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Analysis of Opportunity Cost of Agroforestry among Smallholder Farmers in Western Kenya

Rosebell Owuor

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THE KENYA INSTITUTE FOR PUBLIC POLICY RESEARCH AND ANALYSIS (KIPPRA)

YOUNG PROFESSIONALS (YPs) TRAINING PROGRAMME

Analysis of Opportunity Cost of Agroforestry among Smallholder Farmers in Western Kenya

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Abstract

Agroforestry presents great potential in the restoration of agricultural land and forest base, yet its uptake by smallholder farmers in Kenya remains disappointingly low in the face of deforestation, averaging 12 per cent per annum. The purpose of this paper was to determine whether the foregone profits of pursuing agroforestry are higher than the alternative agricultural enterprise which smallholder farmers prefer to use on their land parcels. The objectives were to estimate the opportunity cost of agroforestry practices in Kenya and establish the factors determining the opportunity cost of agroforestry practices in Kenya. The study used a longitudinal research design and secondary panel data from World Agroforestry Centre Data verse, comprising of 60 smallholder agroforestry farmers residing near Kakamega Forest in Western Kenya, collected over a period of 10 years from 2002 to 2012. The opportunity costs of agroforestry in the study accrued mainly in the form of forgone profits from agricultural activities, which represented the only locally profitable alternative to adopting agroforestry. As such, financial opportunity cost was defined as the difference in profitability per hectare between agroforestry and the alternative conventional annual crop. The average opportunity cost was Ksh -5,052.88 per hectare. The net present gross margins of agroforestry were higher on average than when the same land was invested on alternative land use systems that generated annual revenue. Tobit regression was used to establish factors determining opportunity costs of agroforestry. Overall, empirical results showed that most of the farmers with complete ownership rights to their land increased the number of trees on their farms. Having a certain market for their agroforestry tree products significantly reduced opportunity costs. Older farmers also had lower opportunity costs than younger farmers but only until a certain point when opportunity costs reach an optimal point then begin to increase. There is need to promote farmer trade-relations (contractual arrangements) to ensure assured and continued profitability of agroforestry products. There is also need for direct and improved efforts towards promotion of marketable and profitable agroforestry products to ensure farmers are encouraged to adopt agroforestry. There is also needs to better implementation of land titling programmes to encourage uptake and maintenance of agroforestry.

Abbreviations and Acronyms

GDP	Gross Domestic Product
KWAP	Kenya Woodfuel and Agro-forestry Programme
NPV	Net Present Value
OC	Opportunity Cost
RU	Random Utility
SDG	Sustainable Development Goals
VIF	Variance Inflation Factor

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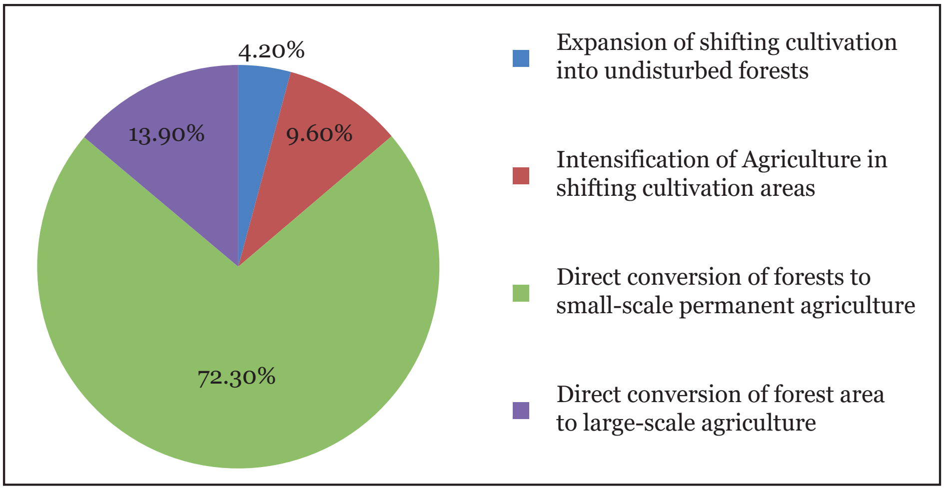
1. Introduction

1.1 Background

Land area and usage has evolved over time in Sub-Saharan Africa countries. The demand for expansion of agricultural land has led to encroachment of land covered by forested area in the tropics (Peralta et al., 2009). Many of these countries highly depend on the agricultural sector for economic growth, which has led to challenges in agriculture land use and management (Franzel and Scherr, 2002). Increased fuel extraction and agricultural dependency for both commercial and subsistence use in these countries has not only seen an increase in cultivated land but has also led to a tremendous decline in forest cover. This has exacerbated environmental degradation through global warming, climate change and destruction of valuable plant and animal species. According to the Food and Agriculture Organization (FAO, 2010), close to 13 million hectares of forests were mainly converted to agriculture among other uses annually during the 2000s in comparison to 16 million hectares observed in the 1990s globally. While this has presented a slight improvement, the deforestation rate still remains an issue at 0.6 forest per capita as at the year 2010. Tropical forest loss in Africa is also 0.6 percent higher than the 0.2 per cent world average (FAO, 2010).

