DETERMINANTS OF ADOPTION OF SHADE COFFEE TECHNOLOGY AND THE ROLE OF AGROFORESTRY IN THE PRODUCTIVITY AND PROFITABILITY OF COFFEE IN IMENTI SOUTH DISTRICT, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

I hereby declare that this is my original work and has not been presented for the award of any other degree elsewhere.

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DEDICATION

I dedicate this work to my children, Evans Munene, Christine Kendi, Grace Gakii, Keynes Koome and Ketra Kathomi, for their patience and understanding during my many long periods of absence, and to my brother, Timothy Kimathi, for his constant encouragement.

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ABSTRACT

Agro-forestry has continued to receive increasing attention from researchers and policy makers especially in coffee farming systems but there is lack of sufficient evidence on its role in productivity and profitability of coffee farming in Kenya. There is also lack of empirical evidence on whether factors that influence adoption of shade technology have the same effect on productivity and profitability of coffee. The general objective of the study was to examine the adoption of agroforestry-based coffee management systems and the role of these systems in increasing the productivity, and profitability of smallholder coffee enterprise in Imenti South District. The study also extends the application of the Tobit model in the realm of analysis of farm productivity and profitability. Specific objectives included categorization of smallholder farmers into adopters and non-adopters of shade technology, productive and non-productive farmers, profitable versus non-profitable coffee farms using the local means as cutoff points. A structured questionnaire was administered to a representative sample, chosen through multistage sampling, of 346 smallholder farmers in Imenti South District of Kenya. First, descriptive statistics, t-tests and chi-square analyses were used to explore socioeconomic characteristics of adopters and non-adopters of shade coffee technology, productive versus non-productive farmers, as well as profitable versus non-profitable coffee farms. Using the sample mean for binary categorsiaztion of coffee farming households, 40 percent of the sample farm households were effectively classified as adopter of shade coffee, 44 percent was classified as productive coffee farmers, while about 43 percent of the farm households were classified as profitable coffee farming households. Socioeconomic characteristics of the productive and non-productive farmers, as well as profitable versus non-profitable farming households, were different and hence requiring different sets of stimuli to increase productivity and profitability. Second, separate Tobit models were then used to examine factors that determine the rate and intensity of adoption of shade technology, as well as determinants of productivity and profitability of coffee/agroforestry system. The Tobit results show that different sets of socioeconomic factors determine the rate and intensity of adoption of coffee shade technology, productivity and profitability requiring proper understanding of the interplay of these factors in order to promote appropriate policy incentives. Policy implications are drawn.

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ACRONYMS AND ABBREVIATIONS

Coeff	Coefficient
Coff	Coffee
Dum	Dummy
Educ	Education
GDP	Gross Domestic Product
Hh	household
KES	Kenya shillings
Kg(s)	Kilogram(s)
Kms	Kilometres
PD(s)	Person-day(s)
MoA	Ministry of Agriculture of the Republic of Kenya
MT	Metric tones
RoK	Republic of Kenya

1 INTRODUCTION

1.1 Background to the study

Agriculture is the mainstay of Kenya's economy. The agricultural sector contributes about 25% of the country's G

DP and employs over 70% of her labor force. Despite this importance, the country's adoption of high-yielding agricultural technologies has mainly concentrated on inorganic fertilizers, pesticides, and hybrid seeds. However, estimates show that only about 50% of farmers use hybrid seed and that the country uses only about a third of its total fertilizer consumption potential (RoK, 1994 a, b). Although inorganic fertilizers, pesticides and hybrid seeds produce indisputable productivity gains, they are often beyond the reach of resource-poor farmers. Besides, their use may compromise biological sustainability through pollution of the environment. Staver *et. al*. (2001) observed that while the use of synthetic pesticides has raised coffee yields substantially, it has also induced increases in production costs, pesticide resistance, as well as environmental hazards. Due to high costs of inorganic inputs and the associated environmental risks, farmers and researchers have continued to experiment with alternative systems of production. Chief among these alternative systems of production are those that are based on agroforestry and integrated pest management (IPM).

Coffee production is one of Kenya's agricultural sub-sectors with a potential to substantially benefit from agroforestry. Kenya's coffee production reached a record 128700 Metric Tonnes (MT) of clean coffee in the period 1987/88, earning the country about KES 107 billion between 1987/88 and 1997/98 (Coffee Board of Kenya, 2009). This accounted for about 10% of agriculture's share of GDP, making the sub-sector a major contributor to the country's national wellbeing, during the period, as well motivating socioeconomic improvements in coffee growing areas of the country. However production has been on a declining trend since 1987/88 production period. According to RoK (2009; 2008), the production for 2007 was a mere 53400 MT of clean coffee, implying that the country is producing at only 41 percent of the 1987/88-production capacity, which translates to a decline of 74300 MT of coffee per year.

It is estimated that about 170,000 ha of the country's high potential land area is planted with coffee. The sub-sector features a dual structure of production with smallholders, who are mainly organized in co-operatives, accounting for 75.5% of the total land under coffee, while 24.5% is under large estates plantations (Coffee Board of Kenya, 2009). However, despite this dominance of smallholders in coffee land acreage, they only account for 48% share of domestic production (RoK, 2009). Smallholder coffee is faced by the twin problems of declining output and low productivity. For example, the average yield in 2005 was 199.2 Kgs/ha for smallholders and 469.0 Kgs/ha for largescale farmers (RoK, 2006). There is thus a productivity gap of about 270 Kgs/ha between large and small scale coffee farmers. According to (MoA, 2009), the registered yield per hectare for the cooperative sector was only a third of the estates sector whose yields registered 532 Kgs/ha in 2008. An immediate concern is then to identify the causes of this relatively low productivity among smallholder farmers in order to come up with strategies that can stop the continued decline of this important smallholder livelihood crop and recommend policy interventions that would make coffee production more profitable.

The growth of Arabica coffee is well suited to the Kenyan highlands and Imenti South District is particularly known for high quality coffee. Coffee was the major foreign exchange earner for Kenya for a long time but the crop has continued to perform poorly with resultant rise in poverty in rural areas where coffee is the major crop. Farmers had, for a long time, been used to attractive well-paying coffee prices when the International Coffee Agreement (ICA) was active. When international coffee prices took a persistent downturn, farmers could not quit easily because of expectations of 'boom' periods. Furthermore, quitting was rather difficult for most farmers because of the high exit costs associated with clearing and uprooting coffee trees, the heavy sunk costs, and shortage of lucrative alternative enterprises or employment opportunities especially in coffee-dominated areas like Imenti South District. There is a general agreement that increased productivity and reduced cost of production are the best strategies to enhance competitiveness of coffee farming in order to face international competitiveness and maintain the most important source of livelihood for the rural farming population in predominantly coffee production zones.

The problems of smallholder coffee farmers were compounded by the strict coffee management regulations that prohibited intercropping and emphasized regular application of expensive inorganic fertilizers and pesticide sprays. Some farmers and extension agents may have taken this as the best practice under all the circumstances. This further increased the likelihood of failure given the high cost system was unsustainable or unprofitable due to falling output prices. Integration of coffee with agroforestry and food crops has generally been slow and has generally lacked mainstream public support. The degree of shading adopted by the farmer is highly variable due to lack of policy guidance.

Smallholder coffee production varies widely by the degree to which conventional technologies such as inorganic fertilizers and pesticides are adopted, as well as the extent to which technologies like *Ruiru II,* a new coffee cultivar, and agroforestry technologies are adopted. This variation means differentials in the productivity, profitability and competitiveness of coffee farming. Purely business-oriented farms are likely to adopt open-grown coffee and the other extreme will involve integration of coffee with food crops and/ or trees. This study examined determinants of adoption of shade coffee technology. Subsequently, the study assessed the role of agroforestry and other socioeconomic factors in determining the productivity and profitability of coffee.

Integration of shade trees with coffee has continued to receive renewed policy and research attention due to increasing costs of inorganic inputs coupled with the high risk on the environment. Growing coffee under shade has the desirable effects of suppressing weeds and preventing build-up of certain pests, thereby cutting costs of production and preventing net losses of coffee berries from diseases and pests. The optimum shade conditions for pest suppression differ with climatic conditions, altitude and soils (Staver *et al.,* 2001). Selection of tree species and density, pruning regime and spatial arrangement are important decisions that a farmer must make. Farmers who do not interplant coffee with trees or food crops have a less integrated system of growing coffee generally referred to as open-grown coffee farming. Other farmers adopt shade-grown coffee by growing trees, shrubs or food crops in or around the field. These different coffee management systems have cost and productivity implications and may be significant factors affecting the profitability and survival of the coffee farming operation. Though literature on role of agroforestry in coffee management systems exists elsewhere, there is scant information about Kenya.

Apart from using shade trees in controlling weeds and pests, some coffee farmers adopt alternative low-cost technologies such as cover crops and mulching for weed control, cultural pest control as well as inter-planting food crops to hedge against risks. Other farmers continue to depend on high-cost systems that rely on external inputs. Overall, productivity of coffee is generally low but there is big farm-to-farm variability implying that some farms are more productive than other farms. The combination of different technologies and management techniques are likely to lead to differences in productivity and profitability. Profitability and productivity received separate treatment in this study because profitability may be enhanced through cost cutting or productivity effects of a technology as well as supplementary outputs of the integrated trees, shrubs or crops.

Since the farmer cannot influence the prices of coffee and inputs, the options left are to adopt cost-cutting and profitability-enhancing strategies, or to discontinue coffee production. In response to declining coffee prices, farmers have followed four distinct routes, namely, to uproot coffee, continue farming as before, or neglect the crop or practice coffee agroforestry. This presents a good opportunity for evaluating factors that determine shade adoption in coffee farming systems and the role of shade trees in the productivity and profitability of coffee. In addition, determinants of productivity and profitability of coffee farming provides good opportunity for examination of factors that can trigger quick recovery on the path of productivity and profitability of a depressed enterprise like coffee. Though liberalization of the coffee sub-sector is over ten years old and profitability is a key indicator of long-term sustainasbility of any business, there is little literature on the role of agroforestry systems on productivity and profitability of coffee. This study characterized coffee management systems based on agroforestry production systems, productivity and profitability of coffee. This enables us to understand the effect of significant factors in the adoption as well as in the outcomes of productivity and profitability of coffee.

1.2 Statement of the problem

International coffee prices have been declining persistently since the 1980s. This is partly due to the collapse of the International Coffee Agreement and partly because per capita production has been rising faster than per capita consumption. The growth in coffee production has increased in countries like Brazil, Colombia and Vietnam but has declined in other countries such as Kenya and Uganda. Internationally, the high-cost coffee producing countries, Kenya included, will be pushed out of production. Millions of farmers have experienced declining incomes and some have quit and more may quit. Though it makes economic sense to quit or enter a business depending on profitability, most smallholder farmers in Kenya have limited attractive alternative sources of livelihood.

Despite the two decades of low coffee prices, some farms have continued production, but research on productivity and profitability of these farms is limited and far apart. It is most likely that the more efficient farms with proper management constitute the bulk of the surviving coffee farms. The bulk of the surviving farms are likely to be those that adopted appropriate low-cost technologies that enabled them to ride over the prolonged period of low coffee prices. Technology adoption and proper management translate into two measurable outcomes, productivity and profitability of the enterprise. This points to the importance of examining technology adoption and the effect of such adoption in the productivity and profitability of an enterprise in order to understand the role of technology in the success or failure of a business. The primary concern of this study was to assess the determinants of adoption of shade technology, as well as the determinants of productivity and profitability of coffee/agroforestry enterprise. Earlier research has not addressed adoption of technology and its outcomes, productivity and profitability, in a joint framework. Although coffee agroforestry is practised in the study area, literature on the efficacy of shade coffee in Kenya and Imenti South District is scant and far apart. When such literature exists for other coffee producing countries such as Brazil and Columbia, there is heavy reliance on on-station data. This study fills this gap in literature and data for Kenya.

1.3 Objectives of the study

The general objective of the study was to examine the adoption of agroforestry-based coffee production system and the role of shade trees in increasing the productivity and profitability, and hence survival, of smallholder coffee enterprise in Imenti South District. In addition, the study extends the application of the Tobit model in the realm of analysis of farm productivity and profitability. The specific objectives were:

i. To determine whether socioeconomic characteristics differ between adopters and non-adopters of shade coffee technology, productive versus non-productive farms, profitable versus non-profitable coffee farms.

ii. To determine whether productivity of shade coffee is statistically different from that of open coffee.

iii. To determine the role of farm, farmer and institutional factors in the rate and intensity of adoption of shade coffee technology.

iv. To determine the role of shade trees and socioeconomic characteristics of the farmer in the productivity of coffee.

v. To determine the role of shade trees and socioeconomic characteristics of the farmer in the profitability of coffee.

1.4 Hypotheses of the study

i. Socioeconomic characteristics of adopters and non-adopters of shade coffee as well as the binary classes of farmers based on productivity and profitability of coffee do not differ significantly.

ii. There is no significant productivity difference between open-grown and shade-grown coffee production systems.

iii. No single household, farm or institutional factor has a statistically significant role in adoption of shade coffee technology.

iv. No single household, farm or technology-specific attribute has a statistically significant role in the productivity of coffee.

v. No single household, farm or technology-specific attribute has a statistically significant role in the profitability of coffee.

1.5 Justification of the study

National coffee production has declined by more than 50% in the last 10 years (RoK, 2009). It is generally agreed that Kenya must ensure that it continues to supply its food and cash needs through improvements in agricultural productivity and reduced production, transportation and marketing costs (MoA, 2009; RoK, 1994b). The key strategy for the country should focus on reducing costs through productivity growth and use of low-cost and environmentally clean inputs. Reduced costs allow farmers to compete in international markets and countries to bargain from a standpoint of strength in international trade agreements.

The results of this study are geared towards facilitation of informed policy guidance necessary to enhance the profitability and survival of smallholder coffee farming in Kenya. The study contributes to the body of literature on modeling of technologies and the role of such technologies on outcomes of the business/ enterprise and thus forms a useful source of knowledge to academicians and researchers. The study addresses the thorny question by farmers and extension agents on whether trees contribute to productivity and profitability of coffee.

1.6 Operational definition of terms

Agroforestry system: refers to whether coffee is planted as open-grown without shade trees or is integrated with food crops or trees. Agroforestry broadly refers to planting of trees or shrubs within or on the edge of a crop field. The trees are pruned periodically and selectively to create the optimal shade for coffee.

Regime: refers to characterization of farmers based on identifiable attributes such as productivity and profitability in such a way that the identifier is statistically significant so that

within-group differences are
minimized and between-groups differences are maximized. For example, we have productive and non-productive coffee farmers based on productivity per hectare of coffee.

Survival of an enterprise: refers to ability of an enterprise to ride over a persistent negative shock to the system and continue production during or after the shock.

Productivity: output per unit of input. In this study, productivity was defined as kilograms of coffee per hectare.

Cutoff point: threshold that delineates adopters and non-adopters of shade technology, productive and non-productive coffee farmers and profitable versus non-profitable farming households.

1.7 Scope and limitations of the study

The study deals only with smallholder coffee farmers who deliver coffee to primary coffee co-operative societies and get a pooled price for their produce. The number of shade trees and not the amount of shading was the subject matter of this research.

2 LITERATURE REVIEW

2.1. Shade versus open-grown coffee systems

According to Perfecto *et. al.,* (2005) shade grown coffee is highly valued for biodiversity conservation. Agronomic studies on the role of agroforestry in coffee production in other coffee-producing countries indicate that such systems confer substantial gains over open-grown coffee. For instance, Brazil, where much integration of trees with coffee is practised, seems to enjoy a competitive advantage over Kenya in the growing of coffee. Baggio *et al*. (1997) used gross margin analysis to evaluate the effect of *Grevillea robusta* (*Grevillea*) at various densities of intercrop with coffee in Brazil compared with open grown coffee and found no decline in the yield of coffee under *Grevillea* at densities of 26, 34, and 48 trees per ha. However, total economic productivity (including the value of both coffee and *Grevillea)* was higher for combinations of coffee and *Grevillea* at 34, 48, and 71 trees per ha. This study differs from that of Baggio *et al*. (1997) in two main ways. First, we did not take adoption of agroforestry as given; instead, we determined the influence of farm household's socioeconomic factors on adoption of the system of shade-grown coffee. Then, conditional on adoption, we determined the combined influence of agroforestry and other socioeconomic factors on productivity and profitability of coffee growing. Integration of shade trees with coffee is a common crop management practice in Kenya. Like in the case of Brazil, *Grevillea* is the most common shade tree in Kenya. Economic analysis of shade-grown coffee must incorporate the benefits of increased productivity (if any) from coffee and the value of such multipurpose species for timber, poles and firewood.

According to Beer *et al*. (1998), shade trees lower the stress suffered by coffee (*Coffea* spp.) and cacao (*Theobroma cacao*) by ameliorating adverse climatic conditions and nutritional imbalances, but they may also compete for growth resources. Shade tree selection and management are potentially important tools for integrated pest management because increased shade may increase the incidence of some commercially important pests and diseases and decrease the incidence of others (Beer *et al.,* 1998). On optimal sites, coffee can be grown without shade using high levels of agrochemical inputs (Beer *et al.,* 1998) but these high cost systems may be responsible for the current uncompetitive nature of Kenyan coffee. These studies (Baggio *et al.,* 1997; Beer *et al.,* 1998) point to the importance of incorporating the benefits of inter-planted trees in cost-benefit analyses of shade coffee.

Considerable amount of empirical work on the deliberate practice of planting of trees or shrubs in rotation with crops is available. Kwesiga *et al*. (1999) concluded that improved tree fallows have great potential for improving soil fertility in areas dominated by nitrogen deficiency. Franzel (1999), in collaboration with researchers from the International Centre for Research in Agroforestry (ICRAF) and national agricultural research systems (NARS), assessed the role of socioeconomic factors in the adoption of improved tree fallows in five African countries (Kenya, Zambia, Cameroon, Tanzania, and Malawi). However, most literature on agroforestry in Africa is biased towards agronomic aspects of food crops. This study examined the role of agroforestry in a cash crop system. Most studies on agroforestry have not explored the use of trees to enhance the productivity and profitability of the enterprise. This was the focus of this study. Coffee, a perennial crop, in some cases is the only source of cash income to rural households in some parts of Kenya. Use of trees to enhance productivity of crops is not a new concept but its potential is not fully utilized and its role in productivity and profitability of cash crop farming in Kenya had not been examined before.

The effect of shade on coffee has received much attention from researchers (Blackman *et. al.,* 2008; Albertin and Nair, 2004; Muschler, 2001; Beer *et al.,* 1998). Depending on the pruning intensity, the shade pattern can vary widely from light and dispersed to heavy and homogeneous shade (Beer *et al.,* 1998). Despite the many discussions of the best levels of shade (Muschler 1997; Beer *et al.,* 1998), there is relatively little information on the effects of shade on productivity and profitability of coffee farming in Kenya. In general, studies like those of Muschler (2001) and Beer *et al.* (1998) have relied on research station data. However, on-farm data would provide more realistic information for extension workers and farmers. This is because households and farms are generally more complex ecosystems than can be devised in on-station research experiments.

