based technologies affects the share of beans sold by households using project participation dummy as a proxy for use of such technologies. Contrary to the hypothesis, the study found that the use of inoculant-based technologies had no effect on the share of beans sold. It therefore failed to reject the null hypothesis that use of inoculant-based technologies has no effect on output commercialization. Thus, market participation, by bean farmers, is influenced by other socio-economic factors and not participation in inoculant-based technology promoting projects. These socio-economic factors include among others, distance to group office and to the market, group participation, extension visits, age of the respondent, years of formal school, total value of assets and total bean production area.

Based on the results of the hypotheses tests, this study concludes that participation in a project that promotes the use of inoculant-based technologies has a positive and significant effect on the

decision by small farm households to adopt such technologies. It also concludes that there is correlation in the farmers' decision to adopt different packages of the inoculant based technologies. Lastly, this study concludes that the use of inoculant-based technologies had no effect on the share of beans sold by farm households.

5.2.   Policy implications

Several policy recommendations arise from the findings of this study:

Agricultural projects typically act as sources of information and technical capacity building for members. The finding of this study that participation in projects promoting the use of inoculant based technologies in bean production and that distance to extension office significantly influences the decision to use the different technological packages underscores the need for farmer education and training on the use of these soil fertility amendment technologies. They imply the need for greater effort by the public extension service providers to educate the farmers on the benefits of using soil fertility amendment and productivity enhancing technologies in order to increase bean yields and hence total production.

The finding that distance to main road and to group office, proxies for transaction costs of input and output market access and access to information, has a significant effect on the decision to adopt some of the packages of the inoculant-based technologies underscores the importance of mobilizing farmers to work together in groups. Collective action through farmer groups reduces transaction costs and resolves some of the farmer-specific market failures that are endemic in

developing countries (Okello and Swinton, 2007). The finding with regard to information access underscores the importance of farmer training on new technologies.

The results of the Tobit regression model imply that efforts to increase farm households' yields using soil fertility amendment and yield enhancing technologies did not translate into increased market participation.

5.3.   Suggestions for further research

Mutuma (2014) focused on use of only one of the inoculation, namely BIOFIX, and on a single crop, that is, soybean. The current study focused on various inoculant-based technologies used farmers. Due to time and budget constraints, the study only focused on one legume crop, bean and in three counties. Inoculant-based technologies have since evolved and are available for most legumes crops such as green grams, pigeon peas, chick peas only to list but a few. However, results obtained from the MVP confirmed the correlation of the different pack sizes which could have yielded biased estimates if a logit regression model was used. The study also confirmed that participation in markets is not tied to project participation but strongly to other socioeconomic factors.

Therefore, future studies should be conducted on wider areas where inoculant-based technologies are currently being used and with larger samples of population in order to obtain a clearer picture of the use and effect of inoculant-based technologies currently being used.

Future studies should also include additional leguminous crops such as groundnuts, cowpeas, chickpea and lima beans which can also greatly benefit from the use of inoculant-based technologies.

REFERENCES

Abansi, C., Duff, B., Lantican, F., & Juliano, B. (1992). Consumer demand for rice grain quality in selected rural and urban markets in the Philippines. *Consumer Demand for Rice Grain Quality, Los Baños: International Rice Research Institute*, 37-57.

Abegunrin, T. P., Awe, G. O., & Ateniola, K. O. (2016). Soil Amendment for Vegetable Production: An Example with Cow Dung Manure and Eggplant (Solanum melongena). Int. J. Curr. Microbiol. App. Sci, 5(8), 901-915.

Abewa, A., Yitaferu, B., Selassie, Y. G., & Amare, T. T. (2013). The role of biochar on acid soil reclamation and yield of Teff (Eragrostis tef [Zucc] Trotter) in Northwestern Ethiopia. Journal of Agricultural Science, 6(1), 1.

Adesina, A. A., & Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural economics, 13*(1), 1-9.

Adesina, A. A., & Zinnah, M. M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural economics, 9*(4), 297-311.

Anetor, M. O., & Akinrinde, E. A. (2006). Differences in the liming potential of some fertilizer materials in a tropical acid alfisol. *Journal of Applied Sciences, 6*, 1686-1691.

Arene, C. (1994). Discriminant analysis of small holder farmer adoption potential and the prediction of extension cost in Nigeria: a comparative enterprise perspective. *Journal of Extension System 10 (1): 46, 58*.

Asiedu-Darko, E. (2013). Agricultural extension delivery in Ghana: A case study of factors affecting it in Ashanti, Eastern and Northern regions of Ghana. *Journal of Agricultural Extension and Rural Development, 5*(2), 37-41.

Bakayoko, S., Soro, D., Nindjin, C., Dao, D., Tschannen, A., Girardin, O., & Assa, A. (2009). Effects of cattle and poultry manures on organic matter content and adsorption complex of a sandy soil under cassava cultivation (Manihot esculenta, Crantz). *African Journal of Environmental Science and Technology, 3*(8), 190-197.

Banya, S. M. (2014). *Dissemination of Agricultural Information to Rural Farmers: A Case Study of the Sustainable Land and Water Management Project in West Mamprusi.* University of Ghana.

Bekere, W., Kebede, T., & Dawud, J. (2013). Growth and nodulation response of soybean (Glycine max L.) to lime, Bradyrhizobium japonicum and nitrogen fertilizer in acid soil at Melko, South western Ethiopia. *International Journal of Soil Science, 8*(1), 25.

Bellemare, M. F., & Barrett, C. B. (2006). An ordered Tobit model of market participation: Evidence from Kenya and Ethiopia. *American Journal of Agricultural Economics, 88*(2), 324-337.

Benfica, R., Tschirley, D., & Boughton, D. (2006). Interlinked transactions in cash cropping economies: the determinants of farmer participation and performance in the Zambezi river valley of Mozambique. International Association of Agricultural Economics, August, Gold Coast (Australia). East Lansing: Department of Agricultural Economics, Michigan State University.