A similar decline has been observed in Kenya. Kenya is predominantly an agricultural country with the sector contributing 27.3 per cent to Gross Domestic Product (GDP) while 42 per cent of the country's total employment comes largely from small scale farming (KNBS, 2015). The area under forests in Kenya is 2.4 million hectares, of which the area under gazetted forests indicates a 0.16 million hectare loss from the 1.8 million hectares recorded at independence, an implication that forest resources have significantly dwindled over time (KLA, 2006). Currently total forest cover stands at 6 per cent of the total land area, way below the national target of 10 per cent as aspired by the Kenya Forest Policy 2010. Over 75 per cent of agricultural output in Kenya is produced by smallholder farmers with average farm sizes of about 2.5ha producing mainly for subsistence using traditional technologies (AfDB, 2010). As depicted in Figure 1.1, Kenya like most Sub-Saharan countries has agricultural expansion persisting to be among the immediate threats to forests in Kenya (Walubengo and Kinyanjui, 2010). This is demonstrated in Figure 1.1.

Figure 1.1: Conversion of forest land to agriculture under different categories



Source: FAO

It is not surprising that most policy interventions in the agricultural sector have been geared towards small scale farmers.

There have been efforts by the government to reverse deforestation through regulations, policy, and incentive systems. In reversing deforestation, policy documents such as the Kenya Constitution and the Vision 2030 are geared towards having sustainable and manageable forests by increasing production of trees through farm forestry and agroforestry schemes on private land from smallholder farming systems. This is supported by the Farm Forestry rules enacted by the Ministry of Agriculture which require 10 per cent of all farms to be covered with trees. Implementation of the policy was directed towards agriculture-oriented smallholders based on the reasoning that they constitute 80 per cent of the Kenyan population (Future Agriculture, 2006) and are the main driving force in rural development (Wiggins et al., 2010). There have also been regulations on logging from public forests to enable rejuvenation of depleted forests and encourage farmers to seek alternative supplies for tree products. This was in response to the negative environmental effects (e.g soil erosion) that resulted from over-cutting of private forests and woodlots to meet the timber demand. The government has also made efforts to have incentive systems that incorporate both individual private benefits and environmental benefits accruing to society. These benefits have mainly been centred around encouraging tree planting by providing various inputs. For example, the government has improved dissemination pathways for example by providing seedlings for free or at a subsidized price. While this has been instrumental in improving adoption of agroforestry, the uptake has not spread with much vigour as previously expected (Zomer et al, 2009). The reasons for this have included inadequate human capacity and forestry staff that are unaware of needs of farmers pertaining to agroforestry.

Meeting the increasing demand for agricultural produce while simultaneously conserving the environment and enhancing livelihoods has promoted the need for implementing sustainable policy objectives. As a result, agroforestry and adaptation of innovative farming practices have been under attention in recent development efforts of enhancing food security, mitigating against effects of degradation and climate change and improving people's livelihoods.

Agroforestry has been identified as a sustainable agricultural system where agriculture and forest resource bases are restored while improving farm production and conserving forest cover. Mercer (2003) technically defines agroforestry as *"...a joint forest production system whereby land, labour, and capital inputs are combined to produce trees and agricultural crops (and/or livestock) on the same unit of land."* The trees incorporated into the land are envisaged to contribute to environmental protection by enhancing water and soil conservation and further contribute towards food commodities which can supplement normal farm yields or serve as substitute products in the event of crop failures, and contribute to income (Hoskins, 1990).

Smallholder farmers typically engage in crop, livestock farming or a combination of both. Before making the decision to allocate a portion of their land towards any enterprise, a rational farmer would be expected to compare the costs to the benefits they will forego (opportunity cost of tree planting). Estimating the benefits presents further complications as the time lag between costs and benefits is at least 3-5 years, unlike other farm enterprises with a much shorter pay-back period. An incentive to motivate farmers towards allocating their land to agroforestry would be to compensate smallholder farmers for what they are losing when they make the decision to allocate a portion of their farming land to planting trees. This paper presents an analysis of opportunity costs of agroforestry among smallholder farmers around Kakamega forest, Western Kenya. Kakamega forest remains the only tropical forest in Kenya and is gazetted spanning 188.7 hectares. The opportunity costs of agroforestry for these smallholder farmers accrue mainly in the form of forgone profits from agricultural activities, which represent the only locally profitable alternative to integrating trees on the farms.

1.2 Problem Statement

Despite the potential of agroforestry in the restoration of agricultural land and forest base, its uptake by smallholder farmers in Kenya regrettably remains disappointingly low. Particularly, small-scale farmers are either reluctant to integrate trees on their farms alongside other crops or there have been instances of abandonment shortly after uptake, attributed to subsistence and non-timber forest products (NTFPs), which have perceived low financial value (Himberg et al., 2009; Mogoi et al., 2012).

Despite a lot of discourse in favour of agroforestry, there is no adequate contextual research to determine whether the foregone profits of pursuing agroforestry are higher than the alternative agricultural enterprise. This presents a dearth in knowledge of the economic cost farmers/land owners face in making the decision on land use changes that incorporates growing trees on the farms alongside agricultural enterprises. This paper attempts to fill this gap by generating a cost benefit analysis of a land use change from a pure agricultural enterprise to agroforestry.

1.3 Research Questions

(i) What is the opportunity cost for agroforestry among small scale farmers?

(ii) What factors determine the magnitude of opportunity cost for agroforestry?