According to Osorio (2002), the persistent decline in international prices of coffee was caused by the growing imbalance between supply and demand for coffee, with supply increasing more rapidly than demand. In an assessment of the consequences of low coffee prices in the international markets, Osorio states that, "Where costs of production are low, technologies are well developed and exchange rate movements have favored exports, coffee farmers can still make a living. This is the case in much of Brazil." There is no doubt that technological advances can play an important role in lowering production costs as well as contributing to other areas such as quality improvement and plant protection (Osorio, 2002).

Quality is an important aspect of coffee and shading has some effects on the quality of coffee. The quality of Arabica coffee is differentiated into three groups comprising Colombian milds, other milds, and Brazilian naturals (Karanja and Nyoro, 2002). Colombian milds are of high quality and are produced in Kenya, Colombia and Tanzania. During the decade ending 2002, the international production of Colombian milds decreased by 9.8% while other milds increased by about 5% (Karanja and Nyoro, 2002). This means that low quality coffee has been increasing at the expense of high quality coffee thereby greatly depressing the world prices. A tasting experiment showed consistent shade induced improvements in appearance of green and roasted coffee as well as in acidity and body of the brew for both varieties of *Coffea arabica* L. vars. Caturra and Catimor (Muschler, 2001). Muschler (2001) suggests a substantial improvement of coffee quality through shading in suboptimal and high-temperature environments where coffee plants are stressed. Muschler summarizes the main benefits from shading as: 1) higher weights of fresh fruits; 2) larger beans; 3) higher ratings for visual appearance of green and roasted beans; 4) higher ratings for acidity (Catimor only) and body; and 5) absence of off-flavors. Unlike the study by Muschler (2001) that relied on experimental data, this study uses cross-sectional data for smallholder co-operative farmers who get a pooled price for their produce, that is, no premium on quality, and hence quality differences were not reflected at household level.

There is a wide body of literature on adoption of agricultural technologies but literature on shade coffee adoption is scarce and scattered. Single adoption decisions are generally modeled by use of binary choice models (logit and probit) that give probabilities of adoption for each determinant. For instance, Bunyinza and Wambede (2008) used logistic regression to examine factors influencing adoption of Crotalaria-maize agroforesry. Age, gender of household head, and family labor were found as major determinants of adoption of Crotolaria/maize agroforestry system. The logit model is used to analyze the likelihood of adoption but cannot model intensity of adoption. This study used the Tobit model instead of logistic regression so as to reveal more policy-relevant information than the logit model does. Ayuk (1997) used the logit model to examine adoption of live hedges in Burkina Faso. Age of the farmer and potential profitability of the type of hedge were important determinants of adoption. The main contribution of the study by Ayuk (1997) was to model profitability of the technology itself in addition to the normal demographic, institutional, and socioeconomic variables. The current study goes beyond looking at adoption of a technology singly and addresses the role of the technology on desired outputs, productivity and profitability. Use of the Tobit model also allows for decomposition of the total elasticity into the probability and intensity effects of the anticipated policy change.

In examining multiple adoption decisions, models such as multinomial probit and bivariate probit have been used. Dorfman (1996) examined adoption of integrated pest management and irrigation in a joint framework that allowed for possibility of interaction in adoption decisions. He modeled the possibility of interaction in adoption decisions using the multinomial probit model (MNP). The MNP variance-covariance matrix allows analysis of more information than when univariate models are used. Dorfman screened the variables because MNP can be problematic if a large number of variables are used. While MNP is theoretically feasible for this analysis, the practical limitation on the number of explanatory variables reduces its appeal.

Johnson and Masters (2004) examined the hypothesis of complementarity. They noted that mechanization may induce the adoption of a new variety or vice versa. Their study tested the magnitude and significance of these linkages using a system of equations approach. The equations had binary choice dependent variables and allowed for joint estimation of the two technologies. The disadvantage of the modeling approach by Johnson and Masters (2004) is the use of binary dependent variable, which leads to loss of information. Instead of testing for complementarity of technologies as in Johnson and Masters (2004), this study used the Tobit model that makes use of more information to analyze complementarity in the determinants of productivity and profitability of coffee.

Cooper and Keim (1996) examined the role of incentive payments in enhancing adoption of water quality protection practices which are promoted by the US Department of Agriculture through the Water Quality Incentive Program (WQIP). The authors adapted the sequential bivariate probit model which is generally used to model simultaneous equation systems of a discrete nature. They point out the inability of the selectivity model with bivariate probit sample selection to address the censored nature of continuous variables like hectares to plant. The authors thus chose a selectivity model with a Tobit structure, referred to as the double hurdle or Cragg model.

In addition to productivity, the set of adopted technologies may determine the extent of competitiveness of the enterprise especially in the face of a negative shock. High cost systems such as those that rely on expensive inorganic inputs may confer high productivity to the system but may be highly vulnerable to downswings in prices leading to near or total financial collapse. The case of coffee farming may be illustrative in this respect whereby half of the farms have ceased production in Kenya. On the other hand, adoption of low cost but sustainable technologies may lead to lower productivity increases but may enhance the system's ability to weather negative shocks by increasing resilience, thereby increasing the likelihood of continued production after the shock. An underlying hypothesis of this study was that integration of coffee with trees and food crops increases the likelihood of survival of the coffee firm through increased food and cash benefits to the household.

Conditional on adoption, it is important to identify whether the surviving coffee farms have productivity and profitability differentials based on the management systems or technologies adopted. This can help in formulating policy aimed at making coffee farming in Kenya internationally competitive. It is important to identify whether these sources of competitiveness will result directly from increased coffee productivity and quality or indirectly through attendant benefits from the value of trees in terms of firewood, poles or timber. Modeling of adoption of shade coffee requires conceptualization and definition of variables that define the bounds of adoption and non-adoption explicitly. This study used local anchoring, that is use of local cut points to delineate key variables (adoption, productivity and profitability) so that the results can have greater policy relevance and contribute to economic modeling of agro-based technologies which do not have easily measurable quantities for cut points between the binary classes.

2.2 Theoretical framework

The theory of utility maximization has been used extensively (Johnston and Masters, 2004; Khanna, 2001) to explain adoption behavior of farmers. It is presumed that farmers adopt a technology or a technical package if and only if the utility derived from adoption is higher than the default utility of non-adoption. Although we cannot observe the underlying internal decision-making process of the farmer, we can observe whether the farmer has adopted the technology or not, hence, technology is modeled as a binary choice variable. There is extensive use of univariate logit and probit models in studies involving adoption. These models assume that farmers make decisions on adoption of each technology independently of others although this differs much from reality as farmers are faced with multiple technologies in the realm of production, management and marketing.

When farm decision making involves consideration of multiple technologies, farmers will employ various criteria to choose one or more technologies from the set. One important criterion is whether adoption of the potential technologies is preconditioned by an earlier technology such that the synergistic effect of the two increases the system's productivity. If the former technology increases the marginal benefits of adopting the new technology, then we have a complementary relationship between the two technology packages. Such a relationship is best modeled as sequential and requires the use of conditional probabilistic models as in Khanna (2001) and, Johnson and Masters (2004). The use of the Tobit model as in Johnson and Masters (2004) is adopted so as to measure both the probability of adoption and the partial elasticities of different socioeconomic factors on adoption, productivity and profitability conditional on exceeding the pre-set cut point.

To differentiate between shade and open grown coffee fields it was necessary to use a cutoff based on number of shade trees per hectare of coffee. During pre-testing of the questionnaire, it was evident that density of shade trees differed greatly and hence operational cutoff for adopters and non-adopters was based on average density of shade trees per hectare of coffee. The perennial decline in coffee prices has led to three categories of response: uproot, neglect or innovative production. Those who uproot go out of business and have zero output of coffee. Those who neglect produce sub-optimally and innovative producers produce relatively higher output than those who neglect. Well-managed farms were associated with relatively high productivity while neglected farms are characterized by low productivity, that is, productive and non-productive farms. A working definition of these two groups must thus be based on relative productivity, because this is measurable. Furthermore, any measure adopted must reflect the local competitiveness of each farm since farmers in the same locality face similar price and local circumstances. The mean of productivity per hectare was used to distinguish between productive and non-productive coffee farms. Primary coffee co-operative societies pay a uniform price per kilogram of delivered coffee and yet some farmers make losses while their counterparts make profits. Whether farmers make profits or losses when faced by the same market conditions is conditioned largely by adopted technologies, which lead to differences in productivity and profitability. In this study, we postulate that technologies can increase enterprise profitability directly or indirectly through productivity. Gross margin per hectare of coffee can be assumed to be a good proxy for profitability and in order to reflect local competitiveness average gross margin was used to delineate profitable and non-profitable coffee farms.

2.3 Conceptual framework

The analysis of technology adoption is grounded in the theory of utility maximization. It is postulated that farmers adopt a technology as long as the utility derived from adoption is greater than that of non-adoption. Since we cannot observe internal decision-making processes of the farmer, what we observe is adoption or non-adoption of a technology. In this case farmers are categorized in binary classes of adopters and non-adopters where researchers assign a value of one for adopters and zero for non-adopters. This forms the basis of widespread use of binary choice models, generally the logit and probit models. These models are appropriate in the analysis of technologies such as fertilizer and chemical input use in which case the measure of adoption is the usage of the input so that zero usage is logically non-adoption. However, such arguments break down when it comes to analysis of adoption of certain technologies such as shade trees and fodders in which case zero cannot practically form the baseline for adoption or non-adoption. For instance, having one tree in one hectare of coffee cannot be taken as adoption of shade coffee technology. Likewise having one or two leguminous trees cannot justify treating that farmer as an adopter of fodder legumes. These cases raise the pertinent question on what is the cut point for such technologies. No empirical research so far has provided even tentative guidelines for delineating adopters and non-adopters of such technologies from a practical perspective.

It is conceptualized that technology adoption is conditioned by a set farmer/farm and institutional factors that influence farmer decision-making. Farmer/farm factors include education, gender and age of household head, opportunities for off-farm job, family structure and income from other enterprises. Institutional factors include land tenure system, extension services and farm size. These circumstances differ from one household to another and it is important to examine whether these circumstances differ between adopters and non-adopters of shade technology. This requires that we categorize coffee farming households into adopters and non-adopters and assess their socioeconomic characteristics.

It is necessary to determine factors which increases the likelihood of adoption of the technology, shade coffee. Researchers are currently interested with evaluation of intensity of use of a technology conditional on being adopted. The need to determine probability and intensity of use of shade technology makes the Tobit model appropriate for analysis of shade technology.

Researchers have made use of the Tobit model which provides the probability of adoption and intensity of use of a technology. The Tobit model is appropriate if there is a mass clustering around a certain point like zero for non-adopters of fertilizer and chemical inputs. However, there being no policy guideline on the minimum number of shade trees that optimize coffee production thereby delineating adopters and non-adopters of shade coffee technology, we require some other reasonable criteria to overcome this bottleneck. The criteria so adopted should reflect the uniqueness of the technology, coffee shade trees in this case. First, the Mt. Kenya highlands, in which Imenti South district is found, is a rich agricultural zone where tree seedlings germinate in the fields sometimes freely. Such a scenario provides a natural regeneration of certain trees when such seedlings escape damage from livestock and farmers. Second, some trees may be left in the fields for subsistence purposes such as firewood, stakes and shade for people during harvesting. Third, it is impractical to consider presence of few trees as a means of providing shade for a whole hectare of coffee. From these considerations, adoption of shade coffee can only be considered to take place if the number of shade trees per hectare of coffee surpasses a certain positive threshold. From experience of the researcher in the area of study coupled with field observations, the mean number of shade trees per hectare was assumed to reasonably approximate the cut point delineating adopters and non-adopters of shade coffee technology.

The cut point so adopted leads to mass clustering of values of the dependent variable, trees per hectare, around the censoring value. The censoring of data makes the Tobit model appropriate for analysis of coffee shade technology. Figure 2.1 provides a conceptual framework for factors influencing adoption of shade coffee technology and the role of the technology on productivity and profitability of coffee.

Figure 2.1 Factors influencing adoption of shade coffee technology and the determinants of productivity and profitability of coffee

Source: Author conceptualization

An important conceptualization of this study is that technology adoption is not an end by itself. That is utility of the farmer is not only maximized by adoption but also by achievement of set objectives or outcomes. Farmers adopt a technology in order to achieve some objectives, some are subjective and others are objective. Some objectives for adopting shade trees include improved quality of coffee berries, increased productivity and profitability of coffee. However, most technology studies stop at adoption yet technology adoption has consequences on other aspects of the enterprise. This study goes beyond adoption and examines the influence of shade trees on two outcomes, productivity and profitability of coffee.

The smallholder coffee enterprise in Kenya poses a major difficulty in analysis because coffee farming has suffered grossly from persistent declines in international coffee price. In response to declining coffee prices farmers reacted differently thereby creating a myriad of classes of coffee farmers with a high degree of heterogeneity. The main classes of farmers include neglected farms, farms where coffee was interplanted with food crops, open coffee and coffee/agroforestry practices. In addition, there were fields where coffee trees were cut so that farmers could allow stumps to regenerate and mature if prices were to improve. Neglected farms and farms where stumps are in their formative years of regeneration were characterized by low productivity and profitability. This implies that to measure productivity and profitability of coffee including outputs from such farms can lead to misleading results. Furthermore, farmers do harvest some output even on untended farms due to inherent fertility of the soil and ample rainfall in the coffee-growing highlands of Mt Kenya. We therefore need to measure productivity of coffee farms where farmers actively tend their crop but make use of data from all farmers. There is no policy guideline on acceptable productivity per hectare especially under adverse farming conditions and therefore we envisaged that farmers who achieved above the sample mean were the active farmers for whose productivity and profitability we wish to measure. The mean cut points for productivity and profitability of coffee were thus used to delineate productive versus non-productive farms as well as profitable versus non-profitable farms. The mass clustering of values around the cut points makes the Tobit model appropriate for analysis of productivity and profitability of coffee in such circumstances. It should be appreciated that the Tobit model makes use of all the sample information and it is the suitable regression model for analysis where there is censoring.

Productivity and profitability are joint outcomes of the same production process. However, researchers do not consider whether the two outcomes face similar incentives/ disincentives. Complementarity is defined here as a relationship between two outcomes, productivity and profitability, such that the direction of influence of the determinant is the same for both outcomes. Knowledge of such interaction is useful in prioritizing those determinants that are likely to be sources of incentives for both policy objectives of increased productivity and profitability of an enterprise, coffee in this case. There is literature on the economics of complementarity (Johnson and Masters, 2004; Khanna, 2001) but previous research has not addressed the complementarity between determinants of two outcomes, such as productivity and profitability, of an agricultural enterprise. This study assessed for complementarity between determinants of productivity and profitability of coffee/agroforestry enterprise. The underlying hypothesis of the study was that determinants of productivity of coffee exhibit complementary relationship with determinants of profitability.

3 THE STUDY METHODOLOGY

3.1 The study area

Although coffee production takes place in many parts of the country, Imenti South District was selected as the study area because it has relatively well-developed agroforestry farming systems. Imenti South District is on the eastern slopes of Mt. Kenya and smallholder farming is the dominant economic activity. Imenti South District has five agroecological zones and rainfall varies greatly across the zones. The uppermost zone forms part of the larger Mt Kenya forest and is uninhabited public land. Agroecological zone two is on the foothills of Mt Kenya and is a tea zone. The coffee-tea zone occupies the third agroecological zone. The coffee zone, which follows the coffee-tea zone, is on the medium altitude areas of the District. The fifth zone is semi-arid lower parts of the district where drought-tolerant crops such as millet and cassava are the major farming activities. Dairy and maize farming is common across the farming zones and horticultural production is gaining importance. Coffee production takes place in the medium altitude coffee-tea zone and coffee zone. The high altitude farming part of the District is predominantly a dairy/tea zone.

3.2 Sampling

A multi-stage sampling approach was used to get a representative sample of coffee processing factories and respondents. In the first stage, Imenti South District was purposively selected for the study because it featured a wide spread of coffee/agroforestry practices. In the second stage, a representative sample of coffee factories was drawn. This was based on a sampling frame provided by the District Co-operative Officer. To ensure accuracy and exhaustiveness of the sampling frame, a list of factories in the district was prepared. There was a total of 26 coffee factories, each of which was owned by a primary coffee cooperative society. According to the District Co-operative Officer, plans were under way to merge some factories to create viable co-operative societies and the starting point was to encourage the merging of two factories such that there would be 13 co-operative societies. A random selection of one of the two factories from each of the 13 pairs in the proposed co-operative re-organization was done so that 13 factories formed the primary sampling unit. The third stage involved a proportionate sampling of farmers based on their numbers per factory. This was preceded by a reconnaissance field visit of sampled factories. The visit was made under the guidance of the Divisional Agricultural Officers. The aim of the visit was to create good rapport for the study and to obtain, from the factory managers, lists of farmers (members) supplying the respective factories. However, the lists were not exhaustive. The lists needed updating to capture new entrants and, for our purpose, members who had neglected farms. The latter, having fallen dormant, were not reflected in the operational lists. To overcome the difficulties of identifying these dormant members, we supplemented old factory lists with knowledge of local leaders. The lists of active and former coffee farmers were combined to obtain a single list for each factory. A proportionate to size random sample of 346 farmers was enumerated. Table 3.1 summarizes the sampling procedure.

Determination of a sample size follows procedures by Groebner and Sharon (2005):

$n= (Z^2PQ)/d^2$

where ‘n’ is the sample size, Z=1.96, ‘d’ is the level of desired precision set at 5 percent for this study, ‘P’ is the population of interest, that is, proportion of farmers who adopt shade coffee practices. Prior to commencement of the survey, the proportion of adopters of shade coffee was unknown and hence ‘P’ was set to 0.5. A proportion of 0.5 results in a statistically reliable size when the population is unknown with certainty (Groebner and Sharon, 2005). Variable ‘Q’ is a weighting variable computed as 1-P (1-0.5=0.5). Based on the above formula, the proposed sample size was: $(1.96^2 x0.5x0.5)/0.05^2=384$. Because of high homogeneity amongst members of the same factory and budgetary constraints, this number was scaled down by 10 percent to 346 farmers.

Table 3.1 Sampling procedure for coffee farmers

Stage	List used	Sampling method	Sample size
One	Districts	Purposive sampling	1
Two	Factories within the selected district	Random selection of one factory for each of the 13 co-operative societies	13
Three	Households	Random proportionate to size sampling based on number of farmers in each factory as a proportion of farmers in sampled factories	346

Data was collected through personal interviews using a structured questionnaire (Appendix A). Questionnaires were administered by trained enumerators under the supervision of the researcher.