Chan, K. Y., Van Zwieten, L., Meszaros, I., Downie, A., & Joseph, S. (2008). Agronomic values of greenwaste biochar as a soil amendment. Soil Research, 45(8), 629-634.

Diagne, A. (2009). Technological Change in Smallholder Agriculture: Bridging the Adoption Gap by Understanding its Source. *Center of Evaluation for Global Action*, University of California

Doss, C.R. 2003. Understanding Farm Level Technology Adoption: Lessons Learned from CIMMYT's Micro Surveys in Eastern Africa. CIMMYT Economics Working Paper 03-07. Mexico, D.F.: CIMMYT

Edje OT, Mughogho LK, Rao YP, Msuku WAB (1981) Bean Production in Malawi. In Potentials for field beans in Eastern Africa. Proceedings of a regional workshop held in Lilongwe,Malawi 9–14 March, 1980

Evans, P. T. (1988). Designing agroforestry innovations to increase their adoptability: a case study from Paraguay. Journal of Rural Studies, 4(1), 45-55.

FAOSTAT, F. Available online: http://faostat3.fao.org/faostat-gateway/go/to/home *E (accessed on 1 June 2015).*

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. Economic development and cultural change, 33(2), 255-298.

Fernandez-Cornejo, J., Daberkow, S., & McBride, W. D. (2001). Decomposing the size effect on the adoption of innovations: agrobiotechnology and precision farming. Economic Research Service, US Department of Agriculture.

Fischer, E. and Qaim, M. (2011) 'Linking smallholders to markets: determinants and impacts of farmer collective action in Kenya', *World Development*, 40, 1255–68.

Gachene, C. K., & Kimaru, G. (Eds.). (2003). Soil fertility and Land productivity: A guide for extension workers in the Eastern Africa Region (No. 30). Regional Land Management Unit.

Gebre-ab, N. 2006. Commercialization of smallholder agriculture in Ethiopia. EDRI Notes and Paper Series No. 3. Addis Ababa, Ethiopia: Ethiopian Development Research Institute.

Giller, K.E., Gilbert R., Mugwira, L., Muza L., Patel, B., & Waddington, S. (1998). *Practical approaches to soil organic matter management for smallholder maize production in southern Africa*. In 'Soil Fertility Research for Maize-Based Farming Systems in Malawi and Zimbabwe'. (Eds. SR Waddington, HK Murwira, JDT Kumwenda, D Hikwa, and F Tagwira), pp. 139-153. (Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe).

Gould, B. W., Saupe, W. E., & Klemme, R. M. (1989). Conservation tillage: the role of farm and operator characteristics and the perception of soil erosion. *Land economics, 65*(2), 167-182.

Greene, W. H. Econometric Analysis, 2008. *Upper Saddle River, NJ: Prentice Hall, 24*, 25-26.

Gujarati, D. N. (2003). Basic Econometrics. 4th. *New York: McGraw-Hill*.

Gukova, M., & Bukevich, W. (1941). Influence of aeration and soil temperature on the development of inoculated and non-inoculated soya plants. *Comptes Rendus de l'Academie des Sciences de l'URSS, 31*, 937-940.

Hale, S. E., Jensen, J., Jakob, L., Oleszczuk, P., Hartnik, T., Henriksen, T., ... & Cornelissen, G. (2013). Short-term effect of the soil amendments activated carbon, biochar, and ferric oxyhydroxide on bacteria and invertebrates. Environmental science & technology, 47(15), 8674-8683.

Heltberg, R., & Tarp, F. (2002). Agricultural supply response and poverty in Mozambique. *Food policy, 27*(2), 103-124.

Hintze, H., Renkow, M., & Sain, G. (2002). Variety characteristics, transactions costs, and maize adoption in Honduras. In documento presentado en la conferencia internacional sobre Impacts of agricultural research and development, San José (Vol. 4).

Hitayezu, P., Okello, J. J., & Obel-Gor, C. (2014). Farm households' participation in rural non-farm employment in post-war Rwanda: Drivers and policy implications. *Development Southern Africa, 31*(3), 452-474.

Huffman, W. E., & Mercier, S. (1991). Joint adoption of microcomputer technologies: An analysis of farmers' decisions. *The Review of Economics and Statistics*, 541-546.

Huizingh, E. K., & Brand, M. J. (2009). Stepwise innovation adoption: a neglected concept in innovation research. *International Journal of Technology Management, 45*(3-4), 267-281.

IFAD, (2013). Investing in smallholder family agriculture for global food security and nutrition. IFAD post-2015 policy brief presented in Madrid on 4 April 2013,

Jack, B. K. (2013). Market inefficiencies and the adoption of agricultural technologies in developing countries.

Jaleta, M.; Gebremedhin, B.; Hoekstra, D. [Moti Jaleta; Berhanu Gebremedhin]. ILRI, Addis Ababa (Ethiopia). Improving Productivity and Market Success of Ethiopian Farmers Project (IPMS). 2009. Smallholder commercialization: processes, determinants and impact. ILRI Discussion Paper 18. Nairobi (Kenya): ILRI.

Kapkiyai, J. J., Karanja, N. K., Qureshi, J. N., Smithson, P. C., & Woomer, P. L. (1999). Soil organic matter and nutrient dynamics in a Kenyan nitisol under long-term fertilizer and organic input management. *Soil Biology and Biochemistry, 31*(13), 1773-1782.

Karanja D. R., Kavoi J., Sperling L., Rubyigo J. and J. Ogecha. (2010). Promotion of improved beans varieties in Nyanza, western and central rift valley in Kenya. 12th KARI scientific conference proceedings held on 8-12th, Nov. 2010. Nairobi, Kenya

Katungi, E., Farrow, A., Chianu, J., Sperling, L., & Beebe, S. (2009). Common bean in Eastern and Southern Africa: a situation and outlook analysis. International Centre for Tropical Agriculture, 61.