1.4 Objectives of the Study

General objective

The overall purpose of this study is to analyze the opportunity cost of agroforestry among small scale farmers in Kenya.

Specific objectives

The specific objectives are:

(i) To estimate the opportunity cost of agroforestry practices in Kenya

(ii) To establish factors determining the opportunity cost of agroforestry practices in Kenya.

1.5 Justification

Agroforestry encompasses a building block towards sustainable development under its economic, social and environmental dimensions. Agroforestry can also contribute to the Kenyan Constitution, National Forest Policy and Kenya's Vision 2030 of attaining 10 per cent forest cover while also contributing to the concept of climate-smart agriculture. Specifically, in line with the Vision 2030, agroforestry seeks to combat desertification, manage forests and reverse land degradation. As such, it has significant contribution towards Sustainable Development Goals, Kenya's Vision 2030 while also contributing to the concept of climate-smart agriculture and meeting the 10 per cent forest cover targeted in National Forest Policy. Furthermore, agroforestry in is line with the 15^{th} Sustainable Development Goal which aims to promote the implementation of sustainable management of all types of forests. However, the low uptake of agroforestry implies a need for improvement of current polices to have better impact on agroforestry adoption. Estimating opportunity costs and its determinants serves as a basis for guiding policy makers in the design of incentive payments to compensate landowners for the additional costs associated with adoption.

2. Literature Review

This section reviews both the theoretical foundations and empirical literature of the study.

2.1 Theoretical Literature

Opportunity costs are based on the concept of scarcity. Maher et al. (2012) define opportunity costs as the benefits forgone by using a resource for one purpose instead of another. The definition of opportunity costs of agroforestry encompasses any benefits generated by alternative land uses which are foregone due to adoption of agroforestry. In this study, land is a scarce resource as a farmer has to choose between different land use alternatives when deciding on how best to improve their well-being or utility. The payback period of the alternatives are not immediate hence farmers need to consider the expected stream of income during the decision making process with the aim to maximize utility (profit). The expected income streams of alternative investments depend on the suitability of the farmer's environment to the production and marketing of agroforestry products, which include access variables, input levels, endowment of resources and both long and short term risks.

Traditional economic theory suggests that individuals make decisions by maximizing a utility function in which all of the relevant constraints and preferences are included and weighed appropriately. Opportunity costs can be analyzed based on the theory of random utility (RU). According to Holmes and Adamowicz (2003), RU is derived from the basic assumption that the true but unobservable utility of a good or service is composed of both deterministic and random components. RU theory is based on the hypothesis that every individual (farmer) is a rational decision maker, maximizing utility relative to his or her choices. However, in the face of incomplete information, an individual may be forced to act in ways that are less economically optimal.

Opportunity costs can also be analyzed based on the theory of rational choice. Rational choice is defined to mean the process of determining what options are available and then choosing the most preferred one according to some consistent criterion. In a certain sense, this rational choice model is already an optimization-based approach. In modeling individual choice behaviour, rational choice theory makes assumptions as stated by Bierlaire (1997), whereby it considers (1) the decision maker, the decision making entity and its characteristics; (2) the alternatives available to the decision maker; (3) identify the attributes of each potential alternative that the decision maker is taking into account to make the decisions; and (4) the decision rules-the process used by the decision maker to reach his/her choice.

This study applies rational choice theory, specifically by considering the effect of incentives related to compensation for investing in agroforestry instead of the alternative pure agricultural enterprise. In making the decision to allocate a portion of their agricultural land towards agroforestry, the study makes the assumption that farmers are unlikely to integrate trees on land that would give higher return in a different farm enterprise. Furthermore, the farmer considers the time period in making an inter-temporal choice by confining their land for perhaps a ten year period, versus achieving an agricultural return on an annual basis. The design of these incentives would require analyzing the opportunity costs.

2.2 Empirical Literature

A significant body of literature has evaluated opportunity costs using different approaches at both farm and regional level for different forestry and environmental issues. However, there are no related studies on opportunity cost of Agroforestry adoption in Kenya and therefore this study borrows from those conducted in mainly tropical countries such as Asia, Africa and other parts of the world. This section presents a synthesis of previous studies that have analyzed adoption of agroforestry systems, the different approaches used in measuring opportunity costs, variables applied by studies on factors affecting opportunity costs and methodologies used.

2.2.1 Adoption of agroforestry

Previous studies on agroforestry focus on whether or not a household adopts agroforestry and the observable farmer and farm characteristics that influence the decision whether a household should adopt agroforestry (Mercer, 2004; Bhubaneswor, 2008). In their review of 120 papers on smallholder adoption of agricultural and forestry technology, Pattanaya et al. (2003) found five significant categories of factors that affect adoption of agroforestry. These were preferences, resource endowments, market incentives, biophysical characteristics, and risk and uncertainty. Socio-economic factors are also strongly associated with agroforestry adoption; for example; gender was found to be a significant factor influencing agroforestry adoption. Specifically, Thangata (1996), Alavalapati (1995) and Nkamleu and Manyong (2005) report higher adoption rates by male famers in comparison to their female counterparts. This is mainly attributed to inability of women to secure land, and tree tenure derived from traditional inheritance structures. A Kenyan study by Sanchez and Jama (2002) found similar results. The Cameroon study by Nkamleu and Manyong (2005) further observed that adoption of agroforestry was positively influenced by family size and security of land tenure.