3.3 Data collection

Data collection was preceded by pre-testing of the questionnaire. The pre-testing survey gave insights into the dynamics of coffee/agroforestry farming over the last decade as well as aiding in understanding local terminologies of technical concepts and tree names. Pre-testing of the questionnaire provided the opportunity to identify common tree species and how they were incorporated into the coffee farms. The trained enumerators were present for this activity so as to familiarize with the concepts and details of the intended study.

Data collection took place in the months of April and May 2007. The type of data collected included number of coffee trees, quantity harvested over the previous year, other farm enterprises and area under various enterprises. In addition, data on types, costs, and quantities of inputs used as well as socioeconomic characteristics of the farmer was collected. Number, uses and types of trees as well as selling prices of trees and value of wood products was also enumerated. Other information gathered in the survey entailed types of cultivars of coffee, coffee production technologies, agroforestry system, pruning regimes and farmer perceptions of shade-grown cultivation coffee versus open-grown cultivation.

3.4 Data analysis

After coding the data was entered into EXCEL spreadsheet and imported into STATA for handling and analysis. Data handling is now an important aspect of scientific research report. The procedures for data handling in this study are elucidated in Baum (2006). Evidence that the model's coefficients have been influenced by a few data points, referred to as influential data, casts doubts on the fitted models worth in any broader context (Baum, 2006). Outliers are the most commonly encountered type of influential data. An outlier in a regression relationship is a data point with unusual value. An outlier may be an observation associated with a large residual, a data point that the model fits poorly (Baum, 2006). In this study, outliers were taken as data points that were more than two standard deviations away from the mean. The handling of outliers followed the procedure described in Baum (2006) and after identifying such outliers, we counterchecked with the filled questionnaires and corrected any typographical errors.

Another major econometric problem is multicollinearity. Multicollinearity denotes the presence of linear relationships (or near linear relationships) among explanatory variables (Koutsoyiannis, 1991). If the explanatory variables are perfectly linearly correlated, that is, if the correlation coefficient for these variables is equal to unity, the parameters become indeterminate (Koutsoyiannis, 1991). STATA automatically detects perfect collinearity and drops one of the variables, but near-collinearity is more difficult to detect, Baum (2006). Near-collinearity arises when pairwise correlations of regressors are high, or in general , in the presence of near-linear dependencies in the regressor matrix (Baum, 2006). The problem with near-collinearity is that small changes in the data matrix may cause large changes in the parameter estimates since they are nearly unidentified. Procedures for handling multicollinearity come with modern econometric software but are described for OLS estimation and are unavailable for other models such as the Tobit and Logit. To overcome this problem, linear regression analysis preceded estimation of the Tobit model and one of the collinear variables dropped from the subsequent Tobit analysis. Carrying out linear regression prior to Tobit analysis facilitated the use of 'estat vif' command (Baum, 2006) for computing variance inflation factors to aid in handling multicollinearity.

3.5. Data and hypothesized effects

Section 3.5 presents the variables used in this study in two parts. Section 3.5.1 summarizes the continuous dependent variables that were used directly in the respective Tobit models for adoption of shade technology, determinants of productivity as well as the determinants of profitability of coffee. A description of how each continuous variable was used to create binary classes of coffee farming households is presented. Section 3.5.2 describes independent variables and their hypothesized direction of influence in the adoption of shade technology and in determining productivity and profitability of coffee.

3.5.1 Dependent variables

Number of shade trees per hectare (treeshect) was computed as number of shade trees divided by the acreage under coffee. The mean number of trees per hectare was used to derive a dummy variable for shade coffee adoption (shadedum). Dummy for shade was a binary variable indicating adoption (1) or non-adoption (0) of shade trees in coffee fields. It involved getting the mean number of shade trees per hectare of coffee and all farmers who had trees equal or exceeding the mean were the adopters. A two-tailed t-test was used to test whether the intensity of shade trees was significantly different between the adopters and non-adopters of shade coffee.

The number of trees per hectare was also used as an independent variable in the Tobit models for productivity and profitability of coffee. It was hypothesized that shading would influence productivity of coffee negatively under sub-optimal management practices. This is because shade trees compete for nutrients with coffee trees under sub-optimal conditions and this competition is likely to erode all the benefits of shading. Most of the famers did not prune their shade trees regularly and cases of over-shading were evident. However, the more the shade trees, the more cash benefits that would come from sale of tree products and the expectation was that this variable would influence profitability positively.

Coffee output per hectare (coffoutput), derived as coffee output in kilograms divided by the area under coffee in hectares, was the dependent variable in the Tobit model for determinants of productivity of coffee. This measure of productivity was used to derive a dummy variable for productivity (outputdum) with the mean productivity as the cutoff between high and low productivity farms. The mean yield of coffee per hectaree was used as a cutoff so that productive farms were taken as those whose mean yield was equal or greater than the sample mean. A two-tailed t-test of significance was used to test whether the mean output per hectare was statistically different for the productive and non-productive farms.

Gross margin, including sales from tree products, per hectare of coffee (profitcofftim) was the dependent variable in the Tobit model for profitability of coffee. It was computed as income from both sale of coffee and tree products less variable costs per hectare of coffee. To examine the characteristics of profitable and non-profitable farms, mean gross margin was used such that adopters were those farmers whose gross margin per hectare was equal or greater than the sample mean. The binary category based on this cutoff (profitdum) was assigned a value of one if gross margin per hectare of coffee including cash benefits from tree products was equal or greater than the local mean, and a value of zero otherwise. The explanatory variables for each of the Tobit model and their expected sign are presented in Table 3.2 and discussed in section 3.5.2.

3.5.2 Explanatory variables

Education of the household head (eduhh) captured the number of years the chief decision maker in the household spent in formal schooling. Education increases farmers' ability to obtain information and make decisions on choice technologies that enhance productivity and profitability. Education was expected to influence adoption of shade coffee positively and similarly, to have a positive effect on productivity and profitability of coffee.

Age of household head (agehh) was presumed to influence adoption negatively since young farmers are assumed to adopt easier. However, coffee farming in Imenti South District is largely carried out by the elderly who cannot easily switch to other enterprises and hence age, based on cultural considerations, would be expected to influence adoption of shade coffee positively.

Sex of chief decision maker (sexhhfml) was a dummy variable taking a value of one if household head was female and zero if male. Local perception is that tree planting is a male activity though women are also concerned about availability of firewood and fruit from trees. Owing to such considerations, the expectation was that female-headed households would have fewer trees than the male headed households and thus unlikely adopters of shade coffee. It was expected that gender of household head being female would have a negative effect on adoption of shade coffee. Due to huge demands on their labor and time, the effect of female heads on productivity and profitability was expected to be negative.

Family labor in person-days per hectare (laborinput) measures the amount of effort the family puts into the coffee activity. One person-day was equivalent to eight hours of work. A mature adult in the age category of 19 to 59 years was assigned one adult equivalent while those 60 years and above were assumed to contribute half an adult equivalent. Higher family labor input indicates greater attention to coffee farming and a tendency to substitute labor for more expensive capital. Labor input was expected to influence adoption of shade coffee, as well as productivity and profitability of coffee positively. More highly productive farms call for high levels of input use but under sub-optimal conditions of production and marketing farmers are bound to use the bare minimum level of costly inputs.

In terms of family structure, children under the age of eighteen years are rarely engaged in tree planting and thus their effect on adoption of shade trees was expected to be positive or negative. Because of demands on family labor, children and dependents were expected to reduce available family labor for coffee production and thus they were hypothesized to have a negative impact on coffee productivity and profitability. Family members in the productive age category of 19-59 years provide the needed labor and management effort to plant more trees and thus their effects on adoption of shade trees was expected to be positive. Households with more people within the productive age category are apt to seek other livelihood activities and neglect coffee due to relatively low returns from coffee. Thus households with many people within the age category of 19 to 59 years were hypothesized to influence productivity and profitability either positively or negatively.

Households with elderly people, sixty years and above were expected to have greater cultural attachment to tree planting and thus their effect on adoption was hypothesized to be positive. The elderly have no opportunities for off-farm income and thus they pay greater attention to coffee farming and thus their effect on productivity and profitability was expected to be positive.

The dummy variable for title to land (titledum) indicates whether the farmer had title to land (1) or just user rights (0). Farmers with title have greater incentives to carry out long term investments in their farms so that this variable was deemed to positively influence adoption of shade coffee as well as adoption of productivity enhancing technologies. Households with title to land normally invest more in land improvements including tree planting and soil-erosion control measures and thus this factor was expected to positively influence profitability.

Adoption of the Ruiru II cultivar in a farm (ruirudum) was expected to improve productivity and profitability of coffee farming. Farmers who adopt Ruiru II variety were expected to adopt similar technical packages like shade coffee and this variable was expected to influence adoption of shade coffee positively. Through relatively higher yields than traditional varieties under sub-optimal conditions, the Ruiru II cultivar was expected to positively influence coffee productivity. By requiring less chemical use, the Ruiru II variety was expected to positively influence coffee profitability.

Distance to urban centres (distmkt) captures the role of urbanization on adoption of agroforestry technologies. Urbanization promotes the growing of high value crops like tomatoes and French beans. Consequently, farmers closer to the emerging business hubs are more likely to clear trees to pave way for such farming. Urbanization was hypothesized to influence adoption of shade coffee negatively. However, closer distances to urban centres cut transaction costs for inputs and product markets and thus distance was expected to have a positive impact on productivity and profitability of coffee.

Agro-ecological zone determines the types of crops farmers can grow as well as how to grow the suitable crops. It was expected that farmers in the coffee/tea zone (coff/teazone) were less likely to grow trees than those in the coffee zone because tea growing requires complete clearance of trees where tea bushes are growing. The coffee/tea agro-ecological zone was expected to influence adoption of shade coffee negatively. However, the coffee/tea agro-ecological zone has higher agricultural potential than the coffee zone and thus the coffee/tea agro-ecological zone was expected to influence productivity and profitability positively.

Number of livestock (numblivest) is an indicator of wealth and this variable was expected to relax working capital constraint, a major constraint to increased agricultural productivity amongst the poor coffee farmers. Manure from dairy farming is used on coffee as a substitute for the more expensive inorganic fertilizers and thus livestock activity was expected to have a positive effect on productivity and profitability of coffee. However, livestock destroy young trees and seedlings and the presence of livestock activity was expected to decrease the probability of adoption of shade trees.

Farmers generally use the more regular income from dairy farming (dairyinc2) to finance farm operations and thus dairy income was expected to influence productivity and profitability of coffee positively. Higher income from tea farming (teainc2) indicates increased specialization of the farmer on tea farming and less time and effort will be devoted to coffee farming. It was expected that tea income would influence adoption of shade coffee negatively. Likewise, higher tea income was expected to have a negative effect on coffee productivity and profitability.

Level of income from banana (banainc2) farming indicates the shifting of focus from traditional cash crops like tea and coffee to emerging new cash crops such as bananas and French beans. This would mean that higher income from banana would lead to less time and effort on coffee farming and thus this variable would affect productivity and profitability of coffee negatively. Most banana varieties require support stakes, which are normally cut from trees within the farm, and thus the growing of banana was expected to have a positive effect on agroforestry adoption.

A dummy variable for farmers who plant trees in coffee chiefly for firewood (firedum) was meant to explore whether smallholder farmers value trees only for firewood. If farmers place a lot of importance on firewood then we expect increased tree adoption. In terms of productivity and profitability, placing high importance on trees as sources of fuelwood was expected to decrease productivity and profitability as farmers will not plant trees strategically for shade nor tend them to minimize over-shading. It was hypothesized that planting of shade trees chiefly for getting firewood would have a positive effect on adoption of shade trees, and negative effects on productivity and profitability of coffee.

Working capital (capital) input per hectare of coffee was estimated from cash inputs that were applied on a hectare of coffee during the last one year of production. Farmers endowed with higher amount of working capital can afford to apply expensive inorganic inputs and thus capital was expected to influence adoption of shade coffee negatively but would have a positive effect on both productivity and profitability of coffee farming.

The dummy indicator for a farmer with off-farm job (offmjobdum) was expected to have different effects on adoption of shade technology, productivity, and profitability of coffee. Coffee is a labor-intensive enterprise that requires maximum devotion of family labor time. However, farmers who engage in off farm jobs have less time to spend on their farms and thus this variable was expected to negatively influence adoption of shade technology. Income from external sources can ameliorate working capital constraints and thus off-farm jobs can increase productivity of coffee but decrease profitability because of lack of sufficient attention to the enterprise.

The dummy variable (membgroup) indicates whether the household head was a member of agricultural organizations. Farmers who belong to such groups benefit from shared knowledge and information networks and membership was expected to positively influence adoption of shade coffee. Such shared knowledge improve farmers decision making on issues of productivity and profitability and hence this variable was hypothesized to influence productivity and profitability positively.

During periods of sustained price decreases farmers adopt various coping strategies. Some farmers neglect their enterprise and the dummy variable for abandonment of coffee at any time (abandum) was expected to decrease adoption of shade trees. During abandonment, farmers apply sub-optimal inputs and may neglect the enterprise fully. This factor was therefore expected to negatively influence both productivity and productivity of coffee.

The area under coffee divided by the farm size (ratiocoff) indicates the degree of specialization in the production of coffee such that the higher the ratio the greater the degree of specialization. Farmers who specialize in coffee production have the incentive to invest in long-term interventions such as use of shade trees and this variable was expected to have a positive effect on adoption of shade technology. Specialization increases the chances of better management practices and greater attention to the enterprise thereby influencing productivity and profitability positively. Ratiocoff was thus hypothesized to positively influence both productivity and profitability of coffee.

Farm size (farmsize) was expected to relax the constraint on scarce land resource thereby enabling the coffee farmer to plant more shade trees. Farmers with bigger farms were expected to plant more shade trees than those with smaller farms and hence farm size was hypothesized to positively influence adoption of shade coffee. Bigger farm sizes also allow farmers to specialize in coffee production and thus farm size was expected to positively influence both productivity and profitability of coffee.

3.6 Specification of empirical models

To achieve the objectives of this study several statistical techniques were used. Data was analyzed using STATA computer software. Definition of variables and their hypothesized signs are shown in Table 3.2.

The first objective of the study was to determine whether socioeconomic characteristics differ between adopters and non-adopters of shade technology, productive and non-productive farmers, and between profitable versus non-profitable coffee farms. To achieve objective 1, *t*-tests and chi-square tests were used to examine the statistical significance of differences between socioeconomic characteristics of the sample farmers across the following categories: (1) adopters and non-adopters of shade coffee, (2) farmers falling under the productive regime and those under the non-productive regime; and (3) farmers falling under the profitable regime and those under the non-profitable regime. The second objective of the study was to determine whether the number of shade trees per hectare of coffee, productivity and profitability differed significantly between adopters and non-adopters of shade coffee technology. The *t*-tests were used in achieving objective 2.

Objectives 3, 4, and 5 were achieved by use of Tobit model. The third objective of the study was to determine the role of farm, farmer and technology attributes in the rate and intensity of adoption of shade coffee technology. For objective three, the number of shade trees per hectare of coffee was the dependent variable in the Tobit model for shade technology. The fourth objective of the study was to determine the role of shade trees and other socioeconomic characteristics of the farmer in the productivity of coffee. For objective four the output of coffee in kilograms per hectare was the dependent variable in the Tobit model for determinants of productivity of coffee. The final objective of the study was to determine the effect of farm, farmer and shade coffee technology in determining the profitability of coffee. Gross margin per hectare of coffee was the dependent variable in the Tobit model for analysis of profitability of coffee.

An adopter of shade coffee was taken as one whose number of shade trees per hectare of coffee was equal or greater than the sample mean. The mean number of shade trees hectare of coffee was set as the lower limit in the Tobit model for shade adoption (Equation 3.1). The empirical Tobit model for adoption of shade coffee is:

$$Y_i = \alpha + \beta_1 ratiocoff + \beta_2 abandum + \beta_3 teainc2 + \beta_4 dairyinc2 + \beta_5 coffoutput + \beta_6 laborinput + \beta_7 distmkt + \beta_8 ruirudum + \beta_9 numblivest + \beta_{10} firedum + \beta_{11} extdum + \beta_{12} membs1\text{-}18 + \beta_{13} membs19\text{-}59 + \beta_{14} membs60 + \beta_{15} sexhhfml + \beta_{16} eduhh + \beta_{17} farmsize + \beta_{18} coff/teazone + \beta_{19} titledum + \epsilon \quad \text{Equation 3.1}$$

where Y_i, the dependent variable, was number of shade trees per hectare of coffee, α is a constant and β_i are the coefficients to be estimated, and ϵ_i is the error term. Definition of variables and their hypothesized signs are shown in Table 3.2.

For objective four, productivity of coffee, measured as output per hectare, was the dependent variable in the Tobit model for productivity (Equation 3.2). Following our working definition, the mean productivity formed the lower limit in the Tobit model for productivity. In addition, the mean value for productivity delineated productive and non-productive farming households. The empirical Tobit model for determinants of productivity of coffee is:

$$Y_i=\alpha+\beta_1 ratiocoff+\beta_2 abandum+\beta_3 teainc2+\beta_4 banainc2+\beta_5 dairyinc2+\beta_6 laborinput+\beta_7 dist\ mkt+\beta_8 farmsize+\beta_9 capitaha+\beta_{10} treesha+\beta_{11} extdum+\beta_{12} memb1\text{-}18+\beta_{13} membs19\text{-}59+\beta_{14} membs60+\beta_{15} sexhhfml+\beta_{16} eduhh+\beta_{17} titledum+\beta_{18} offmjobdum+\epsilon_i \ldots\ldots\ldots\ldots \text{Equation 3.2}$$

where Y_i was the amount of coffee output in kilograms per hectare, α is a constant and βi are coefficients to be estimated, and ϵ_i is the error term.

For objective five gross margin in thousands of Kenya shillings per hectare of coffee was used as the dependent variable in the Tobit model for profitability (Equation 3.3). Definition of variables and their hypothesized signs are shown in the last column of Table 3.2. The empirical Tobit model for determinants of profitability of coffee is:

$$Y_i=\alpha+\beta_1 ratiocoff+\beta_2 abandum+\beta_3 teainc2+\beta_4 banainc2+\beta_5 dairyinc2+\beta_6 laborinput+\beta_7 dist\ mkt+\beta_8 farmsize+\beta_9 capital+\beta_{10} treesha+\beta_{11} extdum+\beta_{12} membs1\text{-}18+\beta_{13} membs19\text{-}59+\beta_{14} membs60+\beta_{15} sexhhfml+\beta_{16} eduhh+\beta_{17} ruirudum+\beta_{18} coff/teazone+\beta_{19} titledum+\beta_{20} offmjobdum+\epsilon i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation.3.3}$$

where Yi was the gross margin in thousands of Kenya shillings per hectare of coffee including cash benefits from trees and tree products, α and βis are constants that were estimated, and Єi is the error term.

