FACTORS INFLUENCING ADOPTION OF GIANT BAMBOO *(DENDROCALAMUS ASPER* {Schult} Backer) FOR AGROFORESTRY IN SELECTED SUBCOUNTIES OF NYANDARUA COUNTY, KENYA

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REG.NO: I503/KIT/20689/2016

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science Degree in Climate Change and Agroforestry in the School of Environment, Water and Natural Resource, South Eastern Kenya University

JULY, 2021

DECLARATION

I understand that plagiarism is an offence and therefore declare that this thesis is my original work and has not been presented in any institution for any other award.

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DEDICATION

This Thesis is dedicated to my two daughters Ivana Mueni and Lynn Mwende, not forgetting my loving husband Stephen Kitua.

ACKNOWLEDGEMENTS

This thesis would not have been successful without the contribution from many people whom I would like to acknowledge. To all who contributed to this thesis, whether mentioned by name herein or not, I say thank you so much and may God bless you.

Firstly, I wish to thank South Eastern Kenya University for giving me an opportunity to study in their institution. I appreciate the contribution of my supervisors Prof. Jacinta Kimiti and Dr. Joshua Matata whose continued support, guidance and constructive criticism led to the completion of this thesis. Similarly, I thank my lecturers who built confidence in me and shared their wealth of knowledge. Furthermore, I thank the Directors of Green Pot Enterprises for allowing me to study while at their Company. I also appreciate the support and cooperation granted by my family, their financial support, prayers, advice and moral support came in handy. Lastly and not the least, I cannot forget to crown it all to the Almighty God for life, divine provision, peace and enough grace during this period.

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ABSTRACT

Giant bamboo (*Dendrocalamus asper*) is a very fast growing plant in the family of Poaceae (Gramineae) with great potential in environmental conservation and poverty alleviation. It has over 1500 documented uses. However, with the reducing sizes and productivity of land in Kenya especially in high potential areas where bamboo is grown, there is a need to identify options of cultivating bamboo as an agroforestry crop. Therefore, the main objective of the study was to establish factors influencing uptake of bamboo for agroforestry in the selected Sub Counties. Specific objectives were; to investigate the agroforestry systems in the selected Sub Counties of Nyandarua County, to establish the factors influencing the adoption of bamboo for agroforestry in selected Sub Counties and to examine the challenges faced by farmers cultivating bamboo in the selected Sub Counties. Closed and open ended questionnaires were administered to 132 bamboo farmers. Likert Chi- square tests were run to establish the relationship between the rate of bamboo adoption and problems encountered, the agroforestry system practiced and the social economic factors. Further, Pearson's chi square tests were run to establish the significance and level of association levels of the study. From the results home gardening was the main type of agroforestry system practiced (X^2=14.173; P=007; Cramer v=0.0457). It was revealed that, monthly household income (X^2 = 29.87 and X^2 =20.053, P = 0.014 and 0.021), size of land X^2=1.433, and X^2=4.633, P value = 0.031 and 0.009) influenced the rate of adoption of bamboo for Olkalou and Oljororok Sub Counties respectively. The study recommended more research on crops suitable for intercropping with bamboo as an agroforestry crop.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Giant bamboo, *Dendrocalamus asper* {(Schult) Backer} is a fast growing non- woody forest produce that is common in forest ecosystems of the world (Kigomo, 2007a). Bamboo species grows naturally on the mountains and highland ranges of eastern African countries and in the medium lowlands of other countries of Africa. There are more than 87 genera and 1500 bamboo species in the world playing vital role in the industrial and domestic economies of China, Japan, Thailand, Combodia, India, and Vietnam (Banerjee et al., 2009). Only one species is native to Kenya, the species *Yushania alpine* which covers about 150,000 ha growing in pure or mixed stands in montane forest of Kenya (Kigomo, 2007b). Pure bamboo comprises about 30% of the vegetation types of the Aberdares forest in Kenya (Kenya Forest Service, 2010).

Giant bamboo plays a critical role in the protection of the soil and water resources in forested catchment areas in Kenya (Kigomo, 2007b). Kenya has less than 20% high potential land against growing human population (Kinyanjui, 2009). Increased population, economic development and increased energy needs have resulted to reduction of other forest resources leading to bamboo being explored for commercial value addition (Muchiri and Muga, 2013). Giant bamboo has been and continues to be a material of choice for construction and traditional uses throughout Africa. These uses of bamboo make a major contribution to rural income and employment, although the unsystematic clearing of natural forests and the lack of priority in its development join forces to erode bamboo status.

Due to rapid growth in human population, gregarious flowering, irregular farming and widespread forest fires, the bamboo population has decreased on farm and in the wild. This has led to decrease in bamboo cover since most of the land that used to grow bamboo is instead utilized for human settlement and is overexploited especially in the more easily reached forest areas. The Kenyan and Ethiopian government in the Eastern African region recognized the deteriorating bamboo and formulated policies to encourage sustainable management of bamboo as renewable resources (Katumbi *et al.*, 2017).

Amongst the major forest goods, bamboo has continued to gain credit. Long time, bamboo was regarded as a weed but today it is considered as a multiple use plant and as a valuable timber substitute (Banerjee *et al*., 2009). Bamboo is used in ornamental flower farming, wood curving, fencing and cottage industries. In Kenya bamboo is gaining a lot of interest in the energy sector, textile and construction sector (Kigomo. 2007a). Raw bamboo materials are nevertheless limited due to the moratorium on bamboo harvesting from government owned forests in Kenya and even when allowed it is allowed to licensed individuals. In Kenya the cover of bamboo resources is presently low due to the excision of the indigenous forests where bamboo was dominant. Consequently, production of bamboo raw materials from farms to ensure expanded supply is necessary (Kigomo, 2007b).

Majority of bamboo products in Kenya comprise of one indigenous species *Yushania alpine* (KEFRI, 2008). According to World Bamboo Organization (2012) during the last 30 years, some research on species selection and investigations on their growth was done mainly by the Kenya Forestry Research Institute (KEFRI) in collaboration with several Asian research institutions. This research project introduced over 20 species of bamboo in Kenya which grow under different ecological zones and half of these species survived. Among these species include; *Bambusa vulgaris, Dendrocalamus giganteus*, *Dendrocalamus asper, Dendrocalamus membranaceus, Bambusa vulgaris Vitatta, Bambusa bambos* among others.

Dendrocalamus asper and *Dendrocalumus giganteus* grows naturally in tropical Asia at low altitudes and up to 1500 m above sea level. They thrive at 400-500m above sea level in areas with average annual rainfall of about 2400mm. They also grow in any type of soil but prefer heavy soils with good drainage. They do well on sandy and acidic soils. The most preferred method of propagation is rhizome offsetting which is highly effective but highly labor intensive. It can also be propagated through culm cutting. (World Bamboo Organization, 2012)

The economic analysis of bamboo based agroforestry was studied in Asia and India (Dhyani *et al*., 2015, Banerjee *et al*., 2009, Nath & Krishnamurty 2008,). Intercrops of bamboo, rice, pigeon peas, ground nuts, turmeric and cowpeas were carried out in Asia. According to the findings, it was found that growth attributes of bamboo plants irrespective of species were significantly higher when grown with intercrops than sole plantation (Banerjee *et al*., 2009). Returns on both crops and bamboo were higher compared to mono-cropping. Leguminous crops showed a better compatibility with bamboo (Banerjee *et al.,* 2009, Nath *et al.,* 2008).

Bamboo growing has been studied in Kenya, (Katumbi *et al.*, 2017, Karanja *et al.,* 2015, Kibwage *et al.*, 2008b). Studies of *Bambusa vulgaris* and *Dendrocalamus giganteus* in Nyanza province have shown that bamboo can be grown by farmers and produce better returns compared to tobacco growing (Kibwage *et al.*, 2008a). Bamboo shoots from *Bambusa Vulgaris, Yushania alpine*, *Dendrocalamus asper* and *Dendrocalamus giganteus* have also been studied in Kenya for their potential food source. Results showed that *Dendrocalamus asper* bamboo grow well in Kenya and are wealthy in critical major-nutrients comparable to edible varieties grown in countries such as China and India (Karanja *et al.,* 2015). Studies of biomass resource of *Yushania alpine* and its ability for sustainable utilization in aberdare forest in Kenya showed that the available bamboo in this area can be an important source of energy and would achieve an even flow of biomass attainable over five years of sustainable management program (Katumbi *et al.,* 2017).

