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

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DECLARATION AND APPROVAL

Declaration

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

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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.
ACKNOWLEDGEMENT

First, I would like to thank the almighty God for the grace and strength for the far I have reached.
I express my heartfelt gratitude to the United States Department of Agriculture – National Institute of Food and Agriculture (USDA-NIFA) project through Cornell University for offering me a full scholarship to pursue my degree of Masters of Science in Agricultural and Applied Economics and MEA Limited, for offering me study leave during this period, without these two organizations, this would not have materialized.

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Above all, I thank God for giving me strength, focus and direction during the entire period.
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 1 percent, 5 percent and 10 percent 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.
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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ALS</td>
<td>Angular leaf spot</td>
</tr>
<tr>
<td>ARDAP</td>
<td>Appropriate Rural Development Agriculture Program</td>
</tr>
<tr>
<td>ASAL</td>
<td>Arid and semi-arid lands</td>
</tr>
<tr>
<td>BNF</td>
<td>Biological nitrogen fixation</td>
</tr>
<tr>
<td>BRR</td>
<td>Bean root rots</td>
</tr>
<tr>
<td>CIAT</td>
<td>International Centre for Tropical Agriculture</td>
</tr>
<tr>
<td>CIMMYT</td>
<td>Centro Internacional de Mejoramiento de Maíz y Trigo</td>
</tr>
<tr>
<td>FAO</td>
<td>Food Agricultural Organization</td>
</tr>
<tr>
<td>GoK</td>
<td>Government of Kenya</td>
</tr>
<tr>
<td>ICT</td>
<td>Information, Communications and Technology</td>
</tr>
<tr>
<td>IFAD</td>
<td>International Fund for Agricultural Development</td>
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<tr>
<td>KALRO</td>
<td>Kenya Agricultural and Livestock Research Organization</td>
</tr>
<tr>
<td>KARI</td>
<td>Kenya Agricultural Research Institute (Now KALRO)</td>
</tr>
<tr>
<td>KSC</td>
<td>Kenya Seed Company</td>
</tr>
<tr>
<td>MoA</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>MVP</td>
<td>Multivariate probit</td>
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</table>
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 33 percent of the production taking place in the Rift Valley, Nyanza and Western Provinces each producing 22 percent. 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 529,265 metric tonnes under the same hectarage.
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 2.69 percent. 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).
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.
CHAPTER TWO

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.

![Innovation Adoption Lifecycle](image)

**Figure 3: Innovation Adoption Lifecycle**

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.
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 ($Fe^{3+}$), 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 (°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:

\[
\text{minimize } C(WX) \\
\text{subject to } f(X, T) \geq q
\]

Where \( C \) is the total cost function; \( W \) is the fixed cost of the input bundle while \( X \) is 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 \( q^0 \). That is:

\[
\begin{align*}
\text{Min } & C(W_iX_i) \\
\text{s.t. } & f(X_i) = q
\end{align*}
\]

Where \( i = 1, 2, 3 \ldots n \) represents the inoculant-based technologies available and which a farmer will choose from, for bean production

\[
\begin{align*}
q & \geq q^0 \\
T & \geq l + h
\end{align*}
\]

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:

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

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 \( \lambda_1 \) and \( \lambda_2 \):

\[
X_i; \ W\frac{\partial q}{\partial X_i} - \lambda_1 \left( \frac{\partial q}{\partial X_i} \right) - \lambda_2 \left( \frac{\partial l}{\partial X_i} - \frac{\partial h}{\partial X_i} \right) = 0
\]
\[ \lambda_1: f(X_i) - q = 0 \]  
\[ \lambda_2: T - l - h = 0 \]

The Lagrange multiplier \( \lambda_1 \) represents the marginal value of output, whereas \( \lambda_2 \) 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 \( X_i, \lambda_1 \) and \( \lambda_2 \)

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 \( q^0 \), input bundle price \( W \) and the cost associated with acquisition of the inoculant-based technology pack \( X_i^* = X_i^*(w,q,x) \)