The premise that farmers maximize utility from adoption or non-adoption of technology underlies most adoption studies. From this premise, utility from adoption of a technology must pass a certain critical threshold for adoption to take place. Though we do not observe the threshold, we observe adoption or non-adoption when utility passes the threshold or not. The dependent variable is thus binary. Binary choice models such as the logit and probit are suitable candidates for adoption studies. However, creating binary variables leads to loss of information. Baidu-Forson (1999) pointed out that possible loss of information may occur if a binary variable is used as the dependent variable. Strictly dichotomous variables do not examine both extent and intensity of use of technologies. The Tobit model is preferred because it uses continuous data and provides information on probability of adoption and intensity of adoption.

Adoption of shade trees was modeled with number of trees per hectare as the dependent variable and the set of explanatory variables included age, education, gender of household head, acreage, agroecological zone dummy, dummy for tenure, as well as access to extension services and income from alternative enterprises. The cutoff for shade coffee adoption was set at the mean of trees per hectare such that farmers with shade trees equal or greater than the local average were taken as the adopters of shade coffee. The hypothesis that no factor singly had significant influence on adoption of shade coffee system was tested.

For the purposes of modeling the determinants of adoption of shade coffee, the condition for adoption of shade coffee was defined as 1 and non-adoption as 0, and following the exposition in Greene (2003) and Nkamleu and Adesina (2000), the underlying utility function which ranks the preference of the ith farmer is assumed to be a function of farmer-specific attributes, "X", such as level of education, income and farm size, and a disturbance term having a zero mean:

$U_{i1}(X) = \beta X_i + \varepsilon_{i1}$ for adoption and $U_{i0}(X) = \beta 0 X_i + \varepsilon_{i0}$ for non-adoption…………Equation 3.4

As the utilities are random, the i^{th} farmer will adopt if and only if $U_{i1} > U_{i0}$. Thus for farmer i, the probability of adoption is given by:

$P(1) = P\ (U_{i1} > U_{i0})$…………………………………………………………..Equation 3.5

$P(1) = P\ (\beta_1 X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0})$……………………………………………………..Equation 3.6

$P(1) = P(\varepsilon_{i0} - \varepsilon_{i1} < \beta_1 X_i - \beta_0 X_i)$……………………………………………………….Equation 3.7

$P(1) = P(\varepsilon_i < \beta X_i)$……………………………………………………………Equation 3.8

$P(1) = \Phi(\beta X_i)$……………………………………………………...…………Equation 3.9

where Φ is the cumulative distribution function for ε. The functional form for Φ depends on the assumptions made about ε. The error term is generally assumed to follow the normal or logistic distribution. If a normal distribution is assumed, the probit model is adopted.

For empirical purposes, the utility function can be inferred from the farmer's binary choice (adopt or not adopt) or some continuous choice over a predetermined interval (intensity of adoption). The former implies a probit or a logit model as in Bunyinza and Wambede (2008), Lapar and Pandey (1999), and Ayuk (1997). To consider intensity of adoption, a Tobit model is needed as in Anley *et. al.* (2007), Adesina and Zinnah (1993), Kazianga and Masters (2001).

The Tobit model has a probit component (Baum, 2006). The model coefficients were estimated by maximizing the Tobit likelihood function (Maddala, 1997) by use of the Stata software. One drawback of the Tobit model is that it constrains the post-estimation marginal effects to have the same sign as the coefficients.

Following McDonald and Moffitt (1980), we have the underlying stochastic Tobit model as:

$Y_i=Y_i^*$ if $Y_i^*>0$, $(Y_i^*=\beta_i X_i+ \epsilon_i)$……………………………………...........Equation 3.10

$Y_i=0$ otherwise

where Y_i is the observed dependent variable (number of trees per hectare of coffee, productivity of coffee per hectare, or gross margin in thousands of KES per hectare), Yi^* is the unobservable latent variable, Xi is a set of factors affecting adoption of agroforestry coffee, β_i represents a vector of unknown parameters to be estimated, and ϵ_i is a residual that is assumed to be independently and normally distributed with zero mean and a constant variance σ^2. The Tobit model for shade tree adoption is a censored regression model because the number of trees was censored at the sample mean for number of shade trees per hectare of coffee. The mass clustering of censored observations around the sample mean makes the Tobit model appropriate for this study. The Tobit model was developed for mass clustering around zero (McDonald and Moffitt, 1980), but we have adapted the clustering to the mean of the sample due to the unique difficulties of delineating adopters and non-adopters of shade trees.

The Tobit model for analysis of productivity of coffee was also censored at the cutoff for mean productivity leading to mass clustering of censored observations at the mean value. The Tobit model for analysis profitability of coffee was censored at the sample mean for gross margin per hectare of coffee. The mass clustering of censored observations at the cut point makes the use of Tobit model more appropriate than OLS. Although the exposition of the Tobit model focuses on adoption of shade coffee technology, the general arguments and formulae are applicable in the Tobit analyzes of productivity and profitability but without the concept of adoption.

Unlike the traditional regression coefficients, β_i, the Tobit coefficients are not direct estimates of the magnitude of the marginal effects of changes in the explanatory variables on the expected value of the dependent variable (McDonald and Moffitt, 1980). Each marginal effect in a Tobit equation includes both the influence of the explanatory variable on the probability of adoption and the intensity of adoption. The decomposition of Tobit coefficients into probability and intensity effects is elucidated in McDonald and Moffitt (1980), expounded in Greene (2003) and further applied in Nkonya *et. al*. (1997) and Anley *et. al.* (2006). This study estimated the marginal effects and elasticity after the Tobit estimation. To decompose the relevant effect of the changes in explanatory variables on the dependent variable, the McDonald and Moffitt (1980) decomposition was employed following the exposition in Chukwuji and Ogisi (2006) as follows:

$E(y)=F(z)E(y^*)=X\beta F(z)+\sigma f(z)$……………..…………………………………Equation 3.11

$E(y^*)=X\beta+\sigma f(z)/F(z)$ ………………………..……………………………Equation 3.12

where,

E(y) indexes the expected value of the level of shade coffee technology adoption. It indicates the level of adoption expected to be made by new adopters of the technology;

E(y*) gives the expected value of the level of adoption by those who already use shade coffee technology;

z is given as is the z-score for an area under the normal curve evaluated at

the mean of X_i;

α is the constant term in the Tobit model;

σ is the standard deviation in the Tobit model

β_i are the estimated coefficients of the independent variables;

f(z) is the unit normal density, that is, the probability density function

F(z) is the cumulative standard normal distribution function. It predicts the probability of adoption of technology given the mean values of the explanatory variables. That is, the percentage chance of a technology being used by new adopters.

The derivatives of E(y) with respect to X_i are

……………………………...….Equation 3.13

Multiplying both sides of equation 3.13 by x/y, and following from McDonald and Moffitt (1980), results in the estimation of the elasticity of expected use intensity and the elasticity of adoption probability, thus:

…………..Equation 3.14

After some algebraic transformations, the following expression results:

…………Equation 3.15

where,

…..………………………………………..Equation 3.16

is the elasticity of expected use intensity and

………………………………………………….Equation 3.17

is the elasticity of probability of adoption.

The summation of the elasticity of expected use intensity and that of the probability of adoption gives the total elasticity. The estimation and decomposition of the Tobit model made use of the “tobit” and “dtobit2” commands of the Stata software.

The Tobit model has not been previously applied to the modeling of shade coffee adoption and thus this study extends the use of the Tobit model in analyzes of agroforestry issues. In this study, we explicitly used the Tobit model to analyze adoption of coffee agroforestry technology. In addition, two separate Tobit models were used to examine productivity and profitability of coffee. A contribution of this study is the extension of the use of Tobit model in the analysis of adoption and use intensity of shade coffee technology. We also demonstrate the need to model different components of an enterprise (technology, productivity and profitability) in a joint framework in order to examine complementarity and non-complementarity between determinants of two outcomes, productivity and profitability in this case, of an enterprise.

Table 3.2 Definition of independent variables used in the empirical models

			Effects		
Variable	Description	Units	Adoption	Productivity	Profitability
Treeshec	Shade trees per hectare of coffee	Number		+	+
Eduhh	Formal education of hh head	Years	+	+	+
Agehh	Age of the household head	Years	-	-	-
Sexhhfml	Dummy for sex of household head	1 female 0 male	-	-	-
Laborinput	Annual family labor used for various coffee operations	Person-days	+	+	+
Membs1-18	Household members below age 19.	Number	-	-	-
Membs19-59	Household members aged between 19 and 59 years	Number	+	+/-	+/-
Membs60	Household members aged over 59 years	Number	-	-	-
Extdum	Dummy for whether hh head received extension services in the last one year	1 for yes 0 for no	+	+	+
Coffoutput	Coffee output per hectare	Kgs	+		
Titledum	Whether hh head had title to land	1 for yes 0 for no	+	+	+
Ruirudum	Indicator for adoption of Ruiru II cultivar	1 for yes 0 for no	+	+	+
Distmkt	Distance to the nearest urban centre	Kms	-	+	+
Coff/teazone	Dummy for the farming hh being in the coffee\tea zone	1 for yes 0 for no	-	+	+
Numblivest	Number of livestock per household	number	-	+/-	+/-
Dairyinc2	Income from dairy farming, in thousands	KES	-	+	-
Teainc2	Income from tea sales, thousands	KES	-	-	-
Banainc2	Income from banana sales, thousands	KES	-	-	-
Firedum	Dummy for trees are planted chiefly for firewood	1 for yes 0 for no	+	-	-
Ratiocoff	Ratio of area under coffee to farm size	fraction	+	+	+
Abandum	Dummy for whether farmer has ever abandoned coffee farm	1 for yes 0 for no	-	-	-
Offmjobdum	Whether household head had access to off-farm income	1 for yes 0 for no	-	+	-
Membgroup	Whether household head was	1 for yes	+	+	+

	affiliated to agricultural groups	0 for no			
Capital	Annual operating cash expenses used on one acre of coffee	KES	-	+	+
Farmsize	Farm size	hectares	+	+	+

4 RESULTS AND DISCUSSION

This chapter begins with the construction of binary classes of the sample farm households based on the three analysis criteria. These are adopters versus non-adopters of shade coffee; productive versus non-productive farmers; and profitable versus non-profitable farming households. Results of characterization of coffee farming households are presented in section 4.1. This is followed by section 4.2 where descriptive and inferential results of shade technology are presented. Section 4.3 presents results on the influence of socioeconomic factors on the productivity and profitability of coffee. The chapter concludes with a summary of key factors that determine the productivity and profitability of coffee in section 4.4.

4.1 Characterization of coffee farming households

As already explained in chapter three, the mean was chosen as the main index in transforming the sample households into binary categories. As shown in Table 4.1, the mean shade tree planting intensity was 140 per hectare, while the mean coffee production and annual gross margins were 3091 Kgs and KES 69,923 per hectare respectively. These three figures provided the cutoff values used in classifying the sample farm households into adopter versus non-adopters of shade technology, productive versus non-productive farms, and profitable versus non-profitable farms, respectively. The results of the construction of the three binary categories shows that about 40 percent of the sample households had above the average number of shade trees, while about 44 and 43 percent performed above average with respect to coffee productivity and coffee farm profitability. In this regard, 40 percent of the sample farm households were effectively classified as adopter of shade coffee, 44 percent were classified as productive coffee farmers, while about 43 percent of the farm households were classified as profitable coffee farming households.

Table 4.1 The mean values of number of shade trees per hectare, productivity and profitability and proportion of farmers with values exceeding the mean value

Parameter	Mean	Proportion of households with value exceeding the mean (%)
Trees per hectare (number)	141.00(104.88)	39.81
Productivity of coffee (kgs/ha)	3089.70(1810.06)	43.57
Gross margin/ha ('000KES)	69.52(43.78)	43.26

Corresponding to these results, the three dependent variables used in the study were defined as follows: adopter of shade technology if the mean number of shade trees per hectare of coffee was greater than 141 trees; productive farming household if the output of coffee was greater than 3089.70 Kgs/ha; profitable farming household if gross margin of coffee was greater than 69.52 thousands KES/ha.

4.2 The coffee shade technology in Imenti South District

This section starts with a summary of commonly used shade trees in the area of study. This is followed by results of socioeconomic characteristics of adopters and non-adopters of the shade technology. The last part of this section presents the results of the Tobit analyzes of determinants of probability of adoption and use intensity of shade technology.

4.2.1 The most commonly used coffee shade trees

The eastern slopes of Mt Kenya enjoy a rich biodiversity. Imenti South District has over one hundred tree species, but this biodiversity is disappearing fast as population density increases and people resort to conventional practices that are not in tandem with biodiversity conservation. Appendix B shows about 63 tree species that we could name and a category of "others" comprising different tree species that the research team and local knowledgeable people could not name. Diversification of species composition can lead to enhancements of stability and productivity of ecosystems (Cottingham *et al.,* 2001). Table 4.2 enumerates the most common tree species used for shade coffee system. Revenue from sale of trees and tree products such as firewood and fruits accounts for about 33% of the income from coffee farms.

Table 4.2 The most common trees used for shade coffee system in Imenti South District

Rank	Scientific name	Local name	Prevalence (percent)	Common uses
1	*Grevillea robusta*	"Mukima"	16.86	Timber, firewood, coffee stakes, banana support, soil fertility
2	*Vitex keniensis*	"Muuru"	13.29	Timber, firewood, soil fertility
3	*Cordia holstii*	"Muringa"	12.61	Timber, soil fertility, yam vine support
4	*Commiphora eminii*	"Mutungugu"	10.82	Yam vine support, boundary marker, fodder
5	*Musa sapientum*	"Marigu"	10.71	Fruits, fodder
6	*Persea Americana*	Avocado	10.24	Fruits, timber
7	Fodder	Fodder shrubs	3.20	Livestock feed, soil fertility
8	"Others"*	"Others"	2.73	Fodder, soil fertility
9	*Macadamia tetraphylla*	Macadamia	2.47	Cash crop, fruits
10	*Croton macrostachyus*	"Mutuntu"	2.31	Shade, traditional healing,

Legend: * Comprise many local species that were difficult to name

Grevillea robusta was the most prevalent tree species, generally favored because of good shade and because it produces a lot of foliage, firewood and timber. *Cordia abyssinica* and *Vitex keniensis* are also widespread because they are multipurpose tree species just like *Grevillea robusta*. These three species also act as a feed bank for livestock farmers during the dry period when fields are bare of grass. The *Commiphora eminii* do not provide much shade but they provide support to yam twines. Yams are commonly planted in unused spaces within the coffee farms or on the edges of the coffee farm. Furthermore, the *Commiphora eminii* has a big cultural value because it is used as a local beacon to demarcate land. Farmers believe the tree has a neutral effect on coffee since it has shallow roots and grows slowly. Multipurpose tree species such as *Grevillea robusta*, avocado and *Vitex keniensis* were preferred over those, like blue gum, which have a narrow range of uses or are exploitative in terms of water and soil nutrients.

Farmers listed four major reasons why they plant trees in the coffee fields. Table 4.3 shows the four major reasons for having trees in the coffee fields and the high percentage for each reason implies that trees were planted to serve multiple purposes that improve coffee ecology as well as meet the household needs for timber, foliage, fruits and firewood.

Table 4.3 Reasons why farmers incorporate trees in their farming system

Reason	Percent of total responses
Firewood	86.8
Shading coffee	81.7
Food or cash	75.7
Improvement of soil fertility	74.6

4.2.2 Socioeconomic characteristics of the adopters and non-adopters of the coffee shade system

Table 4.4 presents means and standard deviations of socioeconomic attributes of the sample households as well as *t*-ratios of *t*-test of difference across adopters and non-adopters of shade coffee. The results show that adopters and non-adopters of shade coffee significantly differ on a number of aspects. The adopters of shade coffee had significantly ($\rho<0.01$) more trees per hectare of coffee than the non-adopters. This also confirms that the groups resulting from the binary classes constructed in section 4.1 were unique with respect to number of shade trees. In addition, the adopters had significantly ($\rho<0.1$) smaller farms than non-adopters. Household heads of adopters of shade coffee were significantly ($\rho<0.10$) younger than those of non-adopters. It was expected that younger farmers would adopt technologies easily because they can absorb greater risks and can put more effort in their farming activities. The number of household members aged 60 years and above was significantly lower ($\rho<0.01$) for adopting households than for the non-adopters of shade coffee. This shows that households with relatively higher number of elderly people were less likely to plant trees because of the long time it takes to reap the benefits from trees.

Table 4.4 Results of independent two-sample t-test for continuous socioeconomic attributes of the adopters and non-adopters of shade coffee agroforestry

Characteristics	Adopters of shade (N=127)	Non-adopters of shade (N=192)	Overall (N=319)	t-ratios
Shade trees/ha (number)	251.50(74.01)	67.79(34.50)	140.92(104.88)	-29.83***
Age of hh head (yrs)	54.88(13.22)	57.14(13.47)	56.24(13.40)	1.483*
Members aged 1-18 yrs	1.63(1.26)	1.67(1.61)	1.66(1.48)	0.232
Members aged 19-59 yrs	2.64(1.61)	2.41(1.66)	2.50(1.64)	-1.276
Members 60 yrs over	0.44(.73)	0.67(0.83)	0.58(0.80)	2.54***
Family size (number)	4.72(1.78)	4.74(2.20)	4.70(2.03)	0.087
Farm size (ha)	1.23(1.02)	1.47(1.38)	1.36(1.25)	1.630*
Labor (pds/yr)	274.71(242.97)	221.77(193.37)	242.85(215.70)	-2.164**
Education of head (yrs)	6.31(4.30)	5.90(4.31)	6.06(4.30)	-0.850
Coff output/ha (kgs)	2949.38(1833.33)	3270.95(1697.85)	3142.93(1848.01)	1.525*
Livestock (number)	3.00(2.66)	3.41(3.30)	3.24(3.07)	1.160
Distance to market (kms)	3.80(2.82)	3.69(2.58)	3.73(2.67)	-0.383
Timber sales/ha ('1000KES)	30.76(32.58)	23.80(28.53)	26.57(30.35)	-2.012**
Capital input/ha ('000KES)	24.43(85.32)	20.76(66.38)	22.19(18.31)	-1.781**

Figures in parenthesis are the standard deviations

***Significant at ρ<0.01, **Significant at ρ<0.05 and *Significant at ρ <0.1

Productivity of adopters of shade coffee was significantly (ρ<0.1) lower than that of non-adopters. There was also a statistically significant (ρ<0.05) difference in the amount of family labor applied on one hectare of coffee to the two groups of coffee producers. Adopters had more family labor (274.71 person-days) per year compared to the non-adopters (221.77 person-days). Adopters of shade coffee put more effort in planting and pruning shade trees.