Both long-term (e.g. tenure security) and short-term (e.g. commodity price fluctuations) influence agroforestry adoption. In a New Zealand study, Bhubaneswor (2008) found that land tenure influenced the extent of investment in forestry by smallholders. Similar results are found in Nagubadi et al. (1996), Romm et al. (1987), Amacher et al. (2003) and Hodges and Cubbage (1990). Studies conducted by Mercer and Pattanayak (2003) and Smucker et al. (2000) demonstrate the inability of tenants to adopt agroforestry in comparison to landowners due to the long gestation period experienced between adoption and initial full benefits. However, these studies focus on the extent of land use for forestry and not opportunity cost of investment in forestry.

Economic incentives and farmer characteristics were strongly associated with increased demand for farm forestry in Lake Victoria, Western Kenya (Rohit, 2008). Rohit (2008) quantifies demand in form of number of trees on the farm while incentives were explored in terms of a hypothetical subsidy received per additional tree planted. Feder et al. (1985), Nkonya et al. (1997) and (Casey et al., 2000) observe a strong correlation between forestry adoption decision and availability of information, as proxied by number of trainings and extension visits.

In studies of the extent of land use for forestry, household income, landholding area and knowledge about cost sharing policies of government have been found to be significant factors (Amacher et al ., 2003; Hardie and Parks, 1996; Hodges and Cubbage, 1990). Buyinza and Wambede (2003) demonstrate higher probability of adoption by households with younger and more educated household heads. Thangata (1996) and Adesina et al. (2001) have consistent findings relating to agroforestry adoption with education and age, respectively.

Income, assets, labour and credit/savings are the main proxies used to measure resource endowments in studies analyzing agroforestry adoption. Studies by Ajayi et al. (2006), Keil et al. (2005) show limited land and labour as constraining factors to agroforestry adoption and expansion.

2.2.2 Opportunity cost of different land uses

Clinch (1999) assessed the magnitude of costs of forestry products and the benefits incurred using a cost benefit analysis. While the study stated the need to address the question on the probability of farm forestry as a more viable prospect for farmers than the alternative land use, the study failed to account for the opportunity cost involved in the conversion of land from an agricultural enterprise to an agroforestry system. The study by Behan and McQuinn (2005) found marginally higher returns from forestry in comparison to dairy enterprise. However, the study failed to consider the opportunity costs incurred by farmers in foregoing income from exiting farm enterprises when considering the decision to plant. Owuodon (2015) estimated the opportunity cost of conservation tillage adoption and factors explaining that opportunity cost in Togo. However, this study focused on improving agricultural output and not agroforestry per se.

2.3 Overview of Literature

Significant progress has been made especially in using binary choice regression models for *ex-post* analyses to examine how past adoption decisions are correlated with variables describing farmers, their farms, demographics and socio-economic conditions. These *ex-post* analyses have been useful for increasing our understanding of who adopts first, identifying communities and households to target as potential early adopters, and developing policies to promote agroforestry. However, the ex-post, binary choice regression studies have contributed little to the problem of designing agroforestry systems that appeal to potential adopters because they are not able to examine how farmer preferences vary for different combinations of characteristics of agroforestry alternatives.

A general observation is the studies collectively measure agroforestry returns and understand what farmers would get from agroforestry, rather than who adopts agroforestry. Although the studies mentioned above have explored the profitability of different Agroforestry systems, the opportunity cost of adopting instead of annual income generating crops needs to be explored. Specifically, they lack comparisons in long-term profitability derived from agroforestry adoption and alternative agricultural enterprises.