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:

\[ Y_{ij}^* = \beta_1 X_i + \mu_i \]  \hspace{1cm} (12)

Where \( Y_{ij} \) for \( j = 1, 2, ..., n \) represents an unobserved latent variable of the inoculant-based technologies \( j \) used by farmer \( i \); \( X \) is a l x k vector of observed variables that affect the inoculant-based technology adoption decision; \( \beta \) is a k x 1 vector of unknown parameters to be estimated; and \( \varepsilon \) 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:

\[
\begin{align*}
Y_1^* &= \beta_1 X_1 + \varepsilon_1 Y_i = 1 \text{ if } Y_1^* > 0 \text{ and } Y_1 = 0 \\
Y_2^* &= \beta_2 X_2 + \varepsilon_2 Y_2 = 1 \text{ if } Y_2^* > 0 \text{ and } Y_2 = 0 \\
Y_3^* &= \beta_3 X_3 + \varepsilon_3 Y_3 = 1 \text{ if } Y_3^* > 0 \text{ and } Y_3 = 0 \\
\end{align*}
\]

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

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_{ij}$</td>
<td>$Y_{ij}$ takes the value of 1 if farmer $i$ uses inoculant $j$, and 0 otherwise.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Hypothesized sign</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farmer Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Lnage</td>
<td>Natural log of age of the household head (Years)</td>
</tr>
<tr>
<td>Gender</td>
<td>Gender of the household head (1=Male, 0=Otherwise)</td>
</tr>
<tr>
<td>Lnyrsoschl</td>
<td>Number of years of formal school (count)</td>
</tr>
<tr>
<td>Inotecexp</td>
<td>Years of experience in growing beans using the chosen inoculant-based technology ($j$)</td>
</tr>
<tr>
<td>householdsize</td>
<td>The number of individuals in the household above 18 years</td>
</tr>
</tbody>
</table>

**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) | - |
| Lnlnasset             | 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) | + |

**Institutional and policy variables**

| grpalt                | 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) | + |
The implicit general form of the empirical model is specified as follows:

\[ Y_{ij} = f(\ln\text{age}, \text{gender}, \ln\text{yrsofschl}, \ln\text{lasset}, \text{inotecexp}, \text{householdsizw}, \text{distrd}, \text{distmkt}, \ln\text{assets}, \text{grpart}, \text{propart}, \text{extvisit}, \text{dagricrxt}, \text{creditaccess}) + \epsilon. \]

The variable \textit{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 \textit{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:

\[ y_i^* = \beta_i X_i + \mu_i \]  

(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, \( \beta_i \) is a vector of parameters to be estimated, and \( \mu \) 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 = \( f(\text{lnage}, \text{gender}, \text{lnyrsofschl}, \text{lnlasset}, \text{inotecexp}, \text{householdsize}, \text{bnland}, \text{distrd, lnassets, grpart, propart, extvisit, creditaccess}) + \varepsilon \).

The variable \textit{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
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:

\[ n = \left( \frac{Z}{e} \right)^2 pq \]  

(15)

Where:

N = Calculated sample size

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

\[ n = \left( \frac{1.96}{0.05} \right)^2 (0.2)(0.8) = 245.8624 \]  

(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

![Map of Bungoma, Kakamega and Busia Counties](http://www.opendata.go.ke and http://www.investmentkenya.com)

**Figure 5: Map of Bungoma, Kakamega and Busia Counties**

Source: [http://www.opendata.go.ke](http://www.opendata.go.ke) and [http://www.investmentkenya.com](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: $0^\circ 17' 08'' N$ and Longitude: $34^\circ 45' 19'' E$ 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 23,432 households. It lies on Latitude $0^\circ 36' 25.2'' (0.607^\circ)$ North and Longitude $34^\circ 16' 33.6'' (34.276^\circ)$ 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 44.4 percent 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.
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 48 years. 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