Shade coffee farmers derived significantly (ρ<0.05) more cash benefits from trees (30756 KES per hectare) compared to the non-adopters (23800 KES). Adopters of shade coffee had more trees to sell and deriving cash benefits is one of the considerations for planting multipurpose trees. Adopters of shade trees used significantly (ρ<0.05) more cash inputs (24425 KES) per hectare of coffee compared to the non-adopters (20715 KES). It is possible that trees increase the cost of coffee farm maintenance especially the cost of insecticides and pesticides because the humid micro-climate created by shading provides conducive environment for growth of diseases and pests.

Table 4.5 shows the results of the chi-square test for categorical characteristics across the adopters and non-adopters of shade coffee agroforestry. The results suggest adopters of shade coffee are more likely (χ^2=4.3, ρ<0.05) to have abandoned coffee farming at least once. When farmers abandon coffee farms they may take the option of not tending the farms and this is likely to provide good opportunities for tree re-establishment. Table 4.5 further shows that more (ρ<0.1) farmers in the high potential coffee/tea zone (64.5 percent) were non-adopters of shade coffee and only 35.5 percent of adopters of shade coffee were within the high potential coffee/tea zone. It implies that there was higher likelihood of shade adoption within the more marginal areas of the district than within the higher potential coffee/tea agro-ecological zone. This is an indication that agro-ecological zone of the farm has important influence in adoption decisions.

Table 4.5 Results of chi-square analysis for categorical socioeconomic attributes of the adopters and non-adopters of shade coffee in Imenti South District

	Proportion of Households			
Household characteristic	Shade adopters	Non-adopters	Overall	χ^2
Farmers who have ever abandoned coffee	44.62	55.38	58.31	4.31**
Female headed households	37.04	62.96	16.93	0.29
Farmers with title to land	36.81	63.13	56.11	1.47
Farms within the coffee/tea zone	35.48	64.52	58.31	3.49*
Farms with tea bushes	33.94	66.06	34.17	2.38
Hh heads with access to off-farm income	37.50	62.50	13.5	0.10
Accessed extension services	43.02	56.98	26.96	0.51
Active membership in agricultural groups	31.94	68.06	22.57	2.40

**Significant at $\rho<0.05$ probability level *Significant at $\rho<0.1$ probability level

4.2.3 Socioeconomic factors influencing adoption and intensity of use of shade trees in coffee

Table 4.6 shows the results of socioeconomic factors influencing adoption and intensity of use of shade trees in coffee. The model fit is shown by the high negative log-likelihood function (-778.977), which is statistically significant ($\rho<0.01$) as shown by the value of the chi-square below the Table. Table 4.6 shows the Tobit coefficients, the standard errors, t-ratios and their levels of significance, mean values of explanatory variables, and model statistical parameters. The results show that some socioeconomic factors have significant effect on adoption and use intensity of shade-coffee agroforestry technology. Except for farm size and ratio of coffee area to farm size, all other significant determinants had the expected signs. Farm size, ratio of coffee area to total farm size, number of elderly members above 59 years of age, and number of livestock had negative sign.

The negative signs imply that a unit decrease in the ratio of coffee area to farm size, the number of elderly members in the household, number of livestock and farm size, would increase probability of adoption and intensity of use of shade coffee. Bigger farm sizes are assumed to accord farmers the opportunity of planting more trees than small farm holdings. However, the hypothesis that farm size has a positive effect on the adoption of shade coffee technology is rejected by the findings of this study. This shows that coffee farmers with bigger holding prefer open coffee to shade coffee. Furthermore, tree planting at the local level might be more subsistence oriented rather than commercial in nature. Family structure has a significant ($\rho<0.1$) effect on adoption of coffee agroforestry. The higher the number of elderly members in a household the lower the likelihood of planting shade trees (Table 4.6) and the hypothesis that household members aged sixty years and above will influence shade adoption negatively cannot be rejected. These results tally with those of Neupane *et. al*. (2002) who found that age of male household head influenced adoption of agroforestry negatively. However, Aturamu and Daramola (2005) found that age was not a significant determinant of adoption of agroforestry technologies in Nigeria.

Table 4.6 Tobit coefficients, standard errors, t-ratios, levels of significance and means of variables for factors influencing adoption and use intensity of shade coffee technology

Variable	Coeff.	Std Err	t ratio	Level of Signif.	Mean of Variable	Mean× Coeff.
Constant	105.641	21.880	4.83	0.000***	1	105.641
Ratio coff area/farm	-98.656	22.315	-4.42	0.000***	0.374	-36.897
Coff ever abandoned	11.229	7.763	1.45	0.149	0.583	6.547
Tea income '000KES	-0.045	0.080	-0.56	0.573	15.423	-0.697
Dairy income '000KES	0.004	0.116	0.04	0.970	16.203	0.070
Coff output/ha (kgs)	-0.002	0.005	-0.34	0.733	1261.7	-2.344
Labor input (pds/yr)	0.005	0.018	0.3	0.765	237.85	1.296
Distance market (kms)	1.038	1.358	0.76	0.445	3.734	3.878
Dummy for Ruiru II	-8.149	9.701	-0.84	0.402	0.182	-1.483
Livestock (number)	-2.356	1.330	-1.77	0.078*	3.245	-7.645
Dummy for firewood	15.861	12.021	1.32	0.188	0.884	14.021
Dummy for extension	3.629	8.043	0.45	0.652	0.27	0.980
Members 1-18 yrs	-0.932	2.693	-0.35	0.730	1.661	-1.548
Members 19-59 yrs	0.086	2.407	0.04	0.971	2.502	0.216
Members 60 yrs over	-9.828	5.469	-1.8	0.073*	0.58	-5.700
Dumy head is female	-0.726	9.975	-0.07	0.942	0.169	-0.123
Educ of hh head (yrs)	0.075	0.952	0.08	0.937	6.063	0.454
Farm size (ha)	-6.443	1.783	-3.61	0.000***	3.373	-21.732
Dummy coff./tea zone	-14.414	7.670	-1.88	0.061*	0.583	-8.403
Dummy for title	-5.895	7.710	-0.76	0.445	0.561	-3.307

$z=(\alpha+X\beta)/\sigma=43.223/\ 52.92578=0.81668$ $E(Y)=48.8971$ $\alpha+X\beta=43.223$

Ancillary parameter (σ)= 52.92578   LR $chi^2(19)$= 55.96   Prob > chi^2 = 0.0000

Log likelihood = -786.951*** $f(z)=0.2858$ $F(z)=0.7929$ $E(y^*)=60.9785$

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

The larger the farm size the less the likelihood of adoption of shade coffee, implying that farmers with large farm sizes prefer open grown coffee. However, Aturamu and Daramola (2005) did not find farm size a statistically significant determinant of agroforestry adoption in Nigeria. The effect of farm size on adoption contradicts that of Chukwuji and Ogisi (2006) who found that farm size positively influenced fertilizer adoption in Nigeria, as well as that of

Lagat *et. al.* (2003) where farm size had a positive influence on adoption of water harvesting technologies in Kenya. The livestock activity had the hypothesized negative sign on adoption of shade trees because livestock damage either young trees or farmers cut the young trees accidentally as they gather the feeds. It was also hypothesized that the ratio of coffee area to total farm size would have a positive sign on adoption and intensity of use of shade trees but the hypothesis could not be sustained. The negative sign on this ratio indicates that farmers whose priority crop is coffee are less likely to adopt shade coffee due to anticipated loss in productivity coupled with non-payment of premium on quality by co-operative societies.

The last column of Table 4.6 gives the product of the coefficient and mean of each explanatory variable, and the sum of these products plus the intercept, when divided by the standard error of the model (σ), resulted in the z value of 0.8167. Table 4.6 also gives the probability of adoption F(z), the expected level of adoption of shade coffee by those farmers at the limit E(Y) and the expected use intensity by those above the limit E(Y*). The predicted probability of adoption of shade coffee given as the cumulative distribution function F(z) is 0.793, which indicates that there is a 79 percent chance that an coffee farmer would adopt shade coffee agroforestry. The expected level of adoption of shade trees by those farmers at the limit E(Y) is 120, which implies that new adopters are expected to have about 120 shade trees per hectare of coffee. For, farmers above the limit, the expected level of adoption E(Y*) is 150, that is, plant 150 shade trees per hectare of coffee.

Table 4.7 shows the coefficients, level of significance and the marginal effects, computed from the partial derivatives, for factors influencing adoption and intensity of use of shade coffee. When the McDonald and Moffitt (1980) decomposition was applied, the likelihood of total change in response to a one percent change in the ratio of coffee area to farm size is 0.7 percent. Out of this change, a change of 0.41 percent would be generated by marginal changes in the intensity of shade trees by farmers who already have them and 0.29 percent would come from new adopters. Likewise, the likelihood of total change due to a unit change in membership of elderly people in the family is 7.7 percent with marginal changes in intensity of use by current users of shade coffee accounting for 4.5 percent of the change (Table 4.7). The remaining 3.2 percent change would come from changes in probability of adoption by new users. The decomposed marginal change due to change in farm size is 4.0 percent. Out of this change, 2.4 percent would be generated by marginal changes in the number of shade trees by current users while the other 1.6 percent would come from changes in adoption by new users.

Likewise, decomposed marginal changes reveal that if the proportion of farmers in the coffee-tea zone was increased by one percent, shade coffee adoption would decline by 2.1 percent. Out of this decline, about 1.5 percent would come from reduced use intensity by current adopters and the remaining 0.5 percent would emanate from decline in probability of adoption by those users on the limit. Similarly, a one percent increase in number of livestock above the current average would lead to total decline of 1.7 percent in shade coffee adoption. This total change would be attributed to decline in intensity of use by current users of shade technology (one percent) and decline in probability of adoption by potential adopters (0.7 percent).

The decomposed results reveal that changes in significant explanatory variables would generate greater impact from expected changes by current users of shade coffee than from changes in probability of potential adoption. This finding colloborates that of Chukwuji and Ogisi (2006) on adoption and use intensity of fertilizer in Nigeria. In order of absolute magnitude, the greatest marginal changes would emanate from, whether farmer had ever abandoned coffee farm, number of household members aged over 59 years and farm size. Number of livestock, changes in ratio of coffee area to farm size, incomes from dairy and tree products would generate small marginal changes on adoption of shade coffee.

Table 4.7 Tobit marginal effects for factors influencing adoption and use intensity of shade coffee technology

	Marginal effects on

Variable	Coeff.	Level of signif.	Total change $\delta EY/\delta X_i$	Change in intensity	Change in probability $EY^*(\delta F(z)/\delta X_i)$
Constant	105.641	0.000***	65.3782	38.2445	27.1337
Ratio coff area to farm	-98.656	0.000***	-70.3859	-41.1739	-29.2121
Coff ever abandoned	11.229	0.149	11.9032	6.9630	4.9401
Tea income,'000KES	-0.045	0.573	-0.0595	-0.0348	-0.0247
Dairy income, '000KES	0.004	0.970	-0.2050	-0.1199	-0.0851
Coffee output/ha, Kgs	-0.002	0.733	-0.0006	-0.0003	-0.0002
Labor input/ha (pds/yr)	0.005	0.765	0.0040	0.0023	0.0016
Distance to mkt (kms)	1.038	0.445	0.9537	0.5579	0.3958
Dum for Ruiru II	-8.149	0.402	-5.9069	-3.4554	-2.4515
Livestock (number)	-2.356	0.078*	-1.7852	-1.0443	-0.7409
Dum trees for firewood	15.861	0.188	11.5041	6.7296	4.7745
Dummy for extension	3.629	0.652	4.7045	2.7520	1.9525
Members aged 1-18 yrs	-0.932	0.730	-1.3667	-0.7995	-0.5672
Members aged 19-59 yrs	0.086	0.971	0.6159	0.3603	0.2556
Members over 59 yrs	-9.828	0.073*	-7.7504	-4.5338	-3.2166
Dummy for hh is female	-0.726	0.942	-0.7503	-0.4389	-0.3114
Education hh head (yrs)	0.075	0.937	-0.0386	-0.0226	-0.0160
Farm size (ha)	-6.443	0.000***	-4.0338	-2.3597	-1.6741
Dum. for coff/tea zone	-14.414	0.061*	-2.1118	-1.4983	-0.530
Dummy for head has title	-5.895	0.445	-4.6096	-3.2704	-0.0904

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

Table 4.8 shows the total and decomposed elasticities of factors influencing the probability of adoption and intensity of use of shade coffee. The elasticities are calculated for the entire sample, for those farmers with some level of adoption above the cutoff point, and for non-adopters. The signs on the elasticities follow those of their respective Tobit coefficients but elasticities are interpreted in percentage changes. The signs indicate the direction of change. The dummy variable for coffee/tea zone and farm size exhibited the highest total elasticities. A one-percentage change in the coffee area/ farm size ratio would generate a 0.32 percent change in intensity of shade trees by current users and 0.22 percent change in the probability of adoption by new users. The total change in intensity of shade tree planting would be 0.54 percent. The interpretation for binary choice variables is different from that of continuous variables. Results in Table 4.8 reveal that if the proportion of sampled farmers who were abandoners was increased by one percent the intensity of shade trees would be expected to increase by nearly 0.14 percent. Of that 0.14 increase, almost 0.08 percent would come from increased tree intensity by current adopters and the remaining 0.06 would come from new adopters. Results in Table 4.8 reveal that greatest impact on coffee shade adoption would come from current users of this technology rather than from new adoption.

Table 4.8 Tobit elasticity for total change, adoption and use intensity of shade coffee technology

Variable	Coeff.	Level of Signif.	Elasticity of Total $\delta E(Y)/\delta X_i(X/Y)$	Intensity $\delta E(Y^*)/\delta X_i$ (X_i/EY^*)	Probability $\delta F(z)/\delta X_i$ (X_i/Fz)
Constant	105.641	0.000***	1.3371	0.7821	0.5549
Ratio of coff area/farm	-98.656	0.000***	-0.5388	-0.3152	-0.2236
Coff ever abandoned	11.229	0.149	0.1419	0.0830	0.0589
Tea income,'000KES	-0.045	0.573	-0.0188	-0.0110	-0.0078
Dairy income '000KES	0.004	0.970	1.3371	0.7821	0.5549
Coffee output/ha (kgs)	-0.002	0.733	-0.5388	-0.3152	-0.2236
Annual labor (pds/yr)	0.005	0.765	0.1419	0.0830	0.0589
Dist. to urban centre (kms)	1.038	0.445	0.0188	0.0110	0.0078
Dummy for Ruiru II	-8.149	0.402	-0.0679	-0.0397	-0.0282
Livestock (number)	-2.356	0.078*	-0.0147	-0.0086	-0.0061
Dum. trees for firewood	15.861	0.188	0.0193	0.0113	0.0080
Dummy for extension	3.629	0.652	0.0728	0.0426	0.0302
Members 1-18 yrs	-0.932	0.730	-0.022	-0.0128	-0.0091
Members 19-59 yrs	0.086	0.971	0.1185	0.0693	0.0492
Members 60 yrs over	-9.828	0.073*	-0.208	-0.1217	-0.0863
Dummy for head is female	-0.726	0.942	-0.0259	-0.0152	-0.0108
Education hh head (yrs)	0.075	0.937	0.0464	0.0272	0.0193
Farm size (ha)	-6.443	0.000***	-0.0315	-0.0184	-0.0131
Dummy coffee/tea zone	-14.414	0.061*	-0.0919	-0.0538	-0.0382
Dummy for title to land	-5.895	0.445	-0.0026	-0.0015	-0.0011

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

4.3 Implications of shade trees on productivity and profitability of coffee

Sections 4.3.1 and 4.3.2 present results of the socioeconomic characteristics of productive and non-productive coffee farming households as well as those of profitable and non-profitable coffee farming households. The results of Tobit analysis of the role of shade trees and socioeconomic characteristics of the farmer in determining productivity and profitability of coffee are presented in sections 4.3.3 and 4.3.4.

4.3.1 Socioeconomic characteristics of the productive and non-productive coffee farmers

Productive coffee farming households had relatively smaller ($\rho<0.1$) families (4.55 persons) than the non-productive households who had 4.98 members (Table 4.9). Similarly, productive farming households had fewer ($\rho<0.1$) household members (2.39) within the relatively more productive age category of 19-59 years than the non-productive counterparts who had 2.64 persons (Table 4.9). The variable ratio of coffee area to total farm size indicates the farmer's level of specialization. Results reveal that productive farming households have a proportionately larger ($\rho<0.1$) ratio of their farms (0.42) under coffee than their non-productive counterparts (0.34). Labor input in person-days per month was higher ($\rho<0.05$) for productive households (23.65) than for the non-productive households (21.31).

Table 4.9 Results of independent t-test for continuous socioeconomic characteristics of productive and non-productive coffee farmers in Imenti South District

Characteristic	Pproductive (N=180)	Non-productive (N=139)	Overall (n=319)	Mean Diff.	t-ratio
Age of hh head (yrs)	56.97(13.42)	55.68(13.4)	56.24(13.4)	-1.30	-0.86
Members 1-18 yrs	1.72(1.67	1.61(1.31)	1.66(1.48)	-0.10	-0.62
Members 19-59 yrs	2.64(1.74)	2.39(1.56)	2.50(1.64)	-0.25	-1.33*
Members 60 yrs over	0.54(0.77)	0.63(0.82)	0.58(0.80)	-0.90	-1.04
Family size(number)	4.98(2.17)	4.55(1.92)	4.74(2.04)	-0.43	-1.87**
Farm size (ha)	1.31(1.09)	1.43(1.37)	1.38(1.26)	0.12	0.88
Ratio coff area/farm	0.42(0.23)	0.337(0.21)	0.37(0.22)	-0.08	-3.44***
Labor (pds/month)	23.65(12.97)	21.31(11.6)	22.33(12.2)	-2.34	-1.70**
Educ of head (yrs)	6.30(4.22)	5.88(4.37)	6.06(4.30)	-0.418	-0.86
Coff output (kgs/ha)	4833.61(1143.66)	1745.63(796.25)	3091.61(1810.55)	-3087	-28.4***
Livestock (number)	3.55(3.22)	3.01(2.93)	3.24(3.07)	-0.54	-1.55*
Shade trees/ha	127.1(91.46)	154.2(113.2)	141.0(103)	23.4	1.99**
Dist. to mkt (kms)	3.29(2.40)	4.07(2.83)	3.73(2.67)	0.78	2.60***
Capital/ha('000KES)	27.47(0.01)	16.93(0.98)	21.52(14.70)	-10.53	-6.78***

Figures in parenthesis are the standard deviation

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

Table 4.9 shows that number of livestock was higher ($\rho<0.01$) for the farmers with productive coffee farms (3.55) than for the less productive farms (3.01). This may be attributed to the fact that the dairy enterprise has remarkably regular payments and income from dairy farming may be used to finance other farm operations. In turn, this may improve overall efficiency of the activity, giving higher productivity for farmers with regular income than for those who depend largely on irregular income from coffee. The number of shade trees per hectare was fewer (127) for the productive farms than for the non-productive farms (154), statistically significant at $\rho<0.05$. This can be explained by the fact that, as the number of shade trees increase relative to coffee bushes, growth conditions for coffee becomes sub-optimal. As a result, competition for nutrients between shade and coffee trees is likely to erode the gains from agroforestry practices. Productive coffee farms were also closer ($\rho < 0.01$) to rural urban centres (3.3 Kms) than their less productive counterparts (4.1 Kms). Proximity to rural commercial hubs improves farmers' access to capital inputs and other services.