3. Methodology

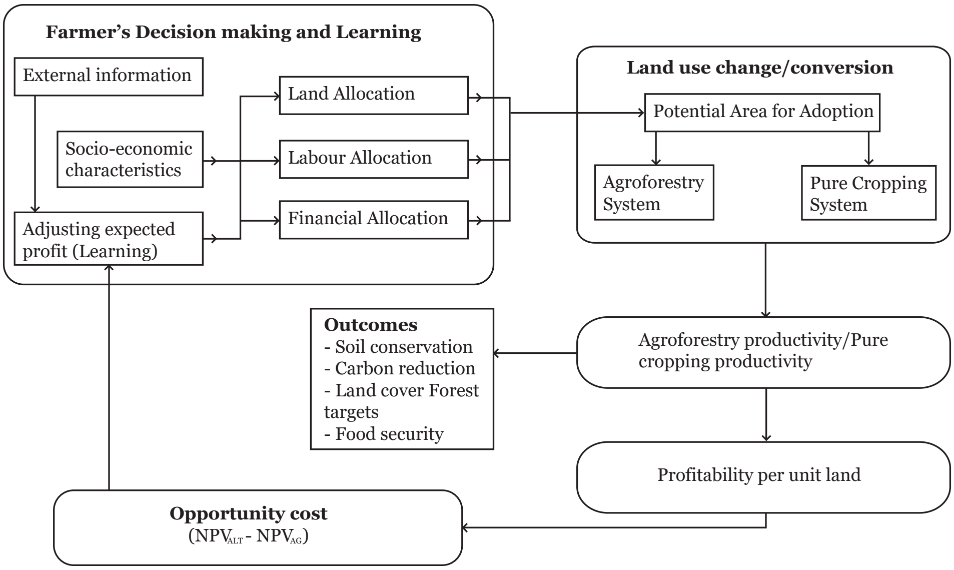
3.1 Conceptual framework

The starting point for the conceptual framework of this study is the consideration that every smallholder farmer is expected to make a decision on land use options (Figure 3.1). The conceptual framework of the study borrows from the FALLOW model that is used to analyze drivers and outcomes of land use change. The role of farmers and feedback from stakeholders on land use changes are considered in the conceptual framework. The starting point is the consideration that every smallholder farmer is expected to make a decision based on the expected change in level of well-being (Figure 3.1). However, the decision on allocating available land to different uses is a behavioural response arising from a set of opportunities and constraints facing the decision maker (Leagans, 1979). Labour, financial capital and land contribute towards the decision a farmer makes in converting a portion of their land towards agroforestry. Borrowing from the FALLOW model, the conceptual framework incorporates an optimization approach making the assumption that farmers make a choice to integrate trees with crops or have a pure cropping system, with the expectation of receiving the highest relative net land return.

The economic expectation emanates from the farmer having had initial knowledge, thus able to make land use change decisions based on experience or new information from external source (e.g. extension). Land use towards agroforestry or the alternative land use only proceeds when the incentives outweigh the disincentives. Economically, incentives are the returns while the disincentives are the costs. The net benefits from both agroforestry and the alternative are compared and used to model opportunity costs in terms of gross margin forgone.

Yield acquired from land use choices involving economic production is considered to contribute to the household's economic resources and food sufficiency. Other outcomes from the landscape dynamics will include environmental dynamics such as changes in carbon stock and biodiversity.

Figure 3.1: A conceptual model of the opportunity costs of agroforestry adoption to smallholder farmers



Source: Adapted from Suyamto (2009)

3.2 Data Sources

The study uses data from the World Agroforestry Centre Data verse, comprising 60 smallholder agroforestry farmers residing near Kakamega Forest in Western Kenya, collected between 2002 and 2012. These farmers were part of a survey on "Assessing the market potential of agroforestry" where smallholder farmers were assisted by non-governmental and research organizations to start tree seedling nurseries with a view to fostering adoption of agroforestry in the region. The Kakamega Forest is one of the few remaining tropical rainforest fragments in Eastern Africa. This region has been considered by the Kenya Woodfuel and Agroforestry Programme (KWAP) as one of the areas that could benefit most from policies that target improvement of forestry projects due to its high population and high agricultural potential. Timber, wood and medicine account for 42, 41 and 4 per cent of forest products, respectively. Farmers in the area prefer to use their land for conventional crops such as maize and beans and use the nearby forest as a source of firewood and charcoal (Shackleton and Shackleton, 2004). The average land size holding is 0.57 hectares and only 38.6 per cent of the population has complete land ownership rights.

3.3 Model Specification

3.3.1 Analytical framework

A farmer i is faced with the decision on whether or not to adopt agroforestry. The farmer compares the net foregone profits, i.e. opportunity costs (OC_i) profitability with and without agroforestry adoption. The farmer will as such invest in agroforestry if the farmer expects to be better off (low opportunity costs) by implementing an agroforestry system. Agricultural land uses provide annual cash flows, and the main measure of profitability is gross margin from income. Agroforestry by contrast is a long-term investment and profitability is generally measured using net present value.

Agroforestry in the study area is mainly dominated by perennial trees which involve long term investment. As such, profitability per hectare will be measured in the net present value (*NPV*) of revenue minus costs (labour, tools, fertilizer, etc) as defined below by Gittinger (1982):

$$NPV = \sum_{t=0}^{t=n} \frac{B_t - C_t}{(1+i)^t} \qquad 3.1$$

Where B_t is benefit at year t, C_t cost at year t, t is time denoting year and i is discount rate. A 5 per cent discount rate was used in this study, primarily as it is the rate most commonly recommended for examining the relative value of different long-term agricultural land use options (e.g. Toivonen and Tahvanainen, 1998; Clinch, 1999; Styles et al., 2008).

Choice and adoption of land use, be it for agroforestry or an alternative enterprise involves trade-offs and opportunity costs. While choosing certain land use options to meet certain objective(s), a farmer loses other important traits from the set of varieties not selected. The opportunity costs of agroforestry accrue mainly in the form of forgone profits from agricultural activities, which represent the only locally profitable alternative to adopting agroforestry until today and in the near future. In the study, financial opportunity costs is defined as shown below, while correcting for potential econometric problems like self-selection:

$$OPPORTUNITY\ COST = (NPV_{ALT} - NPV_{AG}) \qquad 3.2$$

where NPV_{AG} and NPV_{ALT} refer to net present value per hectare (i.e. gross margin per hectare) of the agroforestry and alternative systems, respectively.