Katungi, E., Farrow, A., Mutuoki, T., Gebeyehu, S., Karanja, D., Alamayehu, F., ... & Buruchara, R. (2010). Improving common bean productivity: An Analysis of socioeconomic factors in Ethiopia and Eastern Kenya. *Baseline Report Tropical Legumes II. Centro Internacional de Agricultura Tropical-CIAT. Cali, Colombia*.

Katungi, E., Sperling, L., Karanja, D., & Beebe, S. (2011). Relative importance of common bean attributes and variety demand in the drought areas of Kenya. Journal of Development and Agricultural Economics, 3(8), 411-422.

Khanna, M. (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: A double selectivity model. *American Journal of Agricultural Economics, 83*(1), 35-51.

Kirui, O. K., & Njiraini, G. W. (2013). *Determinants of agricultural commercialization among the rural poor: Role of ICT and Collective Action Initiatives and gender perspective in Kenya.* Paper presented at the 2013 AAAE Fourth International Conference, September 22-25, 2013, Hammamet, Tunisia.

Kirui, O., Okello, J., & Nyikal, R. (2010). *Awareness, use and effect of mobile phone-based money transfer in Kenyan agriculture.* Paper presented at the A paper presented at the African Association of Agricultural Economists Conference, Cape Town, South Africa.

Kisinyo, P. O., Gudu, S. O., Othieno, C. O., Okalebo, J. R., Opala, P. A., Maghanga, J. K., ... & Nekesa, A. O. (2012). Effects of lime, phosphorus and rhizobia on Sesbania sesban performance in a Western Kenyan acid soil. African Journal of Agricultural Research, 7(18), 2800-2809.

Glaser, B., Lehmann, J., Zech, W., 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal e a review. Biology and Fertility of Soils 35, 219e230.

Laing, D., Jones, P., & Davis, J. (1984). Common bean (Phaseolus vulgaris L.). *The physiology of tropical field crops. New York: John Wiley and Sons*.

Lal, J. K., & Mishra, B. (1998). Flyash as a carrier for Rhizobium inoculant. Journal of Research-Birsa Agricultural University, 10, 191-192.

Lehmann, J., & Joseph, S. (2015). *Biochar for environmental management: science, technology and implementation*: Routledge.

Lehmann, J., & Rondon, M. (2006). Bio-char soil management on highly weathered soils in the humid tropics. *Biological approaches to sustainable soil systems. CRC Press, Boca Raton, FL*, 517-530.

Lehmann, J., Gaunt, J., & Rondon, M. (2006). Bio-char sequestration in terrestrial ecosystems–a review. *Mitigation and adaptation strategies for global change, 11*(2), 395-419.

Lehmann, J., Kern, D. C., Glaser, B., & Woods, W. I. (2007). *Amazonian dark earths: origin properties management*: Springer Science & Business Media.

Lehmann, J., Rillig, M. C., Thies, J., Masiello, C. A., Hockaday, W. C., & Crowley, D. (2011). Biochar effects on soil biota–a review. *Soil Biology and Biochemistry, 43*(9), 1812-1836.

Liang, W., Wu, X., Zhang, S., Xing, Y., & Wang, R. (2011, September). Effect of organic amendments on soil water storage in the aeolian sandy land of northeast China. In Electrical and Control Engineering (ICECE), 2011 International Conference on (pp. 1538-1540). IEEE.

Major, J., Rondon, M., Molina, D., Riha, S. J., & Lehmann, J. (2010). Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. *Plant and soil, 333*(1-2), 117-128.

Makokha, M., Odera, H., Maritim, H., Okalebo, J., & Iruria, D. (1999). Farmers' perceptions and adoption of soil management technologies in western Kenya. *African Crop Science Journal, 7*(4), 549-558.

Marenya, P. P., & Barrett, C. B. (2007). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food policy, 32*(4), 515-536.

Marenya, P. P., & Barrett, C. B. (2009). State-conditional fertilizer yield response on western Kenyan farms. *American Journal of Agricultural Economics, 91*(4), 991-1006.

Marenya, P. P., Oluoch-Kosura, W., Place, F., & Barrett, C. B. (2003). Education, nonfarm income, and farm investment in land-scarce Western Kenya, Basis Brief (14) University of Wisconsin, Madison, WI 53706 USA

Martin, S. W., Roberts, R. K., Larkin, S. L., Larson, J. A., Paxton, K. W., English, B. C., . . . Reeves, J. M. (2008). A binary logit estimation of factors affecting adoption of GPS guidance systems by cotton producers. *Journal of agricultural and applied economics, 40*(01), 345-355.

Kiome R, (2009) Ministry of Agriculture, food security in Kenya report, August 2009

Mohajan, H. K. (2014). Food and Nutrition Scenario of Kenya. *American Journal of Food and Nutrition*, *2*(2), 28-38.

Mugwe, J., Mugendi, D., Kungu, J., & Mucheru-Muna, M. (2007). Effect of plant biomass, manure and inorganic fertilizer on maize yield in the Central Highlands of Kenya. *African Crop Science Journal, 15*(3).

Mutune, J., Mburu, J., Nyikal, R., & Kironchi, G. (2011). Determinants of adoption of conservation tillage practices in maize-cowpea cropping systems: The case of Makueni District, Kenya. *Journal of Soil Science and Environmental Management, 2*(11), 354-361.

Muthomi, J. W., Otieno, P. E., Chemining'wa, G. N., Nderitu, J. H., & Wagacha, J. M. (2007). Effect of legume root rot pathogens and fungicide seed treatment on nodulation and biomass accumulation. J Biol Sci, 7, 1163-1170.

Mutuma, S. P., Okello, J. J., Karanja, N. K., & Woomer, P. I. (2014). Smallholder farmers' use and profitability of legume inoculants in Western Kenya. African Crop Science Journal, 22(3), 205-214.