Table 4.10 shows the results of chi-square (test of equality of expected and observed frequencies) for categorical characteristics of productive and non-productive coffee farmers. Results show that the proportion of farmers within the productive and non-productive regimes differed statistically in terms of abandonment of coffee, access to extension, and gender of chief decision maker.

Table 4.10 Results of chi-square analysis for categorical socioeconomic attributes of productive and non-productive coffee farmers in Imenti South District

Characteristic	Non-productive (N=180) Percent	Productive (N=139) Percent	Overall (Percent)	χ^2
Farmer has ever abandoned coffee	63.98	36.02	58.31	10.35***
Chief decision maker is female	66.67	33.33	16.93	2.77*
Farmers with title to land	55.31	44.69	56.11	0.21
Farms within the coffee/tea zone	55.38	44.62	58.31	0.20
Proportion of farms with tea bushes	59.63	40.37	34.17	0.69
Heads with access to off-farm income	55.00	45.00	12.54	0.85
Households with access to extension	48.84	51.16	26.96	2.76*
Membership to agricultural group(s)	58.33	41.67	22.57	0.21

***Significant at $\rho< 0.01$ and *Significant at $\rho <0.1$

Results in Table 4.10 show that non-productive coffee farming households had a greater ($\rho<0.01$) proportion of farmers who had ever abandoned coffee farming (64 percent) compared to the productive farmers (36 percent). This indicates that abandonment of coffee farms increases the likelihood of low productivity. The proportion of female-headed households was lower among the productive households implying a higher proportion within the non-productive category of coffee farmers ($\rho<0.1$). This is probable because female decision makers were inclined to other enterprises that meet immediate family needs like food crops and dairy during prolonged periods of low coffee prices. In terms of access to national extension services, a greater ($\rho<0.1$) proportion of the productive farmers (51 percent) of had accessed compared to 49 percent of the non-productive farmers.

4.3.2 Socioeconomic characteristics of profitable and non-profitable coffee farmers

Using the local mean gross margin per hectare of coffee as a cutoff for profitable and non-profitable regimes, 43.26 percent of the smallholder farmers were profitable and the remaining 56.74 percent were un-profitable. Results of t-test indicate that profitable farming households had characteristically higher sales of tree products, higher usage of family labor input, higher levels of utilization of cash inputs, and smaller farm sizes.

It is evident from Table 4.11 that the profitable farming households had smaller ($\rho<0.05$) farm size (1.21Ha) than their non-productive counterparts (1.51Ha). This indicates that under conditions of low coffee prices and high input costs, farmers can utilize their meagre resources to tend few coffee trees unlike if they have many coffee trees to tend. Cash inputs were used as a proxy for capital in this study. Table 4.11 reveals that in utilization of cash inputs, profitable coffee farmers utilized more ($\rho<0.1$) cash inputs per hectare of coffee (KES 24458.80) than their non-profitable counterparts (KES 19285.50). Family labor input per hectare of coffee was significantly higher ($\rho<0.1$) for profitable coffee farms than for non-profitable coffee farms (Table 4.11). In cash-constrained farming households, family labor is taken as a cheaper substitute for the relatively expensive capital to maintain the coffee business especially in periods of depressed coffee prices.

Table 4.11 Results of independent two-sample t-test for continuous socioeconomic attributes of the profitable versus non-profitable coffee farms

Variable	Profitable (1)	Non-profitable (0)	Overall	Difference	t-ratio
Educ of hh head (yrs)	6.3333	5.8563	6.0627	-.47697	-0.981
Age of hh head (yrs)	55.615	56.715	56.240	1.0995	0.726
Shade trees/ha	137.20	143.70	141.00	6.40	0.539
Livestock (number)	3.4565	3.0829	3.2445	-.3736	-1.079
Members age 1-18 yrs	1.7029	1.6298	1.6614	-.0731	-0.437
Members 19-59 yrs	2.5870	2.4365	2.5016	-.1505	-0.814
Members 60 yrs over	0.638	0.536	0.580	-.102	-1.133
Farm size (ha)	1.210	1.510	1.380	.300	2.252**
Value of trees/ha (KES)	38504.00	17627.00	26658.00	-20877	-7.74***
Labor input (pds/yr)	258.813	221.866	237.849	-36.95	-1.523*
Capital/ha (KES)	24458.80	19286.20	21523.25	-5172.10	-3.16***
Dist. to market (kms)	3.701	3.758	3.734	.0572	0.189

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

Table 4.12 presents results of categorical socioeconomic characteristics based on binary categorization of sampled households into profitable and non-profitable coffee farming households. Results of chi-square analysis reveal that status of abandonment, presence of Ruiru II cultivar, agro-ecological zone, and extension contact were significantly different between profitable and non-profitable farming households. Results show that non-profitable households had a greater ($\rho<0.01$) proportion of abandoners (65.19 percent) than their profitable counterparts (50.52 percent). As was hypothesized, abandonment of coffee farms decreases the chances of making positive profits from coffee.

Adoption of technologies is generally seen as a strategic option for increasing the profitability and competitiveness of an enterprise. Results in Table 4.12 also reveal that profitable farming households had a higher ($\rho<0.1$) proportion of farmers (22.5 percent) who had adopted Ruiru II cultivar compared to their non-profitable counterparts (14.9 percent). Adoption of improved varieties, especially those that cut cost of husbandry practices, is envisaged to increase enterprise competitiveness and profits. The proportion of farmers who received mainstream extension services was higher ($\rho<0.01$) for profitable coffee farms (32 percent) than for non-profitable coffee farms (23 percent). Contact with extension service increases the farmers' knowledge of good husbandry practices and new technologies available for adoption.

Table 4.12 Results of chi-square analysis for categorical socioeconomic attributes of the profitable and non-profitable coffee farmers in Imenti South District

Characteristic	Profitable percentage of the farmers	Non-profitable percentage of the farmers	Overall	χ^2
Coffee ever abandoned	36.56	63.44	58.31	8.161***
Chief decision maker is female	35.19	64.81	16.93	1.727
Farmers growing Ruiru II cultivar	53.45	46.55	18.18	2.998*
Farmers with title to land	41.90	58.10	56.11	0.308
Farm is on the coffee/tea agro. zone	44.39	51.61	58.31	4.777**
Head had access to off-farm income	42.50	57.50	12.54	0.011
Access to extension last one year	44.62	48.84	26.96	2.758*

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

4.3.3 Socioeconomic factors influencing productivity of coffee

Table 4.13 summarizes results for Tobit analysis of factors that determine productivity of coffee. Results reveal that decisions to abandon coffee farming as a response to low coffee prices and proximity to urban centres have a negative and statistically significant influence on productivity of coffee. In contrast, highly specialized coffee farmers as indicated by ratio of farm area to total farm size, farmers with increased income from dairy farming and users of high levels of capital inputs like pesticides and inorganic fertilizers have higher likelihood of being productive.

Table 4.13 Tobit coefficients, standard errors, t-ratios, levels of significance and means of variable for factors influencing productivity of coffee

Variable	Coeff.	Std err	t-ratio	ρ>t	Mean	Mean× Coeff.
Constant	120.535	312.473	0.39	0.700	1.000	120.535

Coff ever abandoned	-227.622	105.588	-2.16	0.032**	0.583	-132.720
Ratio coff area/farm	1133.609	280.809	4.04	0.000***	0.374	424.348
Shade trees/ha	-0.786	1.307	-0.6	0.548	57.519	-45.226
Dairy incom '000KES	2.820	1.508	1.87	0.062*	16.203	45.692
Banana incom '000KES	-1.347	2.357	-0.57	0.568	9.576	-12.900
Tea incom, '000KES	-0.791	1.108	-0.71	0.476	15.423	-12.200
Dummy for offarm job	-113.995	157.492	-0.72	0.470	0.125	-14.294
Labor input/ha (pds/yr)	0.205	0.267	0.77	0.443	237.849	48.807
Capital input/ha (KES)	0.049	0.010	5.12	0.00***	8785.27	433.604
Distance to mkt (kms)	-33.963	19.958	-1.7	0.09*	3.734	-126.801
Dummy for extension	74.044	110.054	0.67	0.502	0.270	19.962
Members age1-18 yrs	13.057	33.292	0.39	0.695	1.661	21.693
Members age 19-59 yrs	30.637	32.097	0.95	0.341	2.502	76.640
Members 60 yrs over	109.683	73.386	1.49	0.136	0.580	63.609
Dummy hh is female	-158.291	143.040	-1.11	0.269	0.169	-26.795
Education of hh head (yrs)	19.134	12.794	1.5	0.136	6.063	116.002
Farm size (ha)	20.151	21.362	0.94	0.346	3.373	67.970
Dummy for title to land	139.319	109.381	1.27	0.204	0.561	78.176

$\alpha+X\beta=1146.1$ $z=(\alpha+X\beta)/\sigma=1.5457$ $F(z)=0.9389$ $f(z)=0.1208$ $EY^*=1241.505$ $EY=1165.664$
sigma(σ)=741.4741 Fraction(η)=0.785

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

Table 4.14 presents the decomposed Tobit marginal effects for factors influencing productivity of coffee. Results reveal that a one percent increase the relative importance of coffee in the farm would increase coffee output by 10.64 Kgs per hectare. Out of this change, 8.35 Kgs of coffee would come from currently productive farms and the remaining productivity increase of 2.29 Kgs per hectare would be from changes in probability of new farm at the limit becoming productive. Other factors with a direct positive effect on coffee productivity are income from dairy and the level of capital input per hectare of coffee. If dairy income increases by 1000 KES above the current mean, total productivity would increase by about 2.7 Kgs of coffee per hectare. Decomposed marginal effects show that the largest change (2.1 Kgs) would come from currently productive farms and the remaining 0.6 Kgs per hectare would be realized from potentially productive farmers (Table 4.14). Similarly, if the level of cash inputs is increased by 1000 KES per hectare of coffee we would expect substantial increases in productivity (36.4 Kgs per hectare) to come from currently productive farms and productivity increases of 10 Kgs per hectare would emanate from those farmers on the margin. Total change in productivity would thus be 46.4 Kgs per hectare.

Table 4.14 shows that the dummy variable for abandon and distance to nearest urban centre have an inverse relationship with high productivity. Conditional on ever abandoned coffee at any one time, abandoners experienced total productivity decline of 213 Kgs per hectare of coffee compared to those farmers who never abandoned their coffee farms. Out of this decline, 167.7 Kgs of coffee per hectare would come from those farmers who are already productive, and the rest of the decline (47 Kgs) would be from those on the limit of achieving the cut point for productivity. Distance to the nearest market has a negative sign indicating that productivity of coffee increases with proximity to urban centres.

Decomposed marginal results reveal that if a farm household is one kilometer further from the urban centre, total coffee productivity would decline by about 32 Kgs per hectare (Table 4.14). This decline would be attributed largely to currently productive farms (25 Kgs per hectare) and to changes in the probability of those firms at the limit becoming productive would account for the remaining 7 Kgs. Urban centres provide farmers with needed inputs and services and proximity cuts on cost of access to such inputs. The greatest policy impacts on coffee productivity should thus focus more on constraints facing currently productive coffee farmers rather than promotion of productivity increases on non-productive farms.

Table 4.14 Tobit marginal effects for factors influencing productivity of coffee in Imenti South District, Kenya

Variable	Coeff.	Level signif.	Marginal effects on		
			of Total change $\delta EY/\delta X_i$	Change in intensity $F(z)(\delta EY^*/\delta X_i)$	Change in probability $EY^*(\delta F(z)/\delta X_i)$
Constant	120.5349	0.700	113.1717	88.7898	24.3818
Coff ever abandoned	-227.6219	0.032**	-213.7169	-167.6735	-46.0434
Ratio area/farm size	1133.6090	0.000***	1064.3591	835.0523	229.3068
Shade trees /ha	-0.7863	0.548	-0.7383	-0.5792	-0.1591
Dairy income '000	2.8201	0.062*	2.6478	2.0774	0.5704
Bana. income '000	-1.3472	0.568	-1.2649	-0.9924	-0.2725
Tea income '000	-0.7911	0.476	-0.7427	-0.5827	-0.1600
Dummy off-farm job	-113.9948	0.470	-107.0311	-83.9722	-23.0589

Labor input (pds/yr)	0.2052	0.443	0.1927	0.1512	0.0415
Capital input (KES)	0.0494	0.000***	0.0463	0.0364	0.0100
Dist. to mkt (kms)	-33.9628	0.090*	-31.8881	-25.0181	-6.8700
Dummy for ext.	74.0442	0.502	69.5210	54.5433	14.9777
Members 1-18yrs	13.0565	0.695	12.2589	9.6178	2.6411
Members 19-59yrs	30.6367	0.341	28.7652	22.5680	6.1972
Members 60 yrs over	109.6832	0.136	102.9829	80.7961	22.1868
Dummy head female	-158.2911	0.269	-148.6214	-116.6022	-32.0192
Educ of head (yrs)	19.1337	0.136	17.9648	14.0945	3.8704
Farm size (ha)	20.1508	0.346	18.9199	14.8437	4.0761
Dummy for title	139.3186	0.204	130.8079	102.6265	28.1814

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

Table 4.14 shows the results for decomposed elasticities for determinants of productivity of coffee. The signs of the elasticities follow those of their respective coefficients and are indicative of the direction of change. In order of absolute magnitude, the variables exhibiting highest elasticities are the dummy variable for abandonment, cash inputs, distance to urban centre and dairy income. Ratio of coffee area to farm size, capital input and dairy income have a direct and positive relationship with productivity of coffee while the decision to abandon coffee and distance from urban centres to the farm have a negative influence on productivity.

The elasticity figures in Table 4.15 show the percentage change in coffee output per hectare given a one percent change in the explanatory variable. Results in Table 4.15 show that a one-percentage increase in the intensity of use of cash inputs per hectare would induce a 0.35 percent increase in coffee output per hectare, *ceteris paribus*. Decomposition of this elasticity for capital reveals that changes by the currently productive farmers would account for 0.27 percent of this elasticity and changes in probability of increased productivity by farms at the margin becoming productive would account for 0.08 percent. Likewise, a ten percent increase in distance from the urban centre above the current mean would lead to a decline of one percent in the productivity of coffee largely from decline productivity of currently productive farms (0.8 percent) and decline in probability of farms at the margin of becoming productive would account for 0.2 percent. Decomposed elasticities show that greater changes in productivity of coffee would come from changes in productivity of currently productive farms than from changes in likelihood of new farms at the limit becoming productive.

Table 4.15 Decomposed Tobit elasticities for determinants of productivity of coffee in Imenti South District of Kenya

Variable	Coefficient	Level of signif.	Total $\delta E(Y/\delta X_i)$ (X/Y)	Elasticity of: Intensity $\delta E(Y^*)/\delta X_i$ (X_i/EY^*)	Probability $\delta F(z)/\delta X_i$ (X_i/Fz)
Constant	120.5349	0.70	0.0971	0.0762	0.0209
Coff ever abandoned	-227.6219	0.03**	-0.1069	-0.0839	-0.0230
Ratio area/farm size	1133.6090	0.00***	0.3418	0.2682	0.0736
Shade trees /ha	-0.7863	0.55	-0.0364	-0.0286	-0.0078
Dairy income '000KES	2.8201	0.06*	0.0368	0.0289	0.0079
Bana. income '000KES	-1.3472	0.57	-0.0104	-0.0082	-0.0022
Tea income '000KES	-0.7911	0.48	-0.0098	-0.0077	-0.0021
Dummy off farm job	-113.9948	0.47	-0.0115	-0.0090	-0.0025
Labor input (pds/yr)	0.2052	0.44	0.0393	0.0308	0.0085
Capital/ha (KES)	0.0494	0.00***	0.3493	0.2740	0.0752
Distance to mkt (kms)	-33.9628	0.09*	-0.1021	-0.0801	-0.0220
Dummy for extension.	74.0442	0.50	0.0161	0.0126	0.0035
Members 1-18yrs	13.0565	0.70	0.0175	0.0137	0.0038
Members 19-59yrs	30.6367	0.34	0.0617	0.0484	0.0133
Members 60 yrs over	109.6832	0.14	0.0512	0.0402	0.0110
Dummy hh is female	-158.2911	0.27	-0.0216	-0.0169	-0.0046
Educ of hh head (yrs)	19.1337	0.14	0.0934	0.0733	0.0201
Farm size (ha)	20.1508	0.35	0.0547	0.0430	0.0118
Dummy for title	139.3186	0.20	0.0630	0.0494	0.0136

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

4.3.4 The role of shade trees and other socioeconomic factors in the profitability of coffee

Table 4.16 shows the Tobit coefficients, standard errors, t-ratios and means of variables for factors influencing profitability of coffee. Results reveal that increased ratio of coffee area to farm size, the growing of Ruiru II cultivar, income from dairy, high potential agro-ecological zones as well as family labor input have a positive and direct influence on profitability of coffee. Two factors, whether farmer had ever abandoned coffee farming and increased income from banana farming, have a negative influence on profitability of coffee. It is notable that Ruiru II cultivar, family labor input, income from bananas and agro-ecological zones were not significant determinants of adoption of shade coffee. These factors were also not significant determinants of productivity but are statistically significant factors in the profitability of coffee.

Ruiru II cultivar has the expected positive sign on profitability of coffee since this cultivar is bred for resistance to Coffee Berry Disease and thus farmers can cut on cost of spray and get greater yields when berries do not fall prematurely due to disease infestation. Ratio of coffee area to farm size has the expected positive sign on profitability since the higher ratio points to greater specialization. Farmers who specialize pay greater attention to the enterprise and greater profits can be realized due to extra effort and management of the enterprise. Income from dairy farming could have either sign, but results show it has a positive sign on profitability of coffee farming. One reason why dairy farmers have higher coffee profits might be that they use manure from their dairy enterprise on their coffee fields. The second reason is that income from dairy is used to finance recurrent expenditures on coffee farms. The dummy variable for coffee/tea zone was statistically significant and had the anticipated positive effect in the profitability of coffee. The coffee/tea zone is a high potential agricultural area and farmers are expected to get extra benefits from the natural environment in comparison to their counterparts in the marginal areas. Family labor input has the expected positive sign on profitability of coffee and the variable was statistically significant ($\rho < 0.05$). Gross margin only includes cash inputs on the cost side and farmers who use more family labor are expected to plough back greater dividends because gross margin incorporates returns to labor on the revenue side.