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

***, ** 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 5 percent 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>
<thead>
<tr>
<th></th>
<th>Adopters (n=99)</th>
<th>Non-Adopters (n=149)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td>82.82</td>
<td>83.22</td>
</tr>
<tr>
<td><strong>Group participation</strong></td>
<td>97.98</td>
<td>55.70</td>
</tr>
<tr>
<td><strong>Credit access</strong></td>
<td>44.44</td>
<td>30.20</td>
</tr>
<tr>
<td><strong>Farmer sold beans</strong></td>
<td>77.78</td>
<td>74.50</td>
</tr>
<tr>
<td><strong>Extension visit</strong></td>
<td>60.61</td>
<td>29.53</td>
</tr>
</tbody>
</table>
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 5 percent (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

<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
<th>p-value</th>
<th></th>
<th>Coeff.</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>/atrho21</td>
<td>0.0735</td>
<td>0.765</td>
<td>rho21</td>
<td>0.0734</td>
<td>0.764</td>
</tr>
<tr>
<td>/atrho31</td>
<td>-0.4746</td>
<td>0.028*</td>
<td>rho31</td>
<td>-0.4419</td>
<td>0.011**</td>
</tr>
<tr>
<td>/atrho32</td>
<td>-0.2836</td>
<td>0.059*</td>
<td>rho32</td>
<td>-0.2763</td>
<td>0.047**</td>
</tr>
</tbody>
</table>

Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi² (3) = 9.75916Prob> chi² = 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

<table>
<thead>
<tr>
<th></th>
<th>Inoculation only</th>
<th>Inoculation and farm yard manure</th>
<th>Inoculation and fertilizer</th>
<th>Coeff.</th>
<th>p-value</th>
<th>Coeff.</th>
<th>p-value</th>
<th>Coeff.</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>gender</td>
<td>-0.168</td>
<td>8.099</td>
<td>-0.516</td>
<td>0.168</td>
<td>0.704</td>
<td>0.000</td>
<td>0.000***</td>
<td>0.072</td>
<td>0.072*</td>
</tr>
<tr>
<td>Householdsize</td>
<td>0.084</td>
<td>0.006</td>
<td>0.016</td>
<td>0.084</td>
<td>0.220</td>
<td>0.939</td>
<td>0.749</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inotecexp</td>
<td>0.049</td>
<td>0.041</td>
<td>0.044</td>
<td>0.049</td>
<td>0.533</td>
<td>0.533</td>
<td>0.476</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distmkt</td>
<td>0.024</td>
<td>0.091</td>
<td>0.035</td>
<td>0.024</td>
<td>0.456</td>
<td>0.124</td>
<td>0.241</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distrd</td>
<td>-0.066</td>
<td>0.557</td>
<td>-0.029</td>
<td>-0.066</td>
<td>0.557</td>
<td>0.124</td>
<td>0.694</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dcoop</td>
<td>-0.019</td>
<td>0.162</td>
<td>-0.028</td>
<td>-0.019</td>
<td>0.703</td>
<td>0.028**</td>
<td>0.463</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dagricext</td>
<td>-0.025</td>
<td>0.005</td>
<td>0.016</td>
<td>-0.025</td>
<td>0.000***</td>
<td>0.412</td>
<td>0.192</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grpart</td>
<td>2.076</td>
<td>6.151</td>
<td>0.152</td>
<td>2.076</td>
<td>0.014**</td>
<td>0.069*</td>
<td>0.976</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propart</td>
<td>4.667</td>
<td>6.366</td>
<td>1.529</td>
<td>4.667</td>
<td>0.000***</td>
<td>0.000***</td>
<td>0.000***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creditaccess</td>
<td>-0.307</td>
<td>0.428</td>
<td>0.258</td>
<td>-0.307</td>
<td>0.340</td>
<td>0.203</td>
<td>0.284</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lnnlasset</td>
<td>0.096</td>
<td>0.267</td>
<td>-0.041</td>
<td>0.096</td>
<td>0.536</td>
<td>0.073*</td>
<td>0.720</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lntassets</td>
<td>-0.248</td>
<td>0.244</td>
<td>0.081</td>
<td>-0.248</td>
<td>0.172</td>
<td>0.125</td>
<td>0.438</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lnrange</td>
<td>0.322</td>
<td>0.629</td>
<td>-0.771</td>
<td>0.322</td>
<td>0.568</td>
<td>0.229</td>
<td>0.088*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lnyrsofschl</td>
<td>0.188</td>
<td>0.607</td>
<td>-0.535</td>
<td>0.188</td>
<td>0.603</td>
<td>0.607</td>
<td>0.119</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cons</td>
<td>-8.064</td>
<td>-10.925</td>
<td>2.237</td>
<td>-8.064</td>
<td>0.000***</td>
<td>0.001***</td>
<td>0.330</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: N=207; Log pseudo likelihood = -147.44052; Wald Chi² (χ²) (45) = 2828.51 Prob> χ² = 0.000
Joint hypothesis test for inoculant-technology packages variables: Wald χ² (45) = 2828.51; Prob> χ² = 0.0000
***, ** and * indicate significance at 1 percent, 5 percent and 10 percent 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 1 percent, respectively. However, for this package, contrary to expectations, group participation had a negative coefficient. Off-farm income is also significant at 10 percent 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 1 percent level) increases the likelihood of adopting this package of inputs. Gender and age of the respondent were also significant at 10 percent, 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>
<thead>
<tr>
<th>Percentage of farmers participating in the market as bean sellers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-adopters (n=149)</td>
</tr>
<tr>
<td>Adopters (n=99)</td>
</tr>
</tbody>
</table>