Studies of intercropping bamboo with food crops have not been done in Kenya. However, from studies elsewhere, it is clear that there are agricultural crops that enhance bamboo growth (Banerjee *et al.,* 2009, Nath *et al.,* 200). In Kenya such studies have not been done. There is therefore a need to identify suitable crop for intercropping with bamboo for its maximum growth.

1.2 Problem statement

In Kenya, giant bamboo farming has recently drawn a lot of attention while limited study or innovation has been done about it (Karanja *et al,* 2015). Most of the land in Kenya is decreasing due to increasing populations, the need for agriculture and settlement. According to Kibwage *et al.,* (2008a), one of the options of increasing bamboo resources is through its domestication on farms.

Despite, bamboo being a fast growing agroforestry crop, good in energy production, a fodder crop and a source of food in Kenya has not been fully adopted for agroforestry (Karanja *et al,* 2015). Bamboo for agroforestry being a new technology in Kenya, the factors affecting its adoption by farmers are not yet known. There is therefore the need to establish the factors influencing adoption of bamboo for agroforestry and the challenges encountered by farmers who are planting bamboo in the selected areas in Nyandarua County.

1.3 Objectives

1.3.1 General objective

The main objective of this study was to establish factors influencing adoption of bamboo for agroforestry in selected sub-counties of Nyandarua County- Kenya.

1.3.2 Specific objectives

Specific objectives of the study were:

i. To investigate the types of agroforestry systems practiced in the selected Sub Counties.
ii. To establish the factors influencing the adoption of bamboo for agroforestry in the selected Sub Counties
iii. To examine the challenges faced by farmers cultivating bamboo in the selected Sub Counties.

1.4 Research questions

The study was guided by the following research questions

i. Which agroforestry systems exist in the selected Sub Counties?
ii. Which factors influence the adoption of bamboo farming in the selected Sub Counties?
iii. What challenges do farmers cultivating bamboo face in the selected Sub Counties?

1.5 Justification of the study.

Since bamboo enterprise is one of the emerging businesses gaining interest in Kenya, there is need to have information on its growth in agroforestry set up. The land in Kenya has reduced due to pressure from settlement and agriculture. It is advisable for farmers to be involved in agroforestry practices for maximum utilization of available land. Bamboo agroforestry has not fully been adopted in Kenya compared to countries such as Asia, China and India. Bamboo market and usage is easy since it can be used either raw or processed. In Kenya, farmers intercrop agroforestry trees with food crops to ensure maximum usage of the land. However, bamboo being a fast growing crop and if fully incorporated in Kenyan agroforestry, can minimize shortages of fuel, fodder and timber related products. It is therefore necessary to establish the factors influencing adoption of bamboo for agroforestry in Nyandarua County.

1.6 Significance of the study

Mixed cropping is the characteristic feature of land use in agroforestry systems in Kenya. It integrates agricultural crops with trees of different species and or with animals. In Nyandarua, bamboo is found on either boundaries or intercropped with agricultural crops such as potatoes, kales, beans, peas, oats and maize among others. Generally, not much inputs or expenditure is required for growing bamboo, whereas seasonal, annual and perennial crops require high labor and inputs. Over 80% of Kenyans depend on forests for provision of domestic energy needs in terms of either charcoal or fuel wood (Githiomi and

Oduor, 2012). Most of the timber and energy requirements in Kenya can be met if bamboo is planted and managed to maturity and harvested for value addition.

The study herein sought to identify the factors influencing uptake of bamboo for agroforestry in Nyandarua County. The findings were beneficial to companies that are interested in bamboo farming. The information could be useful for advising farmers on the best crops to intercrop with bamboo for its better growth. Additionally if the information would be well disseminated, farmers would understand how to fully utilize the small pieces of land while maximizing its production potential. Information on bamboo agroforestry was significant to the Ministries of Agriculture and Environment in terms of forest cover and conservation.

1.7 Scope of the study

The study mainly considered farmers within Olkalou and Oljororok sub counties in Nyandarua County. The research sought to determine the factors influencing adoption of bamboo for agroforestry. Additionally, it examined the problems faced by bamboo farmers in the selected sub counties.

1.8 Limitations of the Study

Cold weather and afternoon heavy rains were the major limitations to the study especially during data collection.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

For this study, information was obtained from secondary data sources such as books, journals, articles, government publications, Kenya Forestry Research Institute and International Bamboo and Rattan (INBAR) publications and the internet. The literature was based on following main themes; General description of bamboo, Distribution of bamboo, Bamboo and agroforestry, factors that influence community uptake of a project, challenges and opportunities of bamboo in agroforestry, Policy and Legislation on bamboo.

2.2 Botanical Description of Bamboo

Bamboo comprises of more than1500 species and 90 genera distributed throughout the world. Bamboos are perennial woody Grasses of plant species belonging to the family Poaceae (Gramineae) and subfamily Bambusoideae (Zehul, 2007). The plant is made of underground axis which comprises rhizomes, roots, buds and above ground axis that comprise of stem, branches and foliage (KEFRI, 2007). The foliage starts to grow when young branches stop developing and is composed of leaf blade and leaf sheath (Zehul, 2007). Bamboo culm is the most utilized part.

Most bamboo plants flower only once in their lifetime and soon dies after (Banerjee, 2009). The flowering behaviors of bamboo are categorized into two; gregarious and sporadic. In Gregarious flowering, bamboo will flower and soon after the whole plantation dies while in sporadic, bamboo flower irregularly and the individual bamboo dies soon after flowering (Zehul, 2007). Bamboo can generate from the fallen seeds if the site is not disturbed by factors such as animals and fire (Lavison, 2013) in Ethiopia noted that after harvesting culms immediately after flowering, new shoot grew from rhizomes left.

Bamboo rhizome is a modified stem with short internodes that grow horizontally below the ground and commonly stores food material and produces root scale leaves and suckers irregularly along its length (Kigomo 2007a). There are two main bamboo rhizome systems; the lemptomorph and pachmorph. The lemptomorph also known as monopodium grows to single stemmed slumps while the latter grow with a branching characteristic (KEFRI, 2007). A bamboo culm takes 3 to 4 years to fully mature. However, when a mature culm grows older, they start deteriorating and eventually die and rot.

Conversely, bamboo is one of the fastest growing plants species with growth ranging from 30-100cm per day in one growing season. Bamboo attains a maximum height of more than 36m with a diameter of 1-30cm (Nath *et al.,* 2009). The new shoots are produced every rain season and attain full eight and diameter in three months (KEFRI, 2007). Mature culm grows older; deteriorates and eventually dies and rots if not harvested. Nonetheless, the life of a bamboo plant is sustained by the new shoots and culms (Zehun, 2007).

Organizations such as The International Network for Bamboo and Rattan (INBAR) are committed to improving the social, cost-effective and ecological benefits of bamboo and rattan, which has resulted to comprehensive research of bamboos resulting to advanced bamboo production techniques in Asia (Lobovikov *et al.*, 2005). INBAR has been facilitating and coordinating researches on biodiversity and genetic conservation, production systems, processing, utilization and socio-economic and policy. In Asia a number of rural development programs in relation to bamboo are being implemented. INBAR has been active in promoting knowledge transfer and information exchange between networks partners (World Bamboo Organisation, 2012). INBAR globally coordinates network of stakeholders from the government, private and non-profit making organisations in more than 50 countries to describe and realize a global agenda for sustainable development through bamboo and rattan. Through her research, it is evident that replication in Latin America and Africa of success stories of the giant bamboo farming. According to Lobovikov *et al.,* (2005) and Kigomo, (2007a) it is evident that the lack of information about bamboo has been main limiting factor to the development of systematic and sustainable development programs.