3.3.2 Model specification for analyzing factors affecting opportunity costs

The theoretical model in this study is built on the assumption that opportunity costs are influenced by several factors such as experience, education level, distance to customers, etc. To test this theoretical model statistically, an econometric model proposed was the Ordinary Least Squares (OLS). However, in the current study, the outcome variable was zero or negative for a substantial part of the sample. In different applications where the dependent variable is zero or negative for a substantial part of the population, the alternative to OLS is the Tobit model (Clevo et al., 2002). The use of OLS in the case of censored data makes the estimates biased and inefficient, thus violating the basic tenets of Best Linear Unbiased Estimator. This is based on comparison of the number of zeros and negative values in relation to the number of observations. Statistical analyses by Clevo et al., (2002) show that when zeros were more than 25 per cent of the total number of observations, then Tobit estimates were more consistent and unbiased. The number of zeros and negatives for the current study were more than 25 per cent. Therefore, Tobit regression was used to analyze factors affecting opportunity cost. Opportunity cost is dependent on the suitability of the farmer's environment; that is, the production and marketing of products resulting from the agroforestry and alternative agricultural systems. Theory suggests that factors determining the suitability of agroforestry to farmers include access variables (input and output markets, extension, credit, irrigation); resource endowment (land, education, labour); and natural factors (soil quality, rainfall, drought, disease, pests, etc). The more favourable these conditions are to the production and marketing of the agroforestry products, the lower the size of the opportunity cost will be. Inputs and local conditions affecting both agroforestry and alternative land use systems equally do not affect opportunity costs. The Tobit model for this paper was defined as the following:

$$OPP\_NPV = \beta 0 + \beta 1 TYPE\_TREES + \beta 2 landcul + \beta 3 lnage + \beta 4 age\_sq + \beta 5 TITLE + \beta 6 LN\_LAND + \beta 7 TREES + \beta 8 gender + \beta 9 EDUC\_R + \beta 10 LNEXP + \beta 11 buyermarket + \beta 12 MARKETTPE\_R + \beta 13 EXTENSION\_R + \varepsilon$$

Opportunity cost was represented as a net value of opportunity cost calculated from the data. The table below shows a description of the variables used in the Tobit regression and expected signs based on theoretical explanations.

Table 3.1: Description of variables used in regression

Variable	Description	Expected sign
TREES	Total number of trees on farm	-
AGE	Age of household head/producer in years	-
AGE_SQ	Age squared	+/-
TITLE	Has title deed =1, 0 Otherwise	-
LANDCUL	Size of land cultivated in acres	+
LN_PRICE	Log transformed price of tree products	-
EXPE_AGRO	Experience in agroforestry	-
CREDIT	Participation in credit	+/-
GENDER	Gender of the producer/manager, male=1, 0 otherwise	+/-
EDUC_R	Education level in years	-
LNEXP	Log transformed experience in years of agroforestry	-
BUYER	Has market for products, yes=1, 0 otherwise	-
MARKETTPE	Market type for agroforestry, commercial =1, 0 otherwise	-
EXTENSION	Receives extension =1, 0 otherwise	-
TEN_PERCNT	Farmer has allocation of 10 percent and above	+/-

4. Results and Discussion

4.1 Descriptive Statistics

Descriptive statistics for variables used in the regression analysis are presented in Table 4.1. There were a total of 60 agroforestry farmers in the study sample. The farmers had cultivated a mean land size holding of 3.04 hectares, ranging from 0.2 acres to 20 acres. Of the land cultivated, only 27 per cent of the farmers allocated at least 10 per cent of land towards growing trees, indicating still few farmers allocated their land to the national requirement of 10 per cent as stipulated in the Constitution and Kenya forest Policy 2014. On average, about 53 per cent of the farmers owned title deeds for their land parcels, 45 per cent received extension services, and a good number (75%) had market for their products. The mean age of farmers was 49 years and they had experience in agroforestry for an average of 16 years, 88 per cent of the respondents were male, 53 per cent had land owned title deeds for their land parcels and 45 per cent had access to extension services.

Table 4.1.: Summary of descriptive statistics

Variable	Description	Min.	Max.	Mean
TREES	Total number of trees on farm	0.00	7000.00	493.19
AGE	Age of household head/producer in years	22.00	69.00	49.19
AGE_SQ	Age squared	484.00	4761.00	2560.92
TITLE	Has title deed	0.00	1.00	0.53
TEN_PERCNT	Farmers with allocation of 10% and above	0.00	1.00	0.27
LANDCUL	Size of land cultivated in acres	0.20	20.00	3.04
EXPE_AGRO	Experience in agroforestry	0.50	45.00	16.40
MARKETTPE	Market type for agroforestry	0.00	1.00	0.56
EXTENSION	Receives extension	0.00	1.00	0.45
BUYER	Has market for products	0.00	1.00	0.72
CREDIT	Participation in credit	0.00	1.00	0.42
LN_PRICE	Log transformed price of tree products	1.25	6.97	4.69

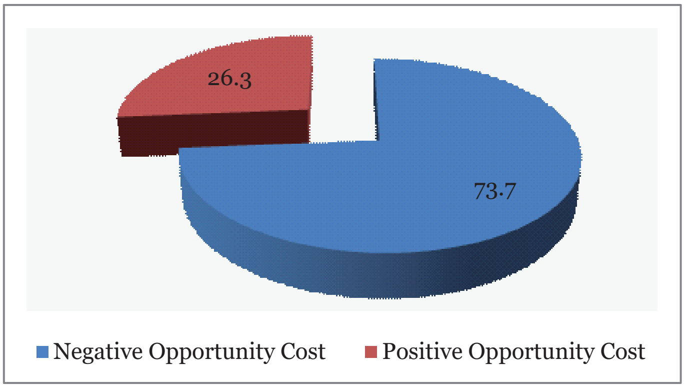
Source: Author's computation from data

The farmers grew an average of three types of trees on their farms, having a maximum of 5 tree species and zero trees as the minimum. The main trees grown by the farmers were fruit trees (pawpaw and mango), and timber trees (Grevillea robusta, Eucalyptus and Casuarina).