Table 4.16 Tobit coefficients, standard errors, t-ratios, levels of significance and means of variable for factors influencing profitability of coffee in Imenti South District, Kenya

Variable	Coeff.	Std. Err.	t-ratio	ρ>t	Mean	Mean× Coeff.
Constant	8.7333	8.5993	1.02	0.311	1.0000	8.733
Ratio coff area/ farm	17.5233	7.5632	2.32	0.021**	0.3743	6.560
Coff ever abandoned	-4.9733	2.8526	-1.74	0.082*	0.5831	-2.900
Dum Ruiru II planted	5.7227	3.4123	1.68	0.095*	0.1818	1.041
Shade trees/ha	0.0252	0.0339	0.74	0.457	57.5187	1.452

Dairy incom '000KES	0.1311	0.0424	3.09	0.002***	16.2026	2.124
Bana. incom '000KES	-0.1340	0.0750	-1.79	0.075*	9.5758	-1.283
Tea income '000KES	0.0344	0.0221	1.55	0.121	15.4228	0.530
Dummy off-farm job	-3.9740	4.3028	-0.92	0.356	0.1254	-0.498
Dummy coff/tea zone	5.4841	2.9954	1.83	0.068*	0.5831	3.198
Family labor (pds/yr)	0.0147	0.0074	1.99	0.047**	237.8490	3.491
Capital/ha (KES)	0.0001	0.0003	0.49	0.626	8785.2700	1.118
Dist. to market (kms)	-0.1626	0.5226	-0.31	0.756	3.7335	-0.607
Dummy for extension	2.1425	2.9973	0.71	0.475	0.2696	0.578
Members 1-18yrs	0.6184	0.9233	0.67	0.504	1.6614	1.028
Members19-59yrs	0.5067	0.8584	0.59	0.555	2.5016	1.268
Members 60 yrs over	1.8472	1.9535	0.95	0.345	0.5799	1.071
Dum hh head female	-3.5982	3.8183	-0.94	0.347	0.1693	-0.609
Educ of head (yrs)	0.1494	0.3565	0.42	0.675	6.0627	0.906
Farm size ()	-0.8554	0.6875	-1.24	0.214	3.3730	-2.885
Dummy for title	0.6056	2.9478	0.21	0.837	0.5611	0.340

σ=20.1774 $\alpha+X\beta$=24.6532 $z=(\alpha+X\beta)/\sigma$=24.6532/20.17744=1.2218   F(z)=0.8891

E(Y*)=28.9451   E(Y)=25.7354   f(z)=0.1891 Log likelihood=-712.1775

Fraction (η)=0.7237

181 left-censored observations at gmcofftimha2<=28.54089

138 uncensored observations

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

The dummy variable for whether the farmer has ever abandoned coffee farming was statistically significant ($\rho<0.10$) and had the expected negative sign on profitability of coffee. This is in conformity with what is expected since abandonment is characterized by neglect of the coffee bushes, introduction of other crops into the coffee farm, and application of extremely low levels of inputs. Surprisingly, income from bananas was significant ($\rho<0.10$) and negatively influenced profitability of coffee. This indicates that banana farming is taken as an alternative competitive enterprise to coffee farming. In the initial stages of neglecting coffee, many farmers plant banana stools in the coffee farms before eventual abandonment of coffee farming.

The predicted probability of profitable farming given as the cumulative distribution function F(z) in Table 4.16 is 0.88. This indicates there is a 88 percent chance that a coffee farmer would earn profits exceeding the cut point, local average. The expected level of profitability, E(Y), is 25.74 which implies that those farmers at the limit of making positive profits beyond the local average are expected to make 25.74 thousand KES per hectare. Also for farmers above the limit the expected level of profits depicted by E(Y*) is 28.95 implying that current profitable coffee farms are expected to earn 28.95 thousand KES per hectare of coffee.

Table 4.17 shows the decomposed marginal effect for total, intensity and probability of profitable farming. The total marginal effect is highest for the presence of Ruiru II cultivar, high potential coffee/tea zone and farmer's decision on abandonment. Family labor input and incomes from both dairy and banana enterprises have the least marginal effects on profitability of coffee/agroforestry system. A one percent increase in the ratio of coffee area to total farm size from the current average would induce current profitable coffee farms to increase their per hectare gross margin by 108.30 KES and 47.5 KES for those on the limit, leading to total increase of 158.0 thousands of KES. Increasing banana income by 1000 KES would decrease the coffee gross margin by 119.10 KES (0.1191x1000) and thereby increasing farmers' income by a huge margin with minimal decrease in earnings from coffee. It is evident that banana farming is increasingly outcompeting the coffee activity especially in the coffee/banana zone and these findings reveal that farmers who replace coffee with bananas are definitely focused on profits.

A unit increase in income from dairying would increase coffee gross margin by 0.12 KES, this total effect largely being accounted for by change in intensity of currently profitable farms (0.08 KES) and changes in probability of those farms at the limit becoming profitable (0.04 KES). Increasing family labor input by one person-day above the current labor input would induce gross margin per hectare of coffee to increase by 13 KES. Out of this change, 9.0 KES per hectare would be attributed to the currently profitable farms while 3.0 KES per hectare would emanate from farms with a higher likelihood of becoming profitable.

The interpretation of dummy variables is different from that of continuous variables. The farm household being in the high potential coffee/tea zone is expected to gain extra 4.88 thousands KES more than an average farmer in the lower marginal coffee/banana zone. Out of this increase, 3.39 thousands of KES would come from farmers already making profits and the remaining 1.49 thousands of KES would arise from changes in probability of new farmers making profits beyond the local average. The coefficient on farmer decision to have ever abandoned coffee reveals that if the proportion of those who abandoned was increased by one percent gross margin per hectare of coffee would decrease by 4.42 thousands of KES. Out of this decline in gross margin, 3.07 thousands of KES would come from currently profitable farms and the remaining 1.35 thousands of KES would come from those farms on the limit of becoming profitable. The dummy variable for adoption of Ruiru II cultivar is associated with a total increment of 5.09 thousands of KES in gross margin per hectare of coffee if the proportion of adopters in the sampled farms was increased by one percent and this increase would come from the currently profitable farms (3.54 KES thousands per hectare) and farmers at the limit of making profits beyond the cut point would account for the rest, 1.55 thousands of KES (Table 4.17).

Table 4.17 Tobit marginal effects for factors influencing profitability of coffee

Y=Gross margin/ha '000 KES			Marginal effects on:		
Variable	Coeff.	Level of signif.	Total $\delta EY/\delta x_i$	Intensity $Fz(\delta EY^*/\delta x_i)$	Probability $EY^*(\delta Fz/\delta x_i)$
Constant	8.7333	0.311	7.7648	5.3955	2.3693
Coff ever abandoned	-4.9733	0.082*	-4.4218	-3.0725	-1.3492
Ratio coffee area/ farm	17.5233	0.021**	15.5801	10.8261	4.7540
Dummy for Ruiru II	5.7227	0.095*	5.0881	3.5356	1.5526
Shade trees per hectare	0.0252	0.457	0.0224	0.0156	0.0068
Dairy income ‘000KES	0.1311	0.002***	0.1166	0.0810	0.0356
Bana income ‘000KES	-0.1340	0.075*	-0.1191	-0.0828	-0.0363
Tea income ‘000KES	0.0344	0.121	0.0306	0.0212	0.0093
Dummy off-farm job	-3.9740	0.356	-3.5333	-2.4552	-1.0781
Dummy cof/tea zone	5.4841	0.068*	4.8760	3.3881	1.4878
Family labor (pds/yr)	0.0147	0.047**	0.0131	0.0091	0.0040
Capital per ha (KES)	0.0001	0.626	0.0001	0.0001	0.0000
Distance to mkt (kms)	-0.1626	0.756	-0.1446	-0.1005	-0.0441
Dummy for extension	2.1425	0.475	1.9049	1.3236	0.5812
Members 1-18yrs	0.6184	0.504	0.5498	0.3821	0.1678
Members19-59yrs	0.5067	0.555	0.4505	0.3131	0.1375
Members 60 yrs over	1.8472	0.345	1.6424	1.1412	0.5011
Dummy head female	-3.5982	0.347	-3.1992	-2.2230	-0.9762
Educ of hh head (yrs)	0.1494	0.675	0.1329	0.0923	0.0405
Farm size (ha)	-0.8554	0.214	-0.7605	-0.5285	-0.2321
Dummy for title	0.6056	0.837	0.5384	0.3741	0.1643

***Significant at $\rho<0.01$, **Significant at $\rho<0.05$ and *Significant at $\rho<0.1$

Table 4.18 shows the decomposed elasticities for determinants of profitability of coffee in Imenti South District. The signs on elasticities follow those of their respective Tobit coefficients and indicate the direction of change. Elasticities in Table 4.18 show the percentage change in per hectare gross margin of coffee given a one-percentage change in each factor. Gross margin from coffee farming would increase by 0.05 percent for farms which are already profitable and 0.02 percent for those farms at the limit of becoming profitable and total gross margin for the entire sample would increase by 0.07 percent if dairy income increased by one percent from the current average. Interpretation for dummy variables is slightly different. The total elasticity of 0.11 associated with the dummy for coffee/tea zone implies that per hectare gross margin of coffee would increase by 0.11 percent if the proportion of sampled farmers currently living in the coffee/tea zone was increased by one percent. About 0.08 percent of the 0.11 percent change would be generated by currently profitable farms and the remaining 0.03 percent would be generated by changes in probability of making profits by new farms at the limit of becoming profitable, attaining above the mean gross margin per hectare of coffee. In terms of magnitude, the ratio of coffee area to farm size, family labor input, agro-ecological zone and decision to have ever abandoned coffee would generate the largest effects. Adoption of Ruiru II cultivar and income from dairy and banana would generate relatively smaller impacts on coffee earnings under the current scenario of low international coffee prices.

Table 4.18 Decomposed Tobit elasticities for profitability of coffee in Imenti South District of Kenya

Y= GM/ha '000KES Variable	Coefficient	P>t	Total δEY/δXi (X/Y)	Elasticity of Intensity δEY*/δXi (Xi/EY*)	Probability δFz/δXi (Xi/Fz)
Constant	8.7333	0.311	0.3017	0.2097	0.0921
Coff ever abandoned	-4.9733	0.082*	-0.1002	-0.0696	-0.0306
Ratio area/ farm	17.5233	0.021**	0.2266	0.1575	0.0691
Dum for Ruiru II	5.7227	0.095*	0.0359	0.0250	0.0110
Shade trees/ha	0.0252	0.457	0.0502	0.0349	0.0153
Dairy income '000KES	0.1311	0.002***	0.0734	0.0510	0.0224
Bana income '000KES	-0.1340	0.075*	-0.0443	-0.0308	-0.0135
Tea income '000KES	0.0344	0.121	0.0183	0.0127	0.0056
Dummy for off-farmjob	-3.9740	0.356	-0.0172	-0.0120	-0.0053
Dummy coff/tea zone	5.4841	0.068*	0.1105	0.0768	0.0337
Family labor input (pds)	0.0147	0.047**	0.1206	0.0838	0.0368
Capital/ha(KES)	0.0001	0.626	0.0386	0.0268	0.0118
Distance to market (kms)	-0.1626	0.756	-0.0210	-0.0146	-0.0064
Dummy for extension	2.1425	0.475	0.0200	0.0139	0.0061
Members aged 1-18yrs	0.6184	0.504	0.0355	0.0247	0.0108
Members aged 19-59yrs	0.5067	0.555	0.0438	0.0304	0.0134
Members 60 yrs over	1.8472	0.345	0.0370	0.0257	0.0113
Dummy for hh is female	-3.5982	0.347	-0.0210	-0.0146	-0.0064
Education of head (yrs)	0.1494	0.675	0.0313	0.0218	0.0096
Farm size (ha)	-0.8554	0.214	-0.0997	-0.0693	-0.0304
Dummy for title to land	0.6056	0.837	0.0117	0.0082	0.0036

***Significant at P<0.01, **Significant at P<0.05 and *Significant at P<0.1

4.4 Complementarity between significant factors influencing productivity and profitability of coffee

An explanatory variable was taken as complementary in productivity and productivity of coffee if it was a significant determinant in both models and had the same direction of influence. Table 4.19 presents a summary of significant explanatory variables and their elasticities computed at the means. It is apparent that different sets of factors influence productivity and profitability of coffee. It is thus evident that one factor can influence productivity and profitability of coffee differently. For example, increased specialization on coffee activity, indicated by the ratio of coffee area to farm size, has a complementary role in determining productivity and profitability of coffee. Agroecological zone being the high potential coffee/tea zone has an insignificant effect in determining productivity of coffee but positively influences profitability.

Increased usage of inorganic inputs like fertilizers has positive effect on productivity of coffee but their high costs prohibits any profits from their usage under the prevailing production and marketing conditions. Increasing availability of such inputs cannot solve such a dilemma but can only lead to sustained losses in farm income despite increasing productivity of the enterprise. Such findings imply that low cost sustainable interventions should continue to receive attention of researchers and policy makers. Results in Table 4.19 reveal that determinants of productivity and profitability of coffee may have similar or contrasting effects in these outcomes. These findings reveal that determinants of productivity may or may not complement profitability thereby raising serious concerns about how to raise coffee productivity and profitability simultaneously. Policy and extension messages should thus be refined to focus on farmer objectives and more so when the market dynamism causes shifting of objectives to reflect new opportunities and new challenges. For instance, promotion of productivity-enhancing interventions can be prioritized when the market for coffee is recovering after a depression and after recovery, focus should shift towards promotion of profitability-enhancing interventions.

In the long run, factors that promote profitability should be key to increasing competitiveness of coffee and survival of the business. Furthermore, the coping strategy of abandonment should be discouraged due to its negative effects on productivity and profitability and the long time it takes coffee to recover in response to market stimuli. More surprising is that income from other farm activities need not necessarily depress coffee productivity and profitability. The role of income from alternative enterprises on productivity and profitability of coffee depends on whether part of that income is used to finance coffee farming and other complementary aspects such as availability of manure from dairy.

Table 4.19 Elasticities calculated at the means of significant variables for productivity and profitability models for coffee farmers in Imenti South District, Kenya

Explanatory Variables	Elasticity Components		
	Total change ηF(z)	Intensity ηE(Y*)	Probability ηE(Y)
Productivity Model			
Ratio coffee area to farm size	0.3418	0.2682	0.0736
Coffee has ever been abandoned	-0.1069	-0.0839	-0.0230
Dairy income (‘000KES)	0.0368	0.0289	0.0079
Capital per hectare (KES)	0.3493	0.2740	0.0752
Distance to market (kms)	-0.1021	-0.0801	-0.0220
Profitability Model			
Ratio coffee area to farm size	0.2266	0.1575	0.0691
Coffee has ever been abandoned	-0.1002	-0.0696	-0.0306
Dairy income (‘000KES)	0.0734	0.0510	0.0224
Dummy for Ruiru II planted	0.0359	0.0250	0.0110
Banana income (‘000KES)	-0.0443	-0.0308	-0.0135
Dummy for coff/tea zone	0.1105	0.0768	0.0337
Family labor input (pds/yr)	0.1206	0.0838	0.0368

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study underscores the important role of agroforestry in smallholder coffee farming. The analytical framework begins by operationalizing categorization of coffee farming using the mean for the dependent variables as the cutoff point for various aspects, that is, adoption and non-adoption of coffee agroforestry technology, productive versus non-productive farming households, as well profitable versus non-profitable coffee farms. Using these cutoff points to delineate the binary classes t-tests, for continuous socioeconomic variables, and chi-square tests, for categorical variables, were used to examine the socioeconomic characteristics of the adopters and non-adopters of agroforestry, productive versus non-productive farmers, as well as profitable versus non-profitable farming households. Subsequently, three separate Tobit models were used to examine the relative significance of socioeconomic factors in influencing adoption/non-adoption of agroforestry, determinants of productivity and profitability of coffee.

Using the mean for a continuous dependent variable to delineate adoption and non-adoption of a technology or to characterize farmers on the basis of productivity and profitability is a major modeling aspect of this study. Unlike most studies on technology adoption that stop at modeling adoption, this study also examined effect of the technology on the productivity and profitability of the enterprise thereby bringing the issues of adoption of technology, productivity and profitability aspects into one logical framework that gives comprehensive treatment of adoption than otherwise. Using the mean for tree intensity as cutoff for adoption and non-adoption of shade coffee was found satisfactory because the test of significance revealed that the two groups were statistically different. The mean for number of shade trees was about 140 trees per hectare of coffee and about 40 percent of the coffee farmers had more than this average and these were effectively the adopters of the shade coffee. Using the mean for coffee output per hectare as a cutoff for productive and non-productive farmers led to two statistically distinct productivity categories of coffee growers. Productivity of coffee for the farming population was about 3091Kgs per hectare and farmers who achieved greater productivity were taken as productive farming households and comprise about 44 percent of the farmers. Using the local mean for gross margin, including the cash benefits from trees per hectare of coffee led to two statistically significant categories of farmers, profitable and non-profitable coffee farms. The gross margin per hectare of coffee was about KES 69923 and 43 percent of the farmers achieved in excess of this average value and these were effectively the profitable farming household.

On average, adopters of shade coffee had 262 shade trees and shrubs per hectare of coffee compared to 68 trees for the non-shade farmers. Productivity of non-shade coffee was significantly higher (3270.75 Kgs per hectare) than that of shade coffee (2949.80 Kgs). Cash benefits from sale of trees and tree products were higher for the shade farmers (KES 30129.60. per hectare) than the non-shade adopters (KES 23799.30 per hectare). The gross margin of the shade coffee adopters was higher compared to that of the non-shade adopters implying that benefits from trees can more than compensate the loss in farm income due to loss in productivity from incorporation of trees into the coffee farms. Furthermore, trees have ecological and environmental benefits that increase human welfare and these benefits were not included in this analysis. T-tests and chi-square analysis reveal that socioeconomic characteristics differed between shade and non-shade farmers. Further, socioeconomic characteristics differed between productive and non-productive farmers as well as between profitable and non-profitable households.

Application of the Tobit model reveals that socioeconomic factors influence the rate and intensity of adoption of shade technology differently. Adoption of shade coffee was negatively influenced by increased specialization in coffee production, increased number of livestock, the number of elderly members in the household, farm size and the high potential agro-ecological zone. Farmers in the relatively high potential coffee/tea zone have a lower likelihood of adopting shade trees compared with their counterparts in the dryer marginal zones in the lower parts of Imenti South District. Increased land under coffee has an inverse relationship with adoption of shade coffee and it has the highest marginal effect on adoption of shade trees. This shows that smallholder coffee farming presents good opportunity for increased tree planting in Kenya.