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  
Pseudo R$^2$ = 0.143

Log pseudolikelihood = -123.02075

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

/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 5 percent. 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 1 percent. 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 an 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 by 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 legume 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.
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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


APPENDIX A1: TABLES

Table 8: Correlation analysis

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Table 9: Awareness and willingness to use soil amendment technologies

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**Condition Number** 3.2066

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

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

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___________
### 1. General Information
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**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

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:
<table>
<thead>
<tr>
<th>Name of group</th>
<th>Type of farmer organization (use the codes below)</th>
<th>Association function (use the codes below)</th>
<th>Position held in this group</th>
<th>Year joined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grpname</td>
<td>Grp</td>
<td>Grpact</td>
<td>positn</td>
<td>Yrjoin</td>
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</tbody>
</table>

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

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:
<table>
<thead>
<tr>
<th>Name of Project</th>
<th>Type of project (use the codes below)</th>
<th>Project function (use the codes below)</th>
<th>Position held in this project</th>
<th>Year started</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prjctname</td>
<td>TPrjct</td>
<td>Prjftn</td>
<td>Propstn</td>
<td>yrstart</td>
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</tbody>
</table>

**Type of project (TPrjct)**
1=Inoculant-based technology  
2=Bean marketing  
3=Faith-based  
4=Saving and credit  
5=Other, specify………..

**Project function (Prjftn)**
1=Inoculant-based technology  
2=Bean marketing  
3=Faith-based  
4=Saving and credit  
5=Other, specify………..