4.2 Opportunity Cost

Gross margins for the alternative land use and agroforestry were calculated for a period of ten years and discounted at 5 per cent to get the net present value. As shown in Table 4.2, then mean gross margin value of using land for agroforestry had a higher net present value than the alternative. 73.7% of the agroforestry farmers had a negative opportunity cost while the rest had positive opportunity cost.

Figure 4.1: Opportunity costs



The average opportunity cost was Ksh -5,052.88 per hectare. Paired t-tests were also conducted to determine whether the means were the same between the two land use options. Comparison of the net present gross margins of these farmers showed that, on average, farmers were better off investing in agroforestry than on alternative land use systems that generated annual revenue.

Table 4.2.1: Comparison of net present value between agroforestry and the alternative

	Alternative land use Net Present Value (NPV_{ALT})	**Agroforestry Net Present Value (NPV_{AG})**	**Opportunity cost Diff = NPV_{ALT} - NPV_{AG}**
Mean	-4118.83 (8747.38)	934.05 (4985.53)	-5052.88*** (1299.82)

*Note: ***, **and * implies significant at 1%, 5% and * 10% respectively*

Figures in parenthesis represent standard deviation

Source: Author's computation from data

This difference, -5,052.88, was significant at 1 per cent implying lower opportunity costs of investing in agroforestry, less benefits foregone.

4.3 Econometric Analysis of Factors Affecting Opportunity Cost of Agroforestry

Before running the econometric model, diagnostic tests for multicollinearity and heteroskedasticity were run. Tests for multicollinearity were done using correlation matrix and the variance inflation factor (VIF) technique. VIF was used to quantify the severity of multicollinearity in order to measure how much of the variance of the estimated regression coefficient increased due to collinearity. A common rule of thumb (Gujarati, 2007) is that if VIF (β_i) is greater than 10 then multicollinearity is high. As shown in Appendix 2D, the choice of variables included in the final model was also based on the VIF which were not showing high multicollinearity. Some variables hypothesized to be in the model were dropped due to multicollinearity. For example the log transformed variable of age was eliminated due to high collinearity with age squared variable. The Breusch-Pagan test designed to detect any linear form of heteroskedasticity, which is inbuilt in STATA was used. Heteroskedasticity was noted and data was corrected using robust standard errors (Gujarati, 2007).

In applying Tobit regression, censoring at the minimum was used. The log transformed variable of opportunity cost was censored at minimum since it allowed for an unknown and non-zero threshold to produce better out-of-sample forecasting performance than the standard Tobit model, which overestimates the effect of the proxy variables.

The model was appropriately specified with an overall and significant ($P \leq 0.01$) chi-square of 34.47, which indicated that the variables included in the model best specified the functional relationship between the independent variables and log transformed opportunity cost. Five of the 12 variables were significant in the model as shown in Table 4.3.1.

In line with *apriori* expectations, having a title deed had negative and significant ($P \leq 0.10$) relationship with opportunity cost (Table 4.3.1). This result implied that having a title deed (owning a land parcel) had 1.168 times of reducing the opportunity cost of agroforestry, while holding all other factors constant. Having a title deed significantly reduced the difference of the economic viability between an alternative agricultural land use and integrating trees on farms. This results are in line with Bhubaneswor (2008) and Thangata Hildebrand, and Gladwin (2002) who found that farmers with land tenure were more likely to plant trees on their land, hence able and willing to invest in agroforestry, which though it had a longer payback period, the landowners were able to avoid extra costs from renting land, thereby having lower opportunity costs in the long run.

Table 4.3.1: Summary of regression results

Variable	Coefficient	t statistic
TREES	-0.00013	(-0.22)
AGE	0.311**	-2.66
AGE_SQ	-0.00357**	(-2.89)
TITLE	-1.168*	(-2.17)
TEN_PERCNT	-0.837**	(-1.40)
LANDCUL	-0.0688	(-0.48)
EXPE_AGRO	0.0129	-0.62
MARKETTPE	-1.526**	(-2.85)
EXTENSION	-0.716	(-1.37)
BUYER	-0.899*	(-1.24)
LN_PRICE	0.223	-1.19
_cons	0.869	-0.28

*Note: ***, **and * implies significant at 1%, 5% and * 10%, respectively*

Source: Author's computation from data

The variable age had a positive and significant (P≤0.05) relationship with the log transformed variable of opportunity costs. This implies that opportunity cost increased by 0.311 times as farmers/landowners get older by an additional year. Older farmers were less prone to risk than younger farmers. Allocating land towards agroforestry would be costly in terms of time due to the long pay-back period associated with the practice. On the contrary age-squared had a negative and significant (P≤0.05) relationship with the log transformed variable on opportunity cost. This implied that while opportunity costs increased the older a farmer was, it reaches a point when opportunity costs increases at a decreasing rate. It is expected here that the relationship between opportunity cost and age is inverted (it is ∩ shaped). At some point, opportunity costs reach an optimal point then begin to decrease. According to Jensen et al (2015), profits received from an Agroforestry system begin to reduce when the marginal productivity of the trees reduce, thereby giving less profits.