Therefore, there is need for further research to determine the cause and solution for making bamboo economically and ecologically viable (Kigomo, 2007b).

2.3 Bamboo Distribution, Resource Base and Ecology

Bamboo vegetation covers an estimated area of 36 million hectares naturally distributed in the tropical and subtropical belt between latitude 46 degrees north and 47degrees south. Bamboo is commonly found in Africa, Asia, and South America. Some species however grow successfully in temperate zones in Europe and North America. Bamboo is a diverse plant that easily adapts to different climatic zones and soil conditions (Muchiri & Muga, 2013). Due to its divergent uses, the ecological and economic values, bamboo was planted at large scales and artificial bamboo forest was developed in the 20th century Worldwide (Zehun, 2007). Bamboo coverage in the world is however increasing at an annual rate of 3% worldwide (Zehun, 2007. The main bamboo producing countries in the world are India and China followed by Indonesia (FAO, 2007; Ongugo *et al.*, 2012).

There are at least ten countries in Latin America with considerable bamboo resources. These countries include Brazil, Chile, Colombia, Ecuador, and Mexico which are the richest bamboo resources (FAO, 2007). Africa has only 45 species and 11 genera occurring on 1.5 million ha. Amongst these, approximately 40 species are mainly found in Madagascar while the remaining 4 are in Africa (Kigomo, 2007a). In Africa, six countries including Kenya, Ethiopia, Nigeria, Uganda, Tanzania and Zimbabwe all have a total of 2.7 million hectares of bamboo. More than 13 genera and less than 40 species of bamboo have been reported to exist in Africa (FAO, 2007).

2.4 Bamboo Farming in Kenya

There is limited literature surrounding bamboo farming in Kenya. Most of the available data dates back to 1980’s which implies that there is lack of current and up to date information. The available data includes the attempts of KEFRI to sum up some regional data on bamboo forest cover and species distribution in the late 1980’s (Lobovikov *et al*., 2005). Nonetheless, in Kenya *Yushania aphina* the only indigenous species occurs in irregular patches in the central highlands specifically in Aberdare Ranges (65,000ha), Mt. Kenya, Mau Range (51,000 ha) and Timboroa plateau (31,000ha) (Ongugo *et al.*, 2000). The total area covered by bamboo in Kenya is about 150,000ha (Kigomo, 2007b). In its natural habitat, it grows together with several trees species including *Junipeus procera, Ocotea usambarensi,* and *Podocarpus gracilior* (Kigomo, 2007b).

2.5 Bamboo for Agroforestry System

Agroforestry is defined as vibrant, ecologically based, natural resource system that through the interaction of trees in farmland diversifies and sustains production for increased social economic and environmental benefits for land users at all levels (Githiomi & Oduor, 2012). However, agroforestry has also been described in several ways by many authors from different perspectives which include; the collective name for land-use systems in which woody perennials are grown in association with herbaceous crops or livestock, in special arrangement, rotation or both (Ongugo *et al.,* 2012). The main concept of developing this system is both ecological and economical through interaction of the components (Nath *et al*., 2009). A diversity of trees and shrubs are known as fertilizer trees for land regeneration as well to agricultural crops. Most of these tree species are multipurpose providing a range of benefits. Similarly, bamboo has been identified as agroforestry crop which occupies the same ecological niche as trees. Bamboo adapts well ecologically, has a wide range of uses and it can be a critical component of many agroforestry systems (Nath *et al*., 2009; Kigomo, 2007b).

A lot of emphasis is placed on intercropping perennial, multiple purpose crops and yield benefits over a long or short period of time. The useful benefits from intercropping these crops are both food for human and animals, industrial raw materials, shelter, fuel wood or construction materials. Tree component in agroforestry has an additional benefit of holding soil material together thus preventing soil erosion and improving soil fertility through nitrogen fixing or bringing mineral from deep the soil to the top through leaf fall (Nath *et al.*, 2009).

Globally, bamboo grows on different niches like natural forests, riverbanks, dam sites and lake boundaries. Bamboo is also planted along farm boundaries to reduce soil erosion, as shelterbelts for homesteads and in degraded land to improve regeneration. In India, at its early stages, farmers intercrop bamboo with agricultural crops and when the stand establishes the bamboo is managed as a pure stand for collection of bamboo shoots for food (Katumbi *et al.,* 2017).

Agroforestry systems with bamboo species lead to a sustainable land use option in different countries such as in Northern Vietnam at the Doge catchment (Kibwage *et al*., 2008). In India, it was observed that growing of soya beans as an intercrop of bamboo during the first six years is economically viable (Ahmed, 2004). Results revealed that, after profitability and cost benefit analysis bamboo held the second position in productivity among cropping groups in mixed home gardens ((Kibwage *et al.*, 2008). In China and Bangladesh mushrooms are raised in bamboo stands (Rai, 2004).

Additionally, at different heights and growth characteristics bamboo may be used as windbreaks thereby protecting other agricultural crops systems from demining effects of other environmental factors (Nath *et al*., 2009). Nonetheless according to Kibwage *et al.*, 2008, bamboos play a critical role in providing forage to livestock during the dry season. Maih and Hussain (2001) in Bangladesh revealed that animals can consume both twigs and leaves of bamboo. Leaf and twigs of highland bamboo are also used as animal feed during dry season when there is shortage of feed (Nath and Krisnamurty, 2008)

In Nigeria, bamboo is planted in an agroforestry system called the taungya system; where farmers plant bamboo together with agricultural crops at the initial stages of its bamboo growth. Once the bamboo establishes and grows taller, the farmer shifts to grow their agricultural crops elsewhere (Muzari *et al.,* 2012). However, land shortage caused farmers to grow the bamboo in hedgerows, alley cropping and as windbreakers. Annuals such as vegetables intercropped with bamboo have been beneficial to the Nigerian farmer both economically and ecologically.

2.6 Adoption of new agricultural technologies in bamboo farming

2.6.1 Technology adoption

Technology and adoption has been defined in different ways. According to Loevinsohn *et al.,* (2013) technology is defined as methods of producing goods and services. A new technology represents new technique that has not been used to the community any other time. Technology itself is aimed at improving a given situation to a more desirable level (Challa, 2013).

On the other hand, adoption is defined as combination of new technology into existing practice. It is usually preceded by a period of trying and some degree of adoption (Mashall & Miguel 2013). Adoption is in two categories; the rate of adoption and intensity of adoption. Rate of adoption is the relative speed of adoption while intensity is how much it is adopted (Muzari *et al.,* 2012). The definitions are based on whether a farmer has adopted the technologies or not. Adoption of a technology is described as an entire procedure of getting information about the available new technologies which guide the target groups in the decision making process, then bringing the technologies into practice followed by further spreading of the equivalent technology to other members of the community (Muchiri & Muga, 2013).

2.6.2 Factors influencing adoption of new agricultural technologies

Agriculture plays a critical function in food security, economic growth, poverty eleviation and rural development. Small holder farmers 'agriculture has been identified as a vital development tool for achieving millennium development goals (World Bank, 2008). Most smallholder farmers rely on traditional agricultural methods which has lowered the level of production (Muzari *et al.*, 2012). Generally, these farmers obtain low crop yield because the local varieties commonly used have low yield potential (Muzari *et al.*, 2012). Increase agricultural productivity is essential to meet rising demand for food which triggers more research on methods of enhancing production and sustainable agriculture.

Agricultural technologies include all kinds of improved techniques and practices which affect growth of agricultural output. Among such technologies and practices is agroforestry (Loevinsohn *et al.*, 2013). By virtue of improved input and output relationship, new technology tends to raise output and reduces average cost of production which in turn results to substantial gains in farm income (Challa, 2013).