Nair, H., Desiraju, R., & Chintagunta, P. K. (2004). Diffusion of New Pharmaceutical Drugs in Developing and Developed Nations.

Nyaupane, N. P., & Gillespie, J. (2009, January). THE INFLUENCES OF LAND TENANCY AND ROTATION SELECTION ON CRAWFISH FARMERS'ADOPTION OF BEST MANAGEMENT PRACTICES. In Selected Paper Prepared for Presentation at the 2009 Southern Agricultural Economics Association Meeting in Atlanta, Georgia, January 31-February 3, 2009.

Ogawa, M. (1989). Inoculation methods of VAM fungi: charcoal ball method and rice hull method. *Recent Advances in Microbial Ecology. Eds. T Hattori T et al*, 247-252.

Ojiako, A., & Ogbukwa, B. C. (2012). Economic analysis of loan repayment capacity of smallholder cooperative farmers in Yewa North Local Government Area of Ogun State, Nigeria. *African Journal of Agricultural Research, 7*(13), 2051-2062.

Okello, J. J., & Swinton, S. M. (2007). Compliance with international food safety standards in Kenya's green bean industry: Comparison of a small-and a large-scale farm producing for export. *Applied Economic Perspectives and Policy*, *29*(2), 269-285.

Oladele, O., & Kareem, A. (2003). Adoption rate and continued use of selected arable crop technologies among farmers. *JOURNAL OF FOOD AGRICULTURE AND ENVIRONMENT, 1*, 291-294.

Omamo, S. W. (1998). Farm-to-market transaction costs and specialisation in small-scale agriculture: Explorations with a non-separable household model. *The Journal of Development Studies, 35*(2), 152-163.

Omonona, B., Oni, O., & Uwagboe, A. (2006). Adoption of improved cassava varieties and its welfare impact on rural farming households in Edo State, Nigeria. *Journal of agricultural & food information, 7*(1), 39-55.

Onwonga, R. N., Lelei, J. J., & Mochoge, B. B. (2010). Mineral nitrogen and microbial biomass dynamics under different acid soil management practices for maize production. Journal of Agricultural Science, 2(1), 16.

Otieno, D. J., Omiti, J., Nyanamba, T., & McCullough, E. (2009, August). Application of Chow test to improve analysis of farmer participation in markets in Kenya. In *A contributed

paper presented at the 27th Conference of the International Association of Agricultural Economists (IAAE) Conference in Beijing China August 16-22, 2009.

Otieno, Z. (2010). The Role of Varietal Traits on the Adoption of Improved Pigeon Pea Varieties in Kenya: The Case of Taita District. *Unpublished Msc. Thesis. University of Nairobi*.

Otieno, Z., Okello, J., Nyikal, R., Mwang'ombe, A., & Clavel, D. (2011). The role of varietal traits in the adoption of improved dryland crop varieties: The case of pigeon pea in Kenya. *African Journal Agricultural Reearch, 6*, 176-193.

Otsyula, R. M., & Ajang, S. I. (1995). Control strategy for bean root rot in western Kenya. Allen DJ, editor.

Pandher, M. S., Gupta, R. P., Bhandal, B. K., & Gupta, S. K. (1993). Studies on growth and survival of Rhizobium isolates in different carriers. Indian Journal of Ecology, 20(2), 141-146.

Paxton, K. W., Mishra, A. K., Chintawar, S., Roberts, R. K., Larson, J. A., English, B. C., Reeves, J. M. (2011). Intensity of precision agriculture technology adoption by cotton producers. *Agricultural and Resource Economics Review, 40*(1), 133.

Program, C. E., Maize, I., & Center, W. I. (1993). *The adoption of agricultural technology: a guide for survey design*: CIMMYT.

Putler, D. S., & Zilberman, D. (1988). Computer use in agriculture: evidence from Tulare County, California. *American Journal of Agricultural Economics, 70*(4), 790-802.

Rahm, M. R., & Huffman, W. E. (1984). The adoption of reduced tillage: the role of human capital and other variables. *American Journal of Agricultural Economics, 66*(4), 405-413.

Rao, A. B. (2008). *Research methodology for management and social sciences*: Excel Books India.

Rao, P., & Rao, V. (1996). Adoption of rice production technology by the tribal farmers. *Journal of research and ANGRAU, 24*(1-2), 21-25.

Ricker-Gilbert, J., Jayne, T. S., & Chirwa, E. (2011). Subsidies and crowding out: A double-hurdle model of fertilizer demand in Malawi. *American Journal of Agricultural Economics, 93*(1), 26-42.

Risse, L., Cabrera, M., Franzluebbers, A., Gaskin, J., Gilley, J. E., Killorn, R., Zhang, H. (2001). Land application of manure for beneficial reuse. *White Paper Summaries*, 20-23.

Roberts, R. K., English, B. C., Larson, J. A., Cochran, R. L., Goodman, W. R., Larkin, S. L., . . . Reeves, J. M. (2004). Adoption of site-specific information and variable-rate technologies in cotton precision farming. *Journal of agricultural and applied economics, 36*(01), 143-158.

Rogers, E. M. (2003). Elements of diffusion. *Diffusion of innovations, 5*, 1-38.

Rogers, E. M., & Shoemaker, F. (1983). Diffusion of innovation: A cross-cultural approach. New York.

Rogers, E. M., & Shoemaker, F. F. (1971). Communication of Innovations; A Cross-Cultural Approach.

Rondon, M. A., Lehmann, J., Ramírez, J., & Hurtado, M. (2007). Biological nitrogen fixation by common beans (Phaseolus vulgaris L.) increases with bio-char additions. *Biology and fertility of soils, 43*(6), 699-708.

Saka, J., & Lawal, B. (2009). Determinants of adoption and productivity of improved rice varieties in southwestern Nigeria. *African Journal of Biotechnology, 8*(19).

Shiferaw, B. A., Okello, J. and Reddy, R. V. (2009) 'Adoption and adaptation of natural resource management innovations in smallholder agriculture: reflections on key lessons and best practices', *Environment, Development and Sustainability*, 11, 601–19.