**Position held (Propstn)**
1= chairman  
2=Vice chairman  
3= treasure  
4=Secretary  
5=Member

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

<table>
<thead>
<tr>
<th>CODES</th>
<th>ASSET</th>
<th>QTY (list if more than one)</th>
<th>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)</th>
<th>TOTAL VALUE (KShs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Donkey/Ox-cart</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2)</td>
<td>Sprayer(pump)</td>
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<tr>
<td>3)</td>
<td>Wheel barrow</td>
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<tr>
<td>4)</td>
<td>Bicycle</td>
<td></td>
<td></td>
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<tr>
<td>5)</td>
<td>Motorbike</td>
<td></td>
<td></td>
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<tr>
<td>6)</td>
<td>Water tank (water storage/rain water harvesting)</td>
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<tr>
<td>7)</td>
<td>Plough</td>
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<tr>
<td>8)</td>
<td>Mobile phone</td>
<td></td>
<td></td>
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<tr>
<td>9)</td>
<td>Store for farm produce</td>
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<tr>
<td>10)</td>
<td>Radio/radio cassette</td>
<td></td>
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<tr>
<td>11)</td>
<td>Television (TV))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12)</td>
<td>Sofa set</td>
<td></td>
<td></td>
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<tr>
<td>13)</td>
<td>Solar lighting (panel or lamps)</td>
<td></td>
<td></td>
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<tr>
<td>14)</td>
<td>Water pump (money maker, petrol, diesel)</td>
<td></td>
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<tr>
<td>15)</td>
<td>Other (specify)..................</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
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? (yrplant) ________________________________
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? (inotecsrc2)
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 amendment technologies, Sources of Information and soil amendment technology use

Which soil amendment technologies do you know? (see codes below)

<table>
<thead>
<tr>
<th>Knowlg</th>
<th>Sinfo</th>
<th>plant1</th>
<th>reson1</th>
<th>Yrplant</th>
<th>inotecsorc1</th>
<th>means1</th>
<th>plant2</th>
<th>reson2</th>
<th>var2</th>
<th>Soilamend dsorc1</th>
<th>qty2</th>
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</table>

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

---

1=Biochar  
2=Lime  
3=Other, specify......
8. **Bean Production and Marketing**

8.1. **Bean Production 2013 per plot**

<table>
<thead>
<tr>
<th>Technology used.</th>
<th>Season (1=long rain 2=Short rain)</th>
<th>Total area planted (acres)</th>
<th>Land rented in (acres)</th>
<th>Intercrop</th>
<th>Bean area share (%)</th>
<th>Total production (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inotec13</td>
<td>Season13</td>
<td>Totarea13</td>
<td>Rented13</td>
<td>Intercrp13</td>
<td>Sarea13</td>
<td>Tprdn13</td>
</tr>
<tr>
<td>1</td>
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<td>4</td>
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</table>

- 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
- 11=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________
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? \( (1 \text{= yes, } 0 \text{= no}) \) \( salcrop \) ________

<table>
<thead>
<tr>
<th>Season</th>
<th>Technology used</th>
<th>Total production per plot (from Table 6.1)</th>
<th>Quantity eaten in Kg (per plot)</th>
<th>Quantity given out (as gifts, to relatives) in Kg (per plot)</th>
<th>Quantity sold in Kg (per plot)</th>
<th>Price (Ksh/kg)</th>
<th>Mode of payment</th>
<th>Buyer for the largest sale.</th>
<th>Distance from farm to the market/place where product is sold</th>
<th>Month of sale for the largest sale transaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=long rain</td>
<td>0=short rain</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Income sources</td>
<td>What is your current monthly earning?</td>
<td>Total income (cash &amp; in-kind)</td>
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<td>Scodes</td>
<td>Pkind</td>
<td>pcash</td>
<td>Ptotal</td>
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<tr>
<td>Rented out land</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Rented out oxen for ploughing</td>
<td>2</td>
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<td></td>
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<tr>
<td>Regular employment</td>
<td>3</td>
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<tr>
<td>Casual village labour</td>
<td>4</td>
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<tr>
<td>Long-term farm labour</td>
<td>5</td>
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<tr>
<td>Off farm work</td>
<td>6</td>
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</tbody>
</table>
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? \(1=\text{yes} 0=\text{no}\) (credit)
10.1.2. Is it easy for you to acquire credit? \(1=\text{yes} 0=\text{no}\) (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?
10.1.6. What do you think can be done to improve the use of inoculant-based technologies?

10.1.7. What do you think can be done to improve use of soil-amendment technologies?

10.1.8. Any other suggestion?

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