Adoption of improved technologies leads to increased production, thus improving social-economic development (Nath *et al.*, 2009). Such adoption is also associated with higher earnings, lower poverty, improved nutrition, lower staple food prices, and increased employment opportunities. Adoption of improved technologies has led to the success of green revolution in many western countries (Kiarie, 2014).

A lot of literature exists on the factors that affect adoption of agricultural technologies. Farmers' choice on how and whether to adopt a new technology is dependent on active interaction between characteristics of the technology, array conditions and circumstances (Loevinsohn *et al.*, 2013). An understanding of the factors influencing this choice is important for economic study of determinants of growth, and generator and disseminators of those technologies (Kinyanjui *et al*, 2009). Among such factors include technological, economic, institutional, and household specific factors.

2.6.2.1 Social-Economic Factors

Access to credit facilities as an economic factor has been reported as an essential aspect in technology adoption (Ayesha & Mohammed, 2012). Credit accessibility promote the acceptance of risky technologies through reduction of the liquidity constrains and boosting of household risk bearing ability (Ahmed, 2004). In some countries, access to credit facilities have been found to be discriminative especially on households headed by females thus affecting the ability of women to engage in yield-raising technologies (Muzari *et al.,* 2013). Kenyan economy promotes women and youth involvement in new technologies by providing activities that provide free interest on loan to them (Muzari *et al*., 2013).

Size of the land plays a major role in adoption of new technology. Land size can affect and in turn be affected by the other factors influencing adoption (Bandiera & Rasul, 2002). Most studies have reported a positive relation between farm size and the adoption of agricultural technology (Ahmed, 2004; Uaine *et al.,* 2009; Mignouna *et al.*, 2011). Farmers with large sizes of land are likely to adopt a new technology as they can afford to devote part of their land to try new technologies unlike those with small pieces of land (Uaine *et al*., 2009). In consideration to total farm size and not the crop acreage on which the new technology is practiced, overall adoption could be influenced more by the consideration of crop acreage with the new technology (Uaine *et al.,* 2009).

Individual preference is a factor that determines the adoption rate of a technology. Taste and cultivation practice will affect how profitability is perceived in a household (Muzari *et al*., 2013). Technologies from other regions may have different flavors and textures than local substitutes and may not be adopted even if they increase yields and income (Challa, 2013). Evidence shows that the amount income earned by individuals determines the investments the person can venture in (Challa, 2013). The size of the household is stated as a key factor for the amount an individual is willing to let go for a certain good or service (Muzari *et al*., 2013). Social normality is significant for technologies where individual adoption decisions generate cost and benefits from both the profitability of technology (Mignouna *et al.,* 2011).

2.6.2.2 Institutional Factors

Being in a social group enhances social capital thus allowing trust, idea and information exchange (Mignouna *et al.,* 2011). Farmers within a social group learn from each other the benefits and usage of a new technology. Uaine *et al.,* (2009) suggested that social networks effects are important for individual decision. In a study by Kiarie (2014) in Nigeria, it was noticed that farmers who participated in most of the community based organizations were likely to engage in social learning about a technology hence raising the likelihood to adopt the technologies.

Although researchers have reported the positive influence of the social groups on technology adoption, these can however have negative impacts on technology adoption especially where free riding behaviors exist. For example a farmer may initiate negative adoption of the technology on the risks and the disadvantages of the project adopted by neighbors (Bandera and Rasul, 2002). However, the characteristic of technology, the trialability or the level to which a potential adopter can try something out on a small scale first before adopting it fully is a major determinant of technology adoption (Mignouna *et al.,* 2011; Doss, 2013).

A study on adoption of agricultural technology in Western Kenya showed that the characteristic of a technology play a vital role in adoption decision process by farmers. Mignouna *et al.,* (2011) and Mamudu *et al.,* (2012) argued that farmers who perceive the technology as being consistent with their needs and compatible with their environment are likely to adopt it since to them it is a worth investment. The results indicated that perception of farmers towards fish farming facilitated its uptake.

Offering extension services to farmers improves farmer's ability to take a technology (Muzari *et al*., 2013). Acquisition of information about a new technology clarifies it and makes it more acceptable to farmers. Availability of data reduces the ambiguity about a technology performance and can change personal assessment from merely skewed to purpose (Challa, 2013). Good information sharing programs and links with producers are essential aspects in knowledge distribution and acceptance. A new technology is as good as its mechanism of information transfer (Challa, 2013).

2.7 Challenges of Bamboo Farming

Bamboo has not been exploited to its full potential in many areas where it grows. A number of studies have highlighted reasons as to why bamboo farming has not been popular within Africa (Lobovikov *et al.,* 2005). According to KEFRI, (2008); Kigomo, (2007a); and Ongugo *et al.,* (2000) the major challenges of growing bamboo include; lack of awareness on bamboo farming, inadequate technology, and market chain systems for bamboo products.

2.8. Conceptual Framework

This study sought to establish the factors that affect adoption of bamboo for agroforestry. Figure 2.1 demonstrates the interaction between dependent and independent variables within the frame work of the study.

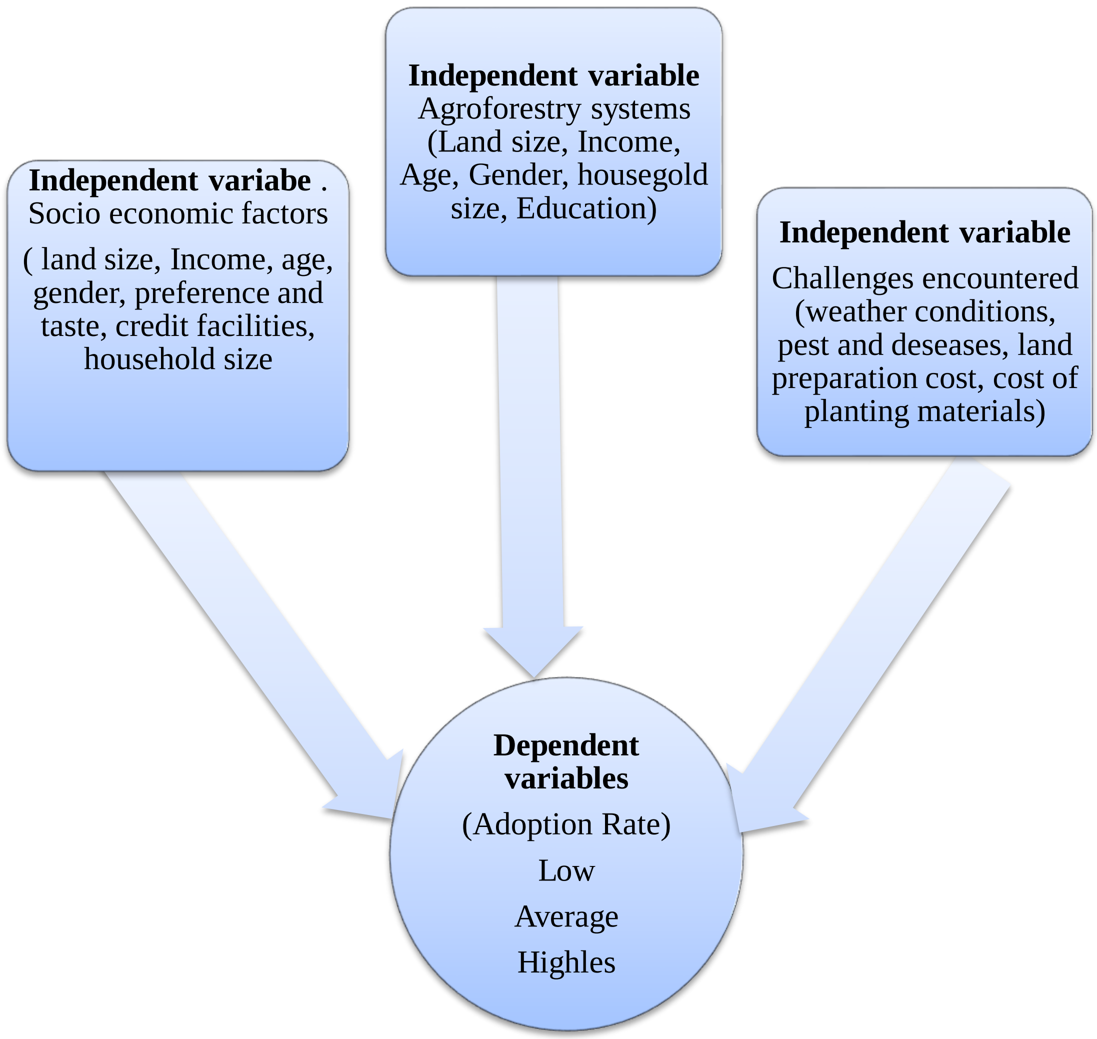

Figure 2.1 Conceptual framework (Modified from Kinyanjui, (2012)

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

This chapter describes the research methodology that was used in this study. It describes the study site, research design, sampling procedures, descriptive research instruments, data collection, data management and ethical consideration and data analysis procedures.