Shirani, H., Hajabbasi, M., Afyuni, M., & Hemmat, A. (2002). Effects of farmyard manure and tillage systems on soil physical properties and corn yield in central Iran. *Soil and tillage research, 68*(2), 101-108.

Singh, I., Squire, L., & Strauss, J. (1986). A survey of agricultural household models: Recent findings and policy implications. *The World Bank Economic Review, 1*(1), 149-179.

Sohi, S., Lopez-Capel, E., Krull, E., & Bol, R. (2009). Biochar, climate change and soil: A review to guide future research. CSIRO Land and Water Science Report, 5(09), 17-31.

Ssali, H. (1988). Rhizobium phaseoli inoculation trials on farmers' fields in Kenya. *East African Agricultural and Forestry Journal, 53*(3), 151-157.

Timu, A. G., Mulwa, R., Okello, J., & Kamau, M. (2014). The role of varietal attributes on adoption of improved seed varieties: the case of sorghum in Kenya. *Agriculture & Food Security, 3*(1), 1.

Traoré, N., Landry, R., & Amara, N. (1998). On-farm adoption of conservation practices: the role of farm and farmer characteristics, perceptions, and health hazards. *Land economics*, 114-127.

Ugrinowitsch, C., Fellingham, G. W., & Ricard, M. D. (2004). Limitations of ordinary least squares models in analyzing repeated measures data. *Medicine and science in sports and exercise, 36*, 2144-2148.

Velandia, M., Rejesus, R. M., Knight, T. O., & Sherrick, B. J. (2009). Factors affecting farmers' utilization of agricultural risk management tools: the case of crop insurance, forward contracting, and spreading sales. *Journal of agricultural and applied economics, 41*(01), 107-123.

Verde, B. S., Danga, B. O., & Mugwe, J. N. (2013). Effects of manure, lime and mineral P fertilizer on soybean yields and soil fertility in a humic Nitisols in the central highlands of Kenya. *International journal of Agricultural science research, 2*, 283-291.

Wambugu, S. N., Okello, J. J., Nyikal, R. A., & Shiferaw, B. (2009, August). Effect of social capital on performance of smallholder producer organizations: the case of groundnut growers in Western Kenya. In *A contributed paper presented at the 27th Conference of the International Association of Agricultural Economists (IAAE)* Conference in Beijing China August 16-22, 2009.

Wiggins, Steve, Gem Argwings-Kodhek, Samuel Gebreselassie, Samuel Asuming-Brempong, Ephraim Chirwa, Mirriam Muhome Matita, Ntengua Mode & Khamaldin Mutabazi, 2013, Cautious commercialisation. Findings from village studies in Ethiopia, Ghana, Kenya, Malawi & Tanzania. FAC Working Paper 82, Brighton, UK: Future Agricultures Consortium.

Whiting, D. E., Wilson, C. R., & Card, A. (2004). *Soil pH*: Colorado State University Cooperative Extension.

Wooldridge, J. M. (2003). Introductory Econometric, A Modern Approach, Thomson, South-Western, USA.

Woomer, P., & Muchena, F. (1996). Recognising and overcoming soil constraints to crop production in tropical Africa. *African Crop Science Journal, 4*(4), 503-518.

71

Wu, M. (1958). Studies on Rhizobium inoculation of legumes in Taiwan. *Journal of Agriculture and Forestry, 7*, 1-48.

Wu, M., & Kuo, K. (1970). Influence of autoclaved compost carrier on the survival of rhizobia for legume inoculant. *Soils Fertility Taiwan 1970,* 46-51. Chunghsing University, Taiwan.

WU, M.-H. (1960). Research on powdered legume inoculant of root nodule bacteria in Taiwan. *Journal of the Agricultural Association of China* (32), 48-58.

Young, I. M., Crawford, J. W., Nunan, N., Otten, W., & Spiers, A. (2008). Microbial distribution in soils: physics and scaling. Advances in agronomy, 100, 81-121.

Table 8: Correlation analysis

	plant13	gender	househ~e	inotec~p	distmkt	distrd	dscino~c	dcoop	dagric~t	grpart	propart	credit~s	extvisit	lnnlas~t	lntass~s	lnage	lnyrso~l
plant13	1																
gender	-0.09	1															
households~e	-0.01	0.02	1														
inotecexp	0.56***	-0.08	-0.05	1													
distmkt	0.04	0.06	-0.18**	-0.01	1												
distrd	-0.15**	-0.04	-0.05	-0.02	0.19***	1											
dscinotec	0.10	-0.04	0.01	0.10	0.08	0.05	1										
dcoop	0.08	-0.12	-0.01	0.04	0.31***	0.14**	0.21***	1									
dagricext	0.00	-0.03	-0.08	0.01	0.11	0.06	0.00	0.04	1								
grpart	0.45***	-0.11	-0.06	0.38***	0.09	0.07	0.19***	0.36***	0.09	1							
propart	0.75***	-0.09	0.04	0.62***	0.03	-0.05	0.11	0.09	0.01	0.60***	1						
creditaccess	0.11	0.01	-0.02	0.10	-0.01	0.08	-0.09	0.20***	0.03	0.10	0.07	1					
extvisit	0.28***	-0.09	-0.06	0.18***	0.11	0.02	0.06	0.10	-0.04	0.26***	0.26***	0.10	1				
lnnlasset	0.10	-0.02	0.04	0.10	0.00	-0.03	0.07	-0.02	-0.06	0.09	0.15**	0.14**	0.12	1			
lntassets	0.11	0.00	0.18**	0.14	-0.01	0.06	0.12**	0.06	0.11	0.18***	0.09	0.09	0.1	0.37***	1		
lnage	-0.09	-0.14**	0.41***	0.07**	-0.15**	0.08	0.04	-0.01	-0.02	0.03	0.05	0.04	-0.13	-0.09	0.15**	1	
lnyrsofschl	-0.03	-0.04	0.09	0.00	-0.02	-0.09	-0.09	0.01	0.05	0.02	-0.04	-0.07	-0.05	-0.11	0.03	0.08	1