Productivity of coffee was influenced positively by increased specialization in coffee production, income from dairy enterprise, and cash inputs per hectare of coffee. Revenue from coffee and other enterprises is generally used to finance recurrent expenditures for farm operations like weeding and spraying, as well as in the purchase of needed inputs. Elasticity coefficients show that productivity would increase by 0.34% if dairy income increased by 1%. Under the current production and market conditions, cost would rise faster than productivity since productivity of coffee would increase by only 0.35 percent if cash inputs were increased by one percent, holding other things constant. This demonstrates that the rational approach to increasing productivity of coffee in Kenya is to look for low cost production alternatives, substantial increase in producer price or significant cuts on cost of marketing.

The decision to abandon coffee farming has a negative influence on the productivity of coffee. Abandonment leads to neglect of coffee and the growing of other crops like Napier grass and beans on coffee farms thus leading to loss in productivity of coffee. Elasticities show that increasing the number of abandoners by one percent in the sample would decrease coffee productivity by 0.11 percent, holding other things constant. In addition, if the mean distance from urban centres increased by one percent, productivity of coffee would decline by 0.10 percent. We conclude that institutional factors, farmer decisions on abandonment, alternative enterprises, and capital inputs have an effect in the productivity of coffee and these attributes differ between productive and non-productive households.

Profitability of coffee was influenced positively by specialization in coffee production, income from dairy farming, adoption of Ruiru II cultivar, farm being in the high potential coffee/tea zone and family labor input. Increased specialization, family labor input and agro-ecological zone have the highest positive profit elasticity in the area of study. Profitability of coffee was adversely affected by the decision to abandon coffee farming and income from bananas. The elasticity on dairy income shows that if income from dairy increased by one percent, profitability of the coffee enterprise would decline by 0.07 percent.

Adoption of agroforestry technology and determinants of productivity and profitability of coffee are influenced by different sets of socioeconomic factors and some factors have contrasting effects in the productivity and profitability of coffee. The degree of specialization in coffee production negatively influences shade adoption but increases both productivity and profitability of the coffee enterprise. Increased number of livestock decreased the likelihood of adoption of shade coffee technology but does not have a statistically significant influence on either productivity or profitability of coffee. Income from dairy financed farm operations and eased the capital constraint, in effect increasing both productivity and profitability of the coffee, but has no statistically significant effect on adoption of shade technology. Adoption of Ruiru II cultivar does not have significant impact on productivity of coffee but influences profitability of the coffee enterprise positively by cutting costs of sprays. Likewise family labor input has a positive effect on profitability due to cost cutting and better husbandry practices as a result of tending the coffee farm.

5.2 Recommendations

Agroforestry has an important role to play in rural livelihoods increasing profitability of coffee, providing cash, food and ecological benefits to the farming community. Indeed shade trees contribute about 33% of the coffee income excluding benefits on savings for firewood as well as ecological considerations. However, productivity of shade coffee is significantly lower than that of non-shade coffee. From the findings of this study, farmers should however be informed that the potential loss in farm income associated with loss in productivity of coffee due to incorporation of shade trees is more than offset by sale of trees and tree products. Because farmers' opinion on whether shade trees were beneficial to their coffee farming was sharply divided, extension can use the results of this study to clear doubts in the farmers mind that cash benefits from shade coffee are higher than from non-shade coffee.

There are factors, such as abandonment, location of the farm in the lower agro-ecological zone and decreased number of livestock that predispose farmers to rapid adoption of agroforestry practices. These aspects can be used for targeting farmers during extension for dissemination of knowledge that enhances adoption of shade coffee for the benefits of the farmers and local ecosystems. Farmers prefer multipurpose tree species to the ones that have a narrow range of uses and hence husbandry practices for suitable tree species should be promoted through extension systems. Commercialization of shade trees should also be encouraged so that farm incomes increase substantially in periods of low and declining coffee prices.

The fact that farmers are selling trees is good for their immediate needs but this act portends serious economic, social and environmental problems to the community, and the country in the long run, unless environmental conservation and re-afforestation interventions are designed and implemented sooner rather than later. Some coffee farms had no trees at all and such families faced serious shortage of firewood for cooking. The number of firewood deficit-households will continue to rise unless tree planting is enhanced. Because of increasing demand for timber and scarcity of trees, trees are now considered as near liquid assets and thus acting as "local safe banks" for the relatively poor farmers. These emerging new concepts provide good background for commercialization of tree planting with the attendant benefits of environmental, aesthetic and bio-diversity conservation.

The Tobit model results on profitability reveals that increased use of conventional inputs such as fertilizers and pesticides does not improve the profitability of coffee though substantial productivity gains are realized. Thus increased profitability under the current prices of inputs and output must rely on unconventional inputs such as shade coffee trees and adoption of improved cultivars. Research into trees that are best for shade coffee should be initiated and such findings form part of information for dissemination. This kind of research should be geared towards promotion of productivity enhancing shade trees that can replace the currently high-cost production system, which is heavily dependent on expensive inorganic inputs.

Decomposed results of the Tobit model show that significant productivity gains can be obtained from increased measures that promote productivity of the currently productive farms rather than increasing the productivity of the unproductive farms. Productive farms have higher likelihood of adopting such measures compared to their unproductive counterparts. Likewise, decomposed Tobit results reveal that currently profitable coffee farms have higher chances of increasing productivity compared to their unprofitable counterparts. These provide support for increasing policy intervention and increased allocation of scarce resources to these groups of farmers as a priority.

Planting trees in coffee fields does not guarantee the benefits of productivity and profitability. These coffee farms needs to be managed so that the benefits from shade can be maximized. Farmers should thus be encouraged to manage trees in the coffee fields by following recommended spacing and pruning regimes. Equally, there is need to study agronomic practices for the common shade trees so that farmers can optimize spacing for shade in order to increase productivity. There was apparently no recommendation of spacing, pruning regime, and density for even the most common tree species. In some cases, trees like blue gums were planted in the coffee farm and yet such trees are known to be exploitative in terms of soil nutrients and water.

Though inorganic inputs such as fertilizers and pesticides confer substantial gains in productivity, they do not guarantee increased farm income to the farmers and hence measures that can cut costs of those inputs should be explored. Since inorganic inputs are imported, issues of importation, distribution and taxation should be addressed with cost reduction as a priority concern. Alternatively, local and/or regional manufacturing of inputs should be explored so that farmers can acquire these inputs cheaply. In addition, the optimal combination of inorganic inputs and various shade coffee practices should be explored with a view to cost cutting and increased profitability of coffee/agroforestry.

Determinants of productivity and profitability of coffee do not necessarily complement each other and thus farm intervention requires prioritization of farmer objectives which are generally dynamic as they reflect changing economic opportunities. Since different sets of factors influence productivity and profitability of coffee, it is necessary to tailor extension objectives depending on the immediate intervention required to increase productivity or profitability.

Further research is needed on the effect of different tree species on coffee yield, productivity and profitability. The dynamics of shade and coffee quality are not documented for the vast Mt. Kenya coffee farming highlands. The ecological contribution and optimal plant density need to be determined so that farmers can maximize yield sustainably. Research into appropriate pruning and other husbandry practices for common shade trees is recommended preferably at the farm level. Pruning, spacing and other management techniques for shade trees should be communicated to farmers as trees were not only unevenly planted but also largely unmanaged thereby leading to pockets of over-shading and lack of the necessary shade on the same farm.

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APPENDICES

APPENDIX A: Coffee/agroforestry questionnaire for Imenti South District of Kenya

This research is conducted for educational purposes and information obtained will be treated with confidentiality and only used for research purposes at Egerton University.

Questionnaire number [ ] Date (dd,mm) ______/______/2007

1. Farmer's Name________________________Enumerator's name_____________________
2. Administrative division……………………Location……………….
3. Factory name………………………Cooperative Society………………………………….
4. Profile of household head (hh)

Sex 1=Male 2=Female	Age (years)	Level of formal education (years in school)	Main activity 1=Coffee growing 2=Tea growing 3=Banana growing 4=Dairying 5=Other farming activities 6=Casual work 7=Permanent employment 8=Business (specify)__________	Experience in coffee growing (years)
[ ]	[ ]	[ ]	[ ]	[ ]

5. Profile of household members

Please provide us with number of household members under each category below:

Category	Number
Less than 18 years of age	[ ]
Male and 18-59 years of age	[ ]
Female and 18-59 years of age	[ ]
Over 59 years of age	[ ]

Human Capital

6. For each household member, please provide us with details about their age, years of formal education, their main occupations and years of experience.

Member 1= Son 2=Daughter 3=Other	Age (years)	Education (years)	Main occupation	Experience main occupation.	Secondary occupation	Experience secondary occupation.
1.Household head						
2.Spouce						
3. [ ]						
4. . [ ]						
5. . [ ]						
6. . [ ]						
7. . [ ]						
8. . [ ]						
9. . [ ]						
10. . [ ]						
11. [ ]						
12. [ ]						

7. Land holdings

What is the form of land holdings and size?

Form of ownership:	1.Owned with title	2.Owned without title	3.Leased in	4. Leased out
	[ ]	[ ]	[ ]	[ ]

8. Distance to the nearest main trading centre [ ] Kms

Distance to the nearest motorable, all-weather road [ ] Kms

9. Type of main house (tick)

House type	(Tick one)
Permanent, stone iron-roofed	[ ]
Semi-permanent timber, iron-roofed	[ ]
Semi-permanent, mud-walled, iron roofed	[ ]
Mud-walled, thatched roof	[ ]

Other (Specify)…………………………….. [ ]

10. Enterprise allocation, yield and revenue

Type of enterprise	Acreage	Cash=1 Food=2 Both=3	Estimated annual production	Units	Estimated annual sales (Ksh)
1. Coffee		[ ]			
2.Tea		[ ]			
3. Maize		[ ]			
4. Beans		[ ]			
5. Bananas		[ ]			
6. Mature cattle (#)		[ ]			
7. Young cattle (#)		[ ]			
8.Sheep (#)		[ ]			
9. Goats (#)		[ ]			
10. French beans		[ ]			
11. Oranges		[ ]			
12. Pawpaw		[ ]			
13. Other:		[ ]			
		[ ]			

11. Historical profile of household coffee activity

Year established	Acreage	Number of trees	Variety:1=Ruiru II, 2=Other varieties
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

12. Since the year of establishment, have you increased the acreage under coffee?

[ ] Yes [ ] No

If 'YES',

Year	Expansion			
	Area	Trees (number)	Variety: 1=Ruiru II, 2=Other varieties	Reasons: 1=Planting Ruiru II 2=Coffee farming was profitable 3=Others were doing so
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]

13. Since establishment, have you uprooted any coffee? [ ] Yes [ ] No

If 'Yes',

Year	Uprooted			
	Area	Trees (number)	Variety: 1=Ruiru II, 2=Other varieties	Reasons: 1=Replacement with another coffee variety 2=Coffee price was low 3=Others were doing so 4=To cut on costs
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]

14. Since establishment, have you ever abandoned or reduced maintenance activity on coffee?
[ ] Yes [ ] No

If 'Yes',

Year	Reduced activities			
	Area	Trees (number)	Variety: 1=Ruiru II 2=Other varieties	Reasons: 1= Traditional varieties were unprofitable 2=Coffee price was relatively low 3=Others were doing so 4=To cut on costs
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]

15. Have you ever re-established coffee farming? [ ] Yes [ ] No

If 'Yes',

Year	Re-establishment			
	Area	Trees (number)	Variety: 1=Ruiru II 2= Other varieties	Reasons: 1= Coffee prices were improving 2=Replacement with another variety 3=Costs were lower due to new technologies 4=Others were doing so

	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]
	[ ]	[ ]	[ ]	[ ]

16. What is the spacing and average annual production for each coffee variety

	Spacing; width X length (m)	Total production per year
1. SL28/34/ K7		
2. Ruiru II		
3. Mixed		

AGROFORESTRY

17. List the type of trees and their number as found within or on the edge of the coffee field. Use common or local names for identification of trees.

Species	Number	
	Within coffee field	On edge of coffee field
1.Grevellea robusta (Mukima)		
2. Meru oak		
3. 'Miringa'		
4. 'Mitungugu'		
5. Banana stools		
6. Avocado		
7. Fodder shrubs		
8.Others:		
9.		
10.		

18. With **one for most important**, rank each tree species for the following purposes:

Species	Purpose				
	Shading coffee	Windbreak for coffee	Soil fertility management	Firewood/Timber	Food/ Cash
1.Grevellea robusta					
2. Meru oak					
3. 'Miringa'					
4. 'Mitungugu'					
5. Banana stools					
6. Avocado					
7. Fodder shrubs					
8. Others:					
9.					

19. Is there a noticeable difference between coffee trees within the shaded area and those not shaded? [ ] Yes [ ] No

If 'Yes', in what ways is the difference noticeable?

1=True 2=False

i) Less build-up of pest for shaded coffee [ ]

ii) Coffee berries from shaded trees are heavier [ ]

iii) Less disease attack for shaded trees [ ]

iv) Increased number of berries for shaded trees [ ]

20. For the 5 most common tree species on your farm, list the average price of the tree for timber, firewood, fruits or poles. Assume a mature tree.

	Value in KSH				
	Timber	Firewood	Fruits	poles	Medicinal
1.Grevellea robusta					
2.Meru oak					
3.'Muringa'					
4.Avocado					
5.Bananas					
6.Others:					
7.					

FARM INPUTS FOR COFFEE

21. For each fixed investments, please tell us the number, year of purchase, cost and approximate useful life.

Item	Number	Unit cost	Year purchased	Expected useful life
1.Bags				
2.Secateurs				
3.Knapsack sprayers				
4.Forked jembe				
5. Pangas				
6. Other:				

22. What is the annual quantity and unit cost of any of the inputs that you have used over the last one year on the coffee field?

		Quantity	Units	Unit cost	Total cost
DAP					
SSP/ 17:17:0					
CAN					
Copper fungicide					
Insecticides					
Herbicides					
Manure					
Mulch					
Fertilizer application labor	1.Family				
	2. Hired				
Manure application labor	1.Family				
	2. Hired				
Weeding labor	1.Family				
	2. Hired				
Spraying labor	1.Family				
	2. Hired				
Coffee pruning labor	1.Family				
	2. Hired				
Tree pruning labor	1.Family				
	2. Hired				
Mulching labor	1.Family				
	2. Hired				
Harvesting labor	1.Family				
	2. Hired				

MARKETS AND INSTITUTIONS

23. Provide information on marketing channels used, annual deliveries and price

Markets	Channel used: 1=Yes 2=No	Price per Kg	Annual delivery (Kgs)
Cooperative	[ ]		
Brokers	[ ]		
Private factories	[ ]		

24. Please provide us with details on extension visits, seminars attended and group membership over the last 12 months.

	Number
Number of extension visits	[ ]
Number of agricultural shows or exhibitions attended	[ ]
Number of agricultural seminars attended	[ ]
Number of agricultural groups of which you are a member	[ ]
Number of coffee-related groups of which you are a leader	[ ]
Number of meetings on coffee attended	[ ]
Number of meetings on agroforestry attended	[ ]
Number of agricultural awards won	[ ]

REVENUES

25. In your opinion, which revenue category best represents your annual earnings (KSH) from each source? Tick

	0-<5,000	5,000-<15,000	15,000-<25,000	25,000-<50,000	50,000-100,000	100,000-200,000	>200,000
Tea							
Dairy							
Beef							
Bananas							
Goats							
Sheep							
Selling trees							
Salary							
Wages							
Rented houses							
Retail business							
Others:							

Sensitivity of coffee activities

26. Now we would like to know how the price of coffee affects your coffee farming practices:

Practice	Current price =	Double price =	Half price =
Number of manual weeding per years			
Number of herbicide sprays per year			
Number of prunings per year			
Number of desuckerings per year			
Number of fungicidal sprays per year			
Number of insecticide sprays per year			
Number of top-dressings per year			
Number of foliar feed sprays per year			
Number of phosphatic applications per yr			
Number of mulching per year			
Pruning of shade trees per year			

THANK YOU

APPENDIX B: Types of tree species used in shade coffee agroforestry system in Imenti South District of Kenya.

Rank	Botanical Name	Local/Common Name	Prevalence (Percent)
1	*Grevillea robusta*	“Mukima”	16.86
2	*Vitex keniensis*	Meru oak	13.29
3	*Cordia holstii*	“Muringa”	12.61
4	*Commiphora eminii*	“Mutungugu”	10.82
5	*Musa sapientum*	Banana stools	10.71
6	*Persea americana*	Avocado	10.24
7		Fodder shrubs	3.2
8		Others	2.73
9	*Macadamia tetraphylla*	Macadamia	2.47
9	*Croton macrostachyus*	“Mutuntu”	2.31
10		“Muatuati”	2.15
11		“Mugumo”	1.31
12		“Muthatha”	1.26
13		Mango	1.05
14		“Muthigia”	1.05
15		“Murembu”	0.68
16		“Mwiria”	0.58
17		Eucalyptus	0.53
18		“Muangua”	0.47
19		Prunas Africana	0.47
20		Cypress	0.37
21		Blue gum	0.26
22		“Mlakia”	0.21
23		“Muriguri”	0.21
24		“Muthanda”	0.21
25		“Mwenjera”	0.21
26		“Mururi”	0.21
27		“Mutuja”	0.21
28		“Muthanduku”	0.16
29		Orange	0.16
30		Lemon	0.16
31		Luquat	0.16
32		Nandi flame	0.16
33		Pawpaw	0.16
34		“Miraa”	0.16
35		“Mukwego”	0.16
36		“Mutamawio”	0.16

37	“Mugwani”	0.11
38	“Markhali”	0.11
39	“Mwiria”	0.11
40	Leucaena	0.11
41	“Murenda”	0.11
42	“Mwethu”	0.11
43	“Munyamwe”	0.11
44	Erythrine abbysinica	0.11
45	Guava	0.05
46	“Mutonyo”	0.05
47	Croton	0.05
48	“Murama”	0.05
49	“Muthithi”	0.05
50	“Mukuura”	0.05
51	“Murukuruku”	0.05
52	“Mukui”	0.05
53	Calliandra	0.05
54	“Muguan”i	0.05
55	“Mutoo”	0.05
56	Jacaranda	0.05
57	“Muthuthu”	0.05
58	“Mutunguru”	0.05
59	White sabaote	0.05
60	Bottlebrush	0.05
61	Cassuarina	0.05
62	“Mutuja”	0.05
63	“Murangati”	0.05
64	“Munyamwe”	0.05
	Total	100