3.2 The Study Area

3.2.1 Geographical location

The study was conducted in Ol'kalou and Ol'jororok Sub Counties which are in Nyandarua County, Kenya. Nyandarua is situated within the central region of Kenya and lies between latitude 0^{o} 8' North and 0^{o} 50' South, & longitude 35^{o}13' East and 36^{o}42' West. The county has an approximate area of 3245.2 km^2 and borders Laikipia to the North, Nyeri to the East, Kiambu to the South, Muranga to the South East and Nakuru to the West.

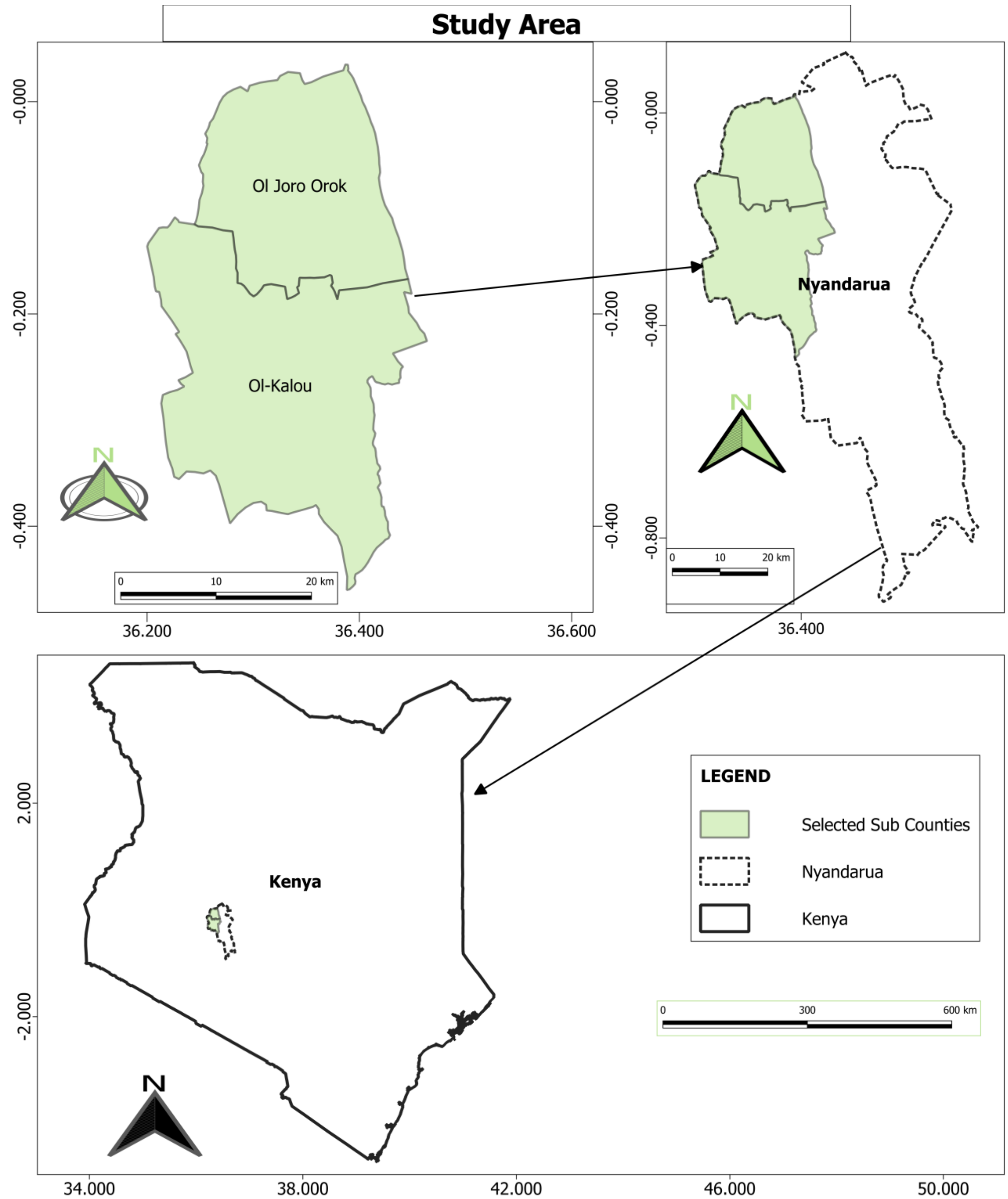

Figure 3.1 Map of Nyandarua County

Nyandarua County has a total of five sub-counties namely; Kinangop, Kipipiri, OlKalou, Ndaragwa and Oljororok. According to 2019 census, it had a total population of 696,268;

173,879 households and covered a totalarea of 3, 245.2 Square Kilometers (Sq. Km). Ol'kalou town is the headquarters both the county and the Sub County. Oljororok is the head quarter of Oljororok sub-county. Both sub-counties are along the Nairobi-Nyahururu road. The two Sub Counties lie within UH-3 and UH-4 Agro- Ecological Zones.

Agriculture is the backbone of the county. Nyandarua County is termed as the bread basket of Kenya due to its high production of agricultural produce such as potatoes, cabbages, maize, beans, carrots, kales, tomatoes and peas. Domestic animal rearing is also a major activity in the region. Farmers engage in dairy farming, sheep rearing, beef production as well as poultry farming. The area has well-drained and slightly acidic soils, humid tropical climate, characterized by a short dry season from January to March while the rest of the year has rainfall. Annually, the County receives an average rainfall of 1500mm and temperatures of 13 degrees Celsius.

3.3 Research design

The research design refers to the general approach that is chosen to combine the different components of the study in a logical and reasonable way, thereby, ensuring effective addressing of the research problem. It comprises of the design for the collection, measurement, and analysis of data.

In this study, purposive sampling of bamboo farmers was employed while random sampling was used to obtain the sample size. Descriptive research design was adopted in this study. Pearson correlation for the social- economic variables and chi square test for independence of variables used to determine the factors influencing adoption of bamboo for agroforestry.

3.4 Data collection

Data was collected from both secondary and primary sources. Secondary sources included journals, books, articles, published and unpublished materials and purposeful desktop search.

Primary data was collected by administering questionnaire to sample population through interviews. In addition, observations and photography were also used.

3.5 Target population

The target population was bamboo farmers from Olkalou and Oljororok Sub Counties. Purposively the farmers were selected from the record of department of Agriculture in Nyandarua County. From the records 200 bamboo farmers which included 103 bamboo farmers from Ol'kalou and 97 bamboo farmers from Ol'jororok Sub-counties.

Table 3.1 Target population from the study area

Sub county	Number of bamboo farmers
Ol'kalou	103
Ol'jororok	97
Total	200

(Source: Department of Agriculture Nyandarua County)

3.6 Sampling techniques and sample size

The sample size for small scale farmers in the two sub counties was chosen using Krejcie and Morgan Table (1970)

$s=X^2 NP(1-P) \pm d^2 (N—])+X^2 P(1—P)$

where,

s = required sample size.

d = the table value of chi-square for 1 degree of freedom at the desired confidence level (0.05 = 3.841).