Table 9: Awareness and willingness to use soil amendment technologies

	Awareness of soil amendment technologies available	Willingness to trial soil amendment technology
No	49.6	30.6
Yes	50.4	69.4

Table 10: Collinearity diagnostics

Variable	VIF	SQRT VIF	Tolerance	R-Squared	Eigenval	Cond. index
Gender	1.08	1.04	0.93	0.07	2.56	1.00
Inoculant- technology use experience	1.71	1.31	0.59	0.41	1.70	1.23
Household size	1.33	1.15	0.75	0.25	1.44	1.34
Market distance	1.24	1.11	0.81	0.19	1.34	1.38
Road distance	1.10	1.05	0.91	0.09	1.11	1.52
Distance to inoculant-technology source	1.12	1.06	0.89	0.11	1.08	1.54
Distance to group/ coop office	1.45	1.20	0.69	0.31	0.99	1.61
Distance to agricultural extension office	1.06	1.03	0.94	0.06	0.99	1.61
Group membership	1.97	1.40	0.51	0.49	0.88	1.70
Project participation	2.39	1.55	0.42	0.58	0.79	1.81
Access to credit	1.14	1.07	0.88	0.12	0.74	1.86
Extension visit	1.17	1.08	0.86	0.14	0.65	1.99
Total non-land assets (natural log)	1.28	1.13	0.78	0.26	0.57	2.12
Total assets (natural log)	1.35	1.16	0.74	0.26	0.50	2.28
Age (natural log)	1.35	1.16	0.74	0.26	0.41	2.50
Years of schooling (natural log)	1.06	1.03	0.94	0.06	0.25	3.21
Mean VIF	1.36					
Condition Number						3.2066

Eigen values & Cond. Index computed from deviation sscp (no intercept) Det (correlation matrix)   0.0950

***, ** and * indicate significance at 1percent, 5percent and 10percent levels respectively.

A commonly given rule of thumb is that VIFs of 10 or higher (or equivalently, tolerances of 0.10 or less). Another rule of thumb is that one needs to be concerned when VIF is over 2.5 and the tolerance is under 0.4

APPENDIX A2: HOUSEHOLD SURVEY QUESTIONNAIRE

FARM / HOUSEHOLD SURVEY QUESTIONNAIRE

Questionnaire No:			

The University of Nairobi, Department of Agricultural Economics is conducting a research survey on the analysis of use and effect of inoculant-based technologies on smallholder bean farms.

You have been identified as a useful informant to assist us to achieve this mission. We are glad that you have agreed to participate voluntarily in this survey. We assure you that the information you will provide us will be treated with confidentiality and will be used for the sole purpose of research.

Kindly respond to the queries below. If you need more writing space, we will provide you with more paper to carry on as an attachment to this survey questionnaire.

Identifying Variables

Survey date (dd/mm/yy)_____**SURDATE**___/___/2014

Household identification number_____**hhid**_____

Respondent name_____**respo**_____

GPS of the Homestead_____**hmgps**_____

Elevation _____**elev**_____

Agro-ecological Zone (AEZ)_____**agzone**_____

District: _____**dist**_____

Division: _____**div**_____

Location : _____**loc**_____

Sub-location : _____**subloc**_____

Village : _____**vil**_____

Supervisor: _____Signature_____**snum** _____

Enumerator: _____Signature_____**enum**_____

Data Entry Clerk: _____Signature_____***declerk***_____

1.   General Information
1.1 Household composition and farmer characteristics

Household member num *(Start with respondent)*	Name of family member *(Start with respondent)*	Relation to HHD *(Use codes below)*	Age	Gender *1=male* *2=female*	Years of schooling	Can this member read and write? *1=yes* *0=no*	Main occupation (Obtain proportion in percentage allocated to main occupation) *(Use codes below)*
Mem	**Name**	**Rshead**	**Age**	**Gender**	**Yrschl**	**Redrit**	**Manoc**
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Relationship to head (*rshead*)

1=Household head
2=Spouse
3=Son/daughter
4=Parent

Main occupation (*manoc*)
1=Farming (crop + livestock)
2=Salaried employment
3=Self-employed on/off-farm
4=Casual laborer on/off-farm
5=School/college child

5=brother/sister 6=Son/daughter in-law 7=Grand child 8= Other relative 9=Hired worker 10=parent-in-law	6=Herds boy/girl 7= Non-school child 8=Other, specify………

1.2 Does the HH head participate in on farm trials? (**PFarmtrls**)*(1=yes, 0=no)*(Circle response)

1.3 Experience (years) in using inoculant-based technology?
(**Inotecexp**)_____

2. Market/ institutional and policy factors
1.1 Infrastructural Characteristics (access to information and extension contact)

Distance to the nearest market from residence (km)	*distmkt*_____
Quality of road to the main market *(1= Very poor; 2= Poor; 3= Average; 4=Good; 5= Very good)*	*roadqlt*_____
What is the distance to the nearest all weather/ murram road?	*distrd* _____
Distance to the nearest source of inoculant dealer from residence (km)	*dscinotec*_____
Distance to the nearest farmer group office from residence (km)	*dcoop*_____
Distance to the nearest agricultural extension office from residence (km)	*dagext*_____

3. Group membership
3.1. Do you belong to any farmer group? *(1=yes 0=no)*
*(Mem)*_____

3.2. If yes, answer the subsequent questions:

Name of group	Type of farmer organization *(use the codes below)*	Association function *(use the codes below)*	Position held in this group	Year joined
Grpname	*Grp*	*Grpact*	*positn*	*Yrjoin*

Type of organization *(grp)*	**Association function** *(gract)*	**Position held** *(positn)*
1=Input supply/service association	1=Produce marketing	1= chairman
2=Producer marketing club	2=Input access/marketing	2=Vice chairman
3=Local administration	3=Seed production	3= treasure
4=Farmers' club	4=Farmer research group	4=Secretary
5=Women's club	5=Savings and credit	5=Member
6=Youth club	6= Welfare/funeral club	
7= Faith-based organization	7=Tree planting and nurseries	
8=Saving and credit group	8=Soil & water conservation	
9=Welfare/funeral club	9=Faith-based organization	
10= Government team	10= Input credit	
11=Water user's club	11=Other, specify………	
12=Other, specify…………….		