Having the minimum required allocation of land of 10 per cent and above towards trees on a parcel of land had a negative and significant relationship (P≤0.05) with opportunity costs. The result imply that a one per cent increase in the number of trees reduced opportunity costs 0.837 times, *ceteris peribus*. These results could be explained by the ratio of different species grown on farm as not all trees are profitable. Most farmers had a high pole to fruit tree ratio. Trees grown for poles had higher profitability in a shorter time period than trees grown for fruits. These results are in line with the focus groups reported by Peralta et al. (2009).

The variable buyer had a negative and significant ($P \leq 0.10$) relationship with the log transformed variable of opportunity cost. This implies that as long as a farmer had any buyer/market for their trees, opportunity costs were expected to decrease by 0.899 times, *ceteris peribus*. However, of more significance was the variable on the type of market for agroforestry products which as expected had a negative and significant ($P \leq 0.05$) relationship with opportunity costs. Unlike farmers who used agroforestry products to serve as substitutes in the event of crop failure, farmers with a commercial market for their products, on average, had reduced opportunity costs by 1.1526 times, holding all other factors constant. These results are in line with Hoskins (1990) who found that commercial farmers had high investment in productive agroforestry and were under contract, and were therefore more prone to a stable income than farmers who sold their products randomly or for the purpose of supplementing subsistence.

5. Conclusion and Policy Recommendations

5.1 Conclusion

This paper investigated the magnitude opportunity cost of agroforestry adoption in Western Kenya and further sought to establish the factors determining those opportunity costs. This study was crucial based on the low uptake of agroforestry which implies a need for improvement of current polices to have better impact on agroforestry adoption. Computing opportunity costs and its determinants serves a basis in the design of incentive payments to compensate landowners for the additional costs associated with adoption. The study used data collected from 60 agroforestry farmers in Western Kenya. All the farmers practiced both agroforestry and farming of conventional crops, specifically maize and beans in their farms. Each farmer allocated a portion of their land towards agroforestry by incorporating species of either fruit trees (mango), timber/pole trees or both on a portion of their farms while at the same restricted a portion of their farming land to agricultural crops. On average, the results show a negative opportunity costs per hectare of Ksh -5,022. A majority (73.7%) of the agroforestry farmer had negative opportunity costs. Overall empirical results showed that most of the farmers with complete ownership rights to their land and having a certain market for their agroforestry tree products significantly reduced opportunity costs. Older farmers also had lower opportunity costs than younger farmers but only until a certain point when opportunity costs reach an optimal point then begin to increase. This implied that (2015), profits received from an agroforestry system begin to reduce when the marginal productivity of the trees reduce, thereby giving les profits especially in the event that the landowner is not applying a rotation system.

5.2 Policy Recommendations

The study appreciates that Kenya has different agro-ecological zones and, as such, the recommendations made here apply to agro-ecological areas surrounded with tropical forests. There is need to promote farmer trade-relations (contractual arrangements) to ensure assured and continued profitability of agroforestry products. Farmers need to be encouraged to enter formal written and binding contracts to ensure they have assured markets for their products. Furthermore, there is need for direct and improved efforts towards promotion of marketable and profitable agroforestry products to ensure farmers are encouraged to adopt agroforestry. This will involve training smallholder farmers on how to promote their products through online platforms from which they can distribute information on their products, make sales transactions, or both. There is also need for better land titling programmes to encourage uptake and maintenance of agroforestry.

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Appendix

Appendix A: Correlation matrix

	TYPE_T~S	TREES	lnage	age_sq	TITLE	gender	landcul	EXPE_A~O	MARKET~R	EXTENS~R	buyerm~t	PERCEN~O
TYPE_TREES	1.0000											
TREES	0.2019	1.0000										
lnage	0.2558	0.0420	1.0000									
age_sq	0.2266	-0.0061	0.9592	1.0000								
TITLE	0.3258	-0.1311	0.4313	0.4104	1.0000							
gender	0.1767	-0.0078	-0.0874	-0.0262	-0.0891	1.0000						
landcul	-0.5493	-0.0351	0.0202	0.0359	-0.3458	-0.0003	1.0000					
EXPE_AGRO	0.0055	-0.0698	0.2341	0.2336	0.3900	0.1100	0.4274	1.0000				
MARKETTPE_R	0.0787	-0.0688	0.0319	0.0720	0.1737	0.0619	0.0045	0.1806	1.0000			
EXTENSION_R	-0.1833	-0.0856	0.0205	-0.0040	0.1571	-0.2075	0.0804	0.0733	-0.1413	1.0000		
buyermarket	0.0353	0.1116	0.0632	0.0492	-0.3118	-0.1111	0.0765	-0.0637	0.0619	-0.4381	1.0000	
PERCENT_AGRO	0.0180	-0.1894	-0.2318	-0.2455	-0.3081	0.0029	-0.2694	-0.4282	-0.0279	-0.2057	0.1912	1.0000

Appendix B: Variance inflation factors

	Collinearity Statistics	
	Tolerance	**VIF**
(Constant)		
Number of tree types	0.429	2.331
Total number of trees on farm	0.477	2.098
Age squared	0.644	1.552
Has title deed	0.337	2.971
Gender of the producer/manager	0.601	1.664
Size of land cultivated in acres	0.248	4.033
Experience in agroforestry	0.347	2.884
Market type for agroforestry	0.866	1.155
Receives extension	0.609	1.641
Has market for products	0.592	1.688
Percentage of land under agroforestry	0.616	1.623

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