N=the population size.

P = the population proportion (assumed to be 0.50 since this would provide the maximum sample size. d the degree of accuracy expressed as proportion (0.05).

Table 3.2 Table for Determining Sample Size from a Given Population

N	*S*	*N*	*S*
10	10	220	140
15	14	230	144
20	19	240	148
25	24	250	152
30	28	260	155
35	32	270	159
40	36	280	162
45	40	290	165
50	44	300	169
55	48	320	175
60	52	340	181
65	56	360	186
70	59	380	191
75	63	400	196
80	66	420	201
85	70	440	205
90	73	460	210
95	76	480	214
100	80	500	217
110	86	550	226
120	92	600	234
130	97	650	242
140	103	700	248
150	108	750	254
160	113	800	260
170	118	850	265
180	123	900	269
190	127	950	274
200	132	1000	278
210	136	1100	285

Source: Adapted from (Krejcie and Morgan, 1970)

Sampling was done by assigning all population size with random numbers and then the sample size will be selected. From the sample size selected, specific sample sizes of small scale farmers for each of the two sub counties was obtained using the formula;

s= (P*n)/P

s=Sample size

p=Target population from each sub county *

n=Total sample size)

P=Total target population as show in the table (Mugenda and Mugenga 2004).

Table 3.3 Sample size calculations

Sub County	Target population	Sample size
Ol'kalou	103	103/200*132=**68**
Ol'jororok	97	97/200*132=**64**
Total	**200**	**132**

From the target population of 200 farmers a sample of 132 farmers was selected using random sampling technique to ensure the respondents were evenly distributed within the study area.

3.7 Description and validity of data collection instruments

Open and closed ended questionnaires, interview and observations schedules were used as instruments for data collection. Additionally, use of questionnaires is a popular method for data collection due to its ease and cost effectiveness with which they are constructed and administered. They give a comparative objective data and therefore are most efficient. In this study, questionnaire was used as the main instrument of data collection from farmers (Mugenda and Mugenda 2004).

3.8 Types of data collected by objective and data analysis

Types of agroforestry systems practiced in the selected Sub Counties.

The data collected included, what type of agroforestry systems were practices by the bamboo farmers in the selected sub counties. The data on the zones where bamboo is planted, the farmers who intercropped and who did not, reasons for intercropping, types of crops intercropped with bamboo and the most preferred uses of bamboo. Open and closed ended questionnaires giving the choices of the types of agroforestry systems were administered to the targeted group.

Factors influencing the adoption of bamboo for agroforestry in selected Sub Counties

Data collected included the socio-economic factors of the targeted group such as gender of the house hold head, age of the household head, house hold size, and size of land, income, and education level of the household head. It also included the sources of information on bamboo farming and the challenges experienced during farming.

Challenges faced by farmers cultivating bamboo in the selected sub counties.

The data collected included any challenges encountered by the bamboo farmers during bamboo farming and whether the challenges influenced their level of its adoption for agroforestry. The data was analyzed through SSPS and results presented in frequency tables. Likert Chi- Square tests were run to determine whether the challenges had any considerable association with the rate of adoption of bamboo for agroforestry.

3.9 Data management and ethical consideration

After getting informed consent of the respondents through a letter of introduction from the University, the questionnaire was administered to the respondents in the target study area. Necessary safeguards were maintained on information obtained for study due to privacy concerns. The soft information records were protected by using passwords. Hardcopy documents were kept under lock and key.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter describes the data analysis, presentation, interpretation and discussion of findings. The results were presented based on the objectives of the study.

4.2 Types of agroforestry systems in the selected sub counties

Data collected indicated that farmers in the selected sub-counties planted bamboo within the cultivated area, homestead farm, farm boundary, grazing area, and along the valleys. On average, it was evident that majority of the farmers across the selected sub-counties planted bamboo within the homestead farm (mean=33%). Majority of farmers in Oljororok sub-county planted bamboo along the valley (30.8%) whereas majority of farmers in Olkalou planted bamboo within the homestead farm (40%). In both the selected sub-counties, bamboo cultivation was the least within the grazing area at an average of (11%) with only 7.5% of Olkalou farmers and 15.4 % of Oljororok farmers growing bamboo within the grazing area at a X^2=14.173; p=0.007(Table 4.1).

Table 4.1 Response (%) of the zone where bamboo is planted and agroforestry

Bamboo planting zone	**Sub-county**		**Mean**	**Chi sq. value**	**P value**	**Phi cramer's value**
	Olkalou	**Oljororok**				
Cultivated area	23.8	11.5	18.0	14.173	0.007	0.457
Homestead farm	40	26.9	33.0			
Farm boundary	11.3	15.4	13.0			
Grazing area	7.5	15.4	11.0			
Along the valley	17.5	30.8	24.0			

Results obtained on bamboo agroforestry systems with bamboo revealed that farmers across the selected sub-counties practiced agroforestry (intercropping) at =83.8% and 75% in Olkalou and Oljororok respectively whereas a few farmers did not intercrop at=21%. From the interviewed farmers 83.8% and 75% in Olkalou and Oljororok sub-counties respectively, planted bamboo alongside other crops (Figure 4.1).

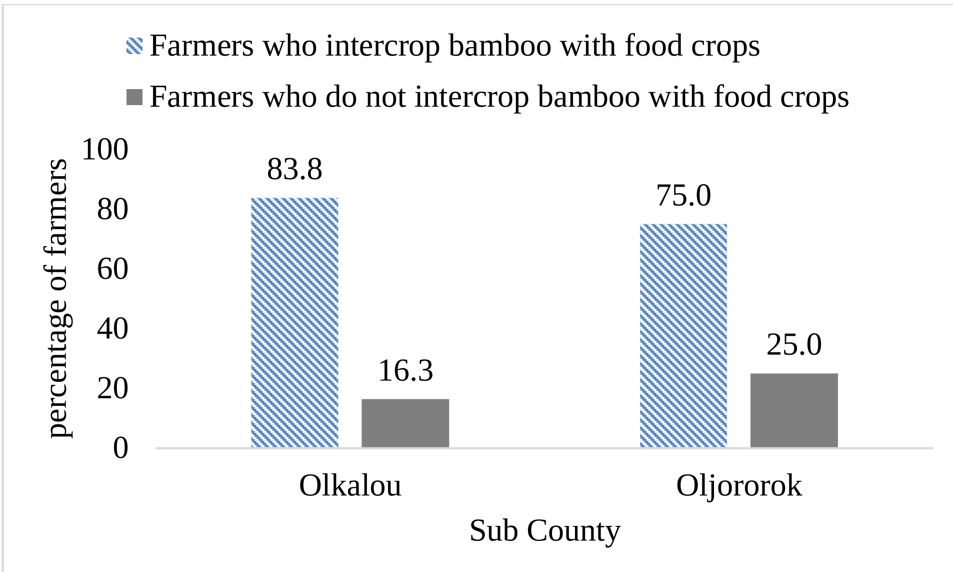

Figure 4.1 Response (%) on bamboo intercropping with and without food crops

On average, ‘potatoes only’ was the most intercropped crop at 29.7 %) across the selected sub-counties. ‘Beans only’ was the least intercropped crop on average at4%) with only 7.7 % of farmers in Oljororok sub-county planting only beans along bamboo. The results had chi square and p values of $X^2 = 114.951$; p=0.000. (Table 4.2)

Table 4.2 Response (%) on food crops intercropped with bamboo

Crops Intercropped with bamboo	Sub-County		Means	Chi^2 value	P value	Cramer's value
	Olkalou	**Oljororok**				
Maize only	7.5	1.9	4.7	114.951	0.000	0.000
Beans only	-	7.7	4.0			
Potatoes only	32.5	26.9	29.7			
Peas only	16.3	15.4	16.0			
Maize and potatoes only	7.5	9.6	9.0			
Beans and potatoes only	15	5.8	10.4			
Maize, beans, peas and potatoes	7.5	7.7	7.6			