4.   Project participation

4.1.   Did you participate in any of the inoculant-based technology promoting projects? *(1=yes 0=no)* *(Propart)*_____

4.2.   If yes, answer the subsequent questions:

Name of Project	Type of project (*use the codes below*)	Project function (*use the codes below*)	Position held in this project	Year started
Prjctname	*TPrjct*	*Prjtftn*	*Propstn*	*yrstart*

Type of project(*TPrjct*)	Project function (*Prjtftn*)	Position held (*Propstn*)
1=Inoculant-based technology	1=Inoculant-based technology	1= chairman
2=Bean marketing	2=Bean marketing	2=Vice chairman
3=Faith-based	3=Faith-based	3= treasure
4=Saving and credit	4=Saving and credit	4=Secretary
5=Other, specify…………….	5=Other, specify……………	5=Member

5.   FARM CHARECTERISTICS
5.1.   Non land assets
5.2.   At present, which of the following assets are usable/ repairable?

CODES	ASSET	QTY (list if more than one)	CURRENT VALUE (where more than one, separate value by commas, measure value by checking condition of the asset in some cases, observe, do not ask)	TOTAL VALUE (KShs)
1)	Donkey/ Ox-cart			
2)	Sprayer(pump)			

3)	Wheel barrow			
4)	Bicycle			
5)	Motorbike			
6)	Water tank (water storage/ rain water harvesting)			
7)	Plough			
8)	Mobile phone			
9)	Store for farm produce			
10)	Radio/radio cassette			
11)	Television (TV))			
12)	Sofa set			
13)	Solar lighting (panel or lamps)			
14)	Water pump (money maker, petrol, diesel)			
15)	Other (specify)….....................			

5.3.   Land holding (size) in 2012/2013 cropping year (acres)

5.3.1. How many acres in **total land holdings** do the household own?
(tacres)_____
5.3.2. How many acres in total land holding do you own?
(ownacre)_____
5.3.3. Does the household practice bean intercropping?
(intercrp)_____
5.3.4. How many acres does the household utilize for bean intercropping?
(intercrpacre)_____
5.3.5. Which type of crops does the household grow as intercrops?
(crpintercrp)_____
5.3.6. How many acres do the household use for pure stand Bean production?
(Tlegacres)_____
5.3.7. What type of land ownership do you have 1= private, 0= other ownership type (communally owned, rented or borrowed)
(pownshp)_____

6.   Inoculant-based technology knowledge, Sources of Information and inoculant-based technology use (The enumerator will be expected to in some cases to explain the technology to the farmers in Kiswahili where necessary and circle the responses from the survey)

6.1.   Have you ever heard of rhizobium inoculant and/ or inoculant? (1=Yes 0=No) (**Inotec**)
6.2.   Have you ever used any inoculant-based technologies in bean production in the year 2012/2013? (1=Yes 0=No) (**plant1**)
(circle the inoculant-based technology used below)

1=Inoculation only, 2=Biochar + Inoculant, 3=Lime + Inoculant, 4=Inoculant + Farm Yard Manure, 5=Inoculant + Fertilizer, 6=None

If the answer is NO to question 4.2, (above), why? (**reson1**)

1=Technology not available, 2=No money to buy the technology, 3=Low yielding seed variety, 4=Not good for intercropping, 5=Lack

information on technology, 6=No market for output, 7= Poor output price, 8= other

If YES to question 4.2 (above), year first planted? (**yrplant1**) _____

6.3.   Did you use the technology in the season 2012/2013? (1=Yes 0=No) (*plant2*)
If YES to question 4.3 (above), which one did you use? (*plant2*)

1=Inoculation only, 2=Biochar + Inoculant, 3=Lime + Inoculant, 4=Inoculant + Farm Yard Manure, 5=Inoculant + Fertilizer, 6=None

If the answer is NO to question 4.3 (above), why? (*reson2*)

1=Technology not available, 2=No money to buy the technology, 3=Low yielding seed variety, 4=Not good for intercropping, 5=Lack information on technology, 6=No market for output, 7= Poor output price, 8=Other (Specify)_____

6.4.   What is the main source of inoculant-based technologies information? (*sinfo*)
1=N2Africa, 2=KARI, 3=NGOs/ CBOs, 4=Agricultural shows/exhibitions, 5=Farmer organizations/groups, 6=On-farm trials in own farm, 7=On-farm trials in another farm, 8= Field day in another farm, 9=agro dealer, 10=Another farmer/neighbor/relative, 11=Radio/newspaper/TV, 12= Other, specify…....……

6.5.   What was the main source of inoculant-based technology you used   last season? (*inotecsorc2*)
1=N2Africa, 2=KARI, 3=NGOs/CBOs, 4=Agricultural shows, 5=another farmer, 6=Relative/friend/neighbor, 7= Farmer Group, 8= Grain trader/stockiest, 9=Own sourcing, 10=other, specify…

6.6.   What is the quantity used in grams (g) and reason for using the specific pack size (*qty2*)
_____
_____
_____
Pack size: 10g, 20g, 50g and 100g

7.   Soil amendments use (Biochar and Lime). The enumerator is expected to explain what soil amendments are to the interviewee
7.1.   Awareness of soil amendments, source of information and use
7.1.1. Are   you   aware   of   any   soil   amendments   technologies   available?   (1=Yes   0=No)   (*SAexp*)
_____