From the results obtained on the time farmers from the selected sub-counties commenced intercropping, it was evident that majority of the farmers in the two sub-counties intercropped when the bamboo crop was less than three years old (mean=57.3%). At least 58.8 % and 55.8 % (X^2=0.68; P=0.000) of the farmers in Olkalou and Oljororok sub-counties respectively, introduced other crops alongside bamboo when the crop was less than three years old (Table 4.4). A few farmers intercropped throughout bamboo cultivation across the selected sub-counties (mean=1.6%)

Table 4.3 Response (%) on the age of bamboo plants upon intercropping

Bamboo age (years)	Sub-County		Means	Chi² Value	P value	Cramer's value
	Olkalou	**Oljororok**				
Less than three years	58.8	55.8	57.3	0.680	0.000	1.000
3 to 5 years	26.3	17.3	21.8			
Throughout bamboo cultivation	1.3	1.9	1.6			

Bamboo farmers in from the selected sub-counties planted other crops alongside bamboo in order utilize the available land at 32.3%, and to soil fertility at 4.1%, control weed during bamboo growth at 7.3%, to increase farm income at 34.2%, and to provide fodder at 2.8%) (Table4.5) Utilization of the available land (mean=32.3%) and increment of farm income (mean=34.2%) were the major reasons why farmers practiced intercropping. The results were statistically significant at X^2=115.004 and P=0.000). A few farmers indicated provision of fodder as the reason for intercropping (mean=2.8%).

Table 4.4 Response (%) on reasons for intercropping other crops with bamboo

Reason for intercropping	Sub-County		Mean	Chi² value	P value	Cramer's value
	Olkalou	**Oljororok**				
To optimally utilize the available land	33.8	30.8	32.3	115.004	0.000	0.933
For humus	6.3	1.9	4.1			
To control weed during bamboo growth	8.8	5.8	7.3			
To increase farm income	33.8	34.6	34.2			
To provide fodder	3.8	1.9	2.8			

On average, commercial use was the most preferred bamboo use across the selected sub counties on average (mean=54.7%). Atleast 61.3 % and 48.1 % of farmers in Olkalou and Oljororok respectively reported that commercial use was their most preferred purpose for bamboo farming. Erosion control was the second most preferred bamboo use (mean=19.7%) across the selected sub-counties the significance level was at X^2=12.652 and P= 0.542 (Table 4.5).

Table 4.5 Response (%) on bamboo uses in order of preference

Preferred use	Sub County		Means
	Olkalou	**Oljororok**	
To act as windbreakers	8.8	9.6	9.2
For erosion control	16.3	23.1	19.7
For commercial use	61.3	48.1	54.7
Source of firewood	1.3	1.9	1.6
For fencing	1.3	5.8	3.5
For cleaning and increasing water flow	7.5	3.8	5.6

4.3 Factors influencing the adoption of bamboo for agroforestry in the selected Sub Counties

Averagely, the female gender had adopted more bamboo farmingin Olkalou (Mean= 32%) un like Oljororok who had more male bamboo farmers (28%). Across the two sub counties, farmers of household head age bracket 31-40 had adopted bamboo more (Olkalou=21%; Oljororok = 18%) compared to other age groups. Additionally, bamboo farmers with Tertiary education level (mean=36% and 59%) in Olkalou and Oljororok respectively had adopted bamboo farming followed by Secondary education level (mean=12% and 49%). Bamboo farmers with small household sizes (mean=29% and 49%) had adopted bamboo farming compared to farmers with larger household sizes in both the sub counties (Table 4.6 and 4.7).

Table 4.6 Selected household socio- economic characteristics in percentage (n=132) and their association to adoption of bamboo for agroforestry in Olkalou sub county

Variable	Sub categories	A	NA	Chi 2 Value	P value	Cramer's Value
Gender	Male	29	4	0.232	0.030	0.058
	Female	32	3			
Age(Yrs)	18-30	8	0	2.866	0.080	+0.205
	31-40	21	3			
	41-50	12	1			
	51-60	18	2			
	Above 61	2	1			
Household size	1-3	29	2	2.305	0.011	-0.184
	4-6	22	3			
	7-9	8	1			
	Above 10	2	1			
Level of Education	Never attended	4	1	2.269	0.018	+0.221
	Primary	9	0			
	Secondary	12	3			
	Tertiary	36	3			
Occupation	Farmer	12	1	6.386	0.94	+0.306
	B.Man/woman	11	4			
	Farming&business	22	2			
	Teacher	16	0			
Monthly Income(Ksh)	<10,000	1	1			
	10,001-20,000	14	2	29.870	0.014	+0.241
	20,001-30,000	29	3			
	>30,000	17	1			
Land size (acres)	<2	29	0	1.433	0.031	+0.720
	2-5	16	2			
	5-9	13	2			
	More than 10	3	3			

Table 4.7 Selected household social economic characteristics (n=132) and their association to adoption of bamboo for agroforestry in Oljororok sub county

Variable	Sub categories	A (n=132)	NA (n=132)	Chi 2 Value	P value	Cramer's Value
Gender	Male	28	6	0.635	0.026	0.059
	Female	26	4			
Age(Yrs)	18-30	7	1	3.421	0.040	+0.231
	31-40	18	3			
	41-50	9	4			
	51-60	15	2			
	Above 61	2	1			
Household size	1-3	48	7	4.194	0.041	-0.256
	4-6	44	4			
	7-9	17	3			
	Above 10	6	3			
Level of Education	Never attended	8	3	3.359	0.540	+0.222
	Primary	30	2			
	Secondary	49	4			
	Tertiary	59	8			
Occupation	Farmer	13	3	2.053	0.051	+0.232
	B.Man/woman	15	4			
	Farming&business	18	3			
	Teacher	8	0			
Monthly Income(Ksh)	<10,000	0	4	20.053	0.021	+0.625
	10,001-20,000	13	2			
	20,001-30,000	23	4			
	>30,000	18	0			
Land size (acres)	<2	26	0	4.633	0.009	+0.942
	2-5	14	2			
	5-9	9	4			
	More than 10	0	7			

Farmers from the selected sub-counties sourced information from neighbors, media and extension officers (Figure 4.2).

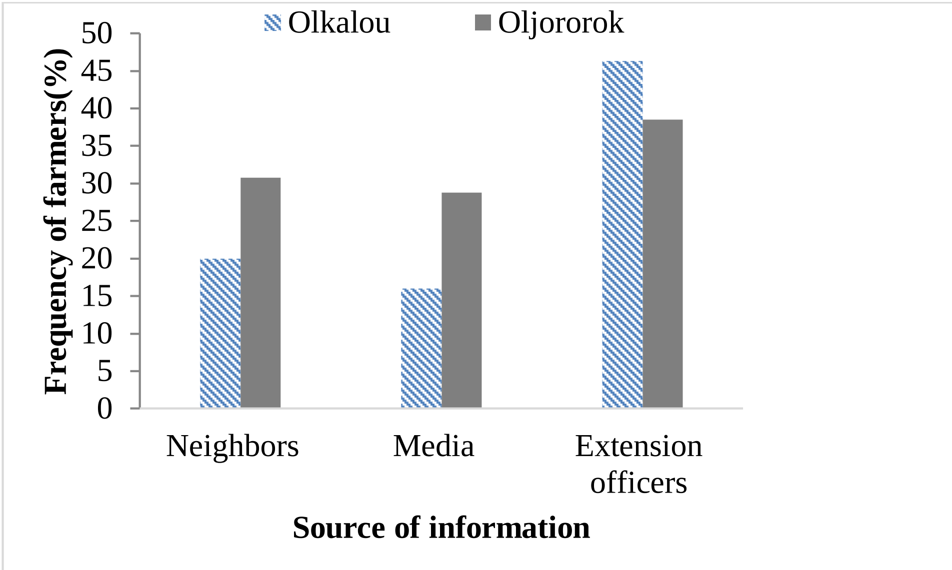

Figure 4.2: Response (%) on source of information about bamboo farming

Results obtained on sources where farmers received training on bamboo farming confirmed that bamboo farmers received training from the ministry of agriculture 30%; 35%, non-governmental organizations (NGOs) at 7%; 43% and online sources at 22%; 23% (Figure 4.3). Most farmers received training from NGOs at 37.1% and the ministry of agriculture at 23.3%. Only 5.6 % of farmers across the selected sub counties relied on online sources for training on bamboo farming