Knowledge of soil amendments technologies, Sources of Information and soil amendments technology use. Which soil amendment technologies do you know? *(see codes below)*	Main source of soil amendment technologies information *(see codes below)*	Have you ever planted using soil amendment technologies? *(1=yes, 0=no)*	If NO, Why? *(see codes below)*	If YES, year amendment was first used	Main source of first soil amendment technology *(see codes below)*	Means of acquiring first soil amendment technology *(see codes below)*	Did you plant using a soil amendment technology in 2012/13 (1=yes 0=no)	If no give reasons	Which soil amendment technologies did you use in 2012/13 *(see codes below)*	What was the main source of soil amendment technology you used last season? *(see codes below)*	Quantity Kg
Knowlg	*Sinfo*	*plant1*	*reson1*	*Yrplant*	*inotecsorc1*	*means1*	*plant2*	*reson2*	*var2*	*Soilamen dsorc1*	*qty2*
											``

Soil amendment technologies 1=Biochar 2= Lime 3=Other, specify…...	Main source of information (*SAINFO*) 1=N2Africa 2=KARI 3=NGOs/ CBOs 4=Agricultural shows/exhibitions 5=Farmer organizations/groups	Reasons (RESON 1&2) 1=Technology not available 2=No money to buy the technology 3=Low yielding seed variety	Source of soil amendment technology (SOASORC1 and 2) 1=N2Africa 2=KARI 3=NGOs/CBOs 4=Agricultural shows	Means of acquiring the technology 1. Gift/free 2. Borrowed soil amendment technology 3. Cash 4. Payment in kind

85

……	6=On-farm trials in own farm 7=On-farm trials in another farm 8= Field day in another farm 9=Agrodealer/ 10=Another farmer/neighbor/relative 12=Radio/newspaper/TV 13= Other, specify…..…….	4=Not good for intercropping 5=Lack information on technology 6=No market for output 7= Poor output price 8=Other (Specify_____)	5=Another farmer 6=Relative/friend/neighbor 7= Farmer Group 8= Grain trader/stockiest 9=Own sourcing 10=Other, specify…	5. Exchange with other farm outputs 6. Other, specify_____

8. Bean Production and Marketing
8.1. Bean Production 2013 per plot

Technology used.	Season (1=long rain 2=Short rain)	Total area planted (acres) Use conversion factor if intercropped to obtain area of bean crop only	Land rented in (acres)	Intercrop 1=None 2=Maize 3= Millet 4=Cassava 5=Sorghum 6=Bananas 7= Other, Specify	Bean area share (%)	Total production (kg)
Inotec13	*Season13*	*Totarea13*	*Rented13*	*Intercrp13*	*Sarea13*	*Tprdn13*
1						
2						
3						
4						

5					
6					

Inoculant- based technologies 1,2,3,4 and 5

1=Inoculation only; 2=Biochar + Inoculant; 3=Lime + Inoculant; 4=Inoculant + Farm Yard Manure; 5=Inoculant + Sympal (legume fertilizer blend) ; 6=None

8.2.   Bean Utilization

8.2.1. Did the household sell any beans produced in the last cropping season? *(1=yes, 0=no) salcrop* _____

Season 1=long rain 0=short rain	Technology used	Total production per plot (from Table 6.1)	Quantity eaten in Kg (per plot)	Quantity given out (as gifts, to relatives) in Kg (per plot)	Quantity sold in Kg (per plot)	Price (Ksh/kg)	Mode of payment 1=Cash 2=Cheque 3=Promissory note 4=Warehouse receipt 5=Barter system 6=In-kind 7=Other	Buyer for the largest sale. 1=small trader 2=large trader 3=NCPB 4=miller 5=NGO 6=consumer 7=exporter 8=food processor 9=supermarket 10=Broker 11=farmer group 12=brewer 13=animal feed processor	Distance from farm to the market/place where product is sold	Month of sale for the largest sale transaction Month codes: 1=2013LR 2=2013SR

Season	Inotec	Tprdn	Teat	Tshare	Sqty	price	paymode	Buyer	km		

9. Other Sources of Income

Income sources		What is your current monthly earning?		Total income (cash & in-kind)
		Payment in kind (Cash equivalent)	Cash payment (Ksh)	
	Scodes	Pkind	pcash	Ptotal
Rented out land	1			
Rented out oxen for ploughing	2			
Regular employment	3			
Casual village labour	4			
Long-term farm labour	5			
Off farm work	6			

Pension income	7			
Non-farm agribusiness NET income (e.g. grain mill)	8			
Remittances (sent from family and relatives)	9			
Business net income (shops, trade, tailor, etc)	10			
Other short term employment	11			
Livestock (limited to cows, goats, sheep)	12			
Other, Specify	13			

10.   Credit and Extension
10.1.   Access to credit
10.1.1. Did you apply for credit for the purchase of the farming inputs (seeds, fertilizers, inoculant-based technologies, herbicides) (both cash and kind in the last cropping year? *(1=yes 0=no)* (**credit**)

10.1.2. Is it easy for you to acquire credit? *(1=yes 0=no)* (**easecrdt**)

If   answer   is   NO,   why?

_____

_____

___

10.1.3. Which source of credit did you use? (**credmeth**) 1=bank, 2=Sacco, 3= Merry go-round, 4= MFI, 5= Other, specify

10.1.4. How many times were you visited by an extension agent in the 2013 cropping season?
(**ext**)_____

10.1.5. What do you think can be done to improve the production of beans?

(***Imprvbp***)_____
_____

10.1.6. What do you think can be done to improve the use of inoculant-based technologies?
(***imprvinotec***)_____
_____
_____

10.1.7. What do you think can be done to improve use of soil-amendment technologies?
(***Imprvsa***)_____
_____
_____

10.1.8. Any other suggestion?
(***asugg***)_____
_____
_____

Thank the interviewee for sparing his/her time for the survey