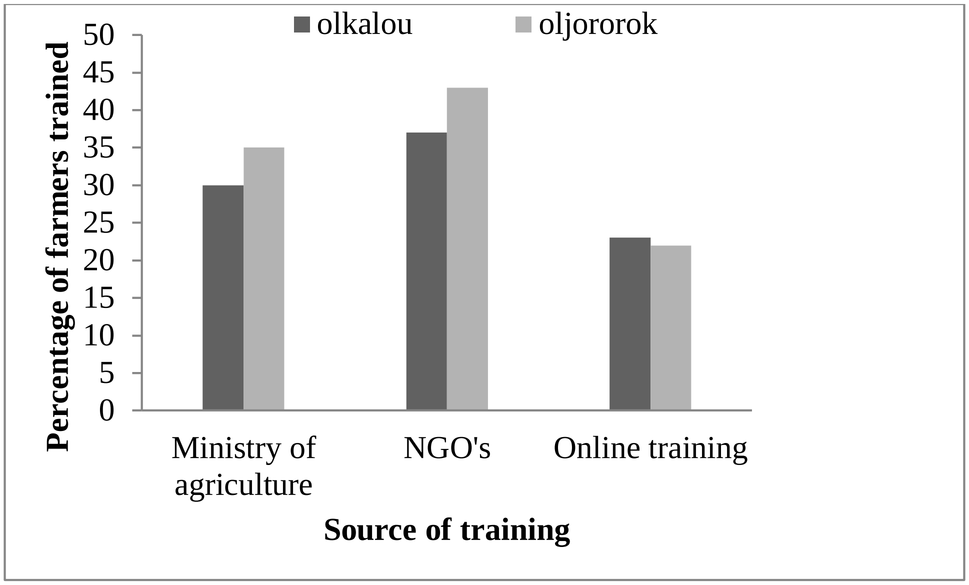

Figure 4.3 Response (%) on source of training on bamboo farming

Farmers from the selected sub counties were trained on seedling raising, bamboo planting, management practices, harvesting and marketing of bamboo products (Figure 4.4). On average, 50.3% of farmers received training on bamboo planting. There were no farmers who received training on harvesting and marketing of bamboo in Oljororok Sub County

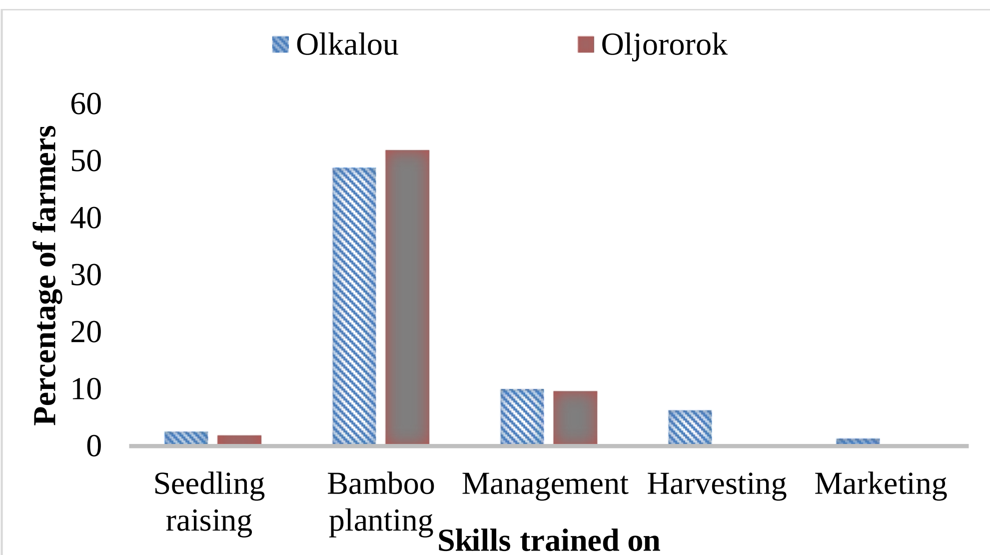

Figure 4.4 Response (%) on skills trained on

4.4 Challenges faced by farmers cultivating bamboo in selected Sub Counties

Seedling wilting, costly land preparation, insufficient humus, and expensive management practices were identified as the main challenges faced by bamboo farmers in the selected sub-counties (Table 4.8). Averagely, land preparation cost was the main challenge experienced by most of the farmers at 30.3% followed by expensive management practices at 21.6%. Seedling wilting at 7.9% and insufficient humus at 9.2% posed as insignificant problems faced by bamboo farmers.

Table 4.8 Response (%) on problems during land preparation and planting

challenges faced by farmers	Sub-County				Chi^2 value	P value	Cramers value
	Olkalou		Oljororok				
	Yes	No	Yes	No			
Seedling wilting	6	0	7	1	11.763	0.019	0.299
Costly land preparation	19	2	33	2			
Insufficient humus	2	1	4	4			
Expensive crop management practices	8	1	4	26			
Harsh weather conditions	12.5	3	3.8	2			
Source of manure	13	2	11.5	1			

Majority of bamboo farmers from the selected sub counties identified lack of information on where to source planting materials at 32.1% as the most critical problem they faced when accessing bamboo seedlings (Figure 4.5). High cost of seedlings at 23.1% was the other more critical problem experienced by bamboo farmers within the study area.

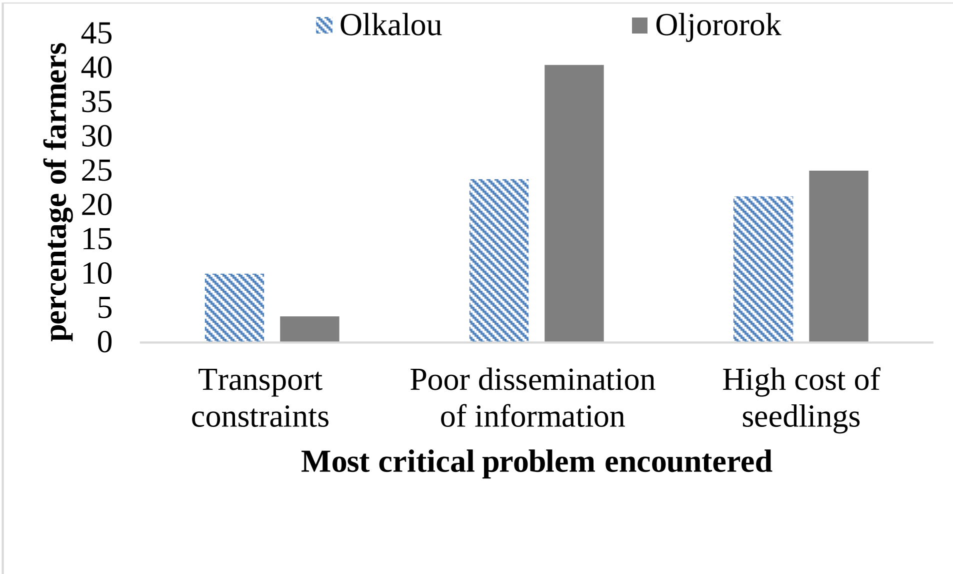

Figure 4.5 Response (%) on Critical problems encountered

Results obtained from the study area revealed that majority of the bamboo farmers did not encounter bamboo diseases or insects affecting the crop at 86.7%. Only a few farmers at 3.2% encountered bamboo diseases/insects (figure.4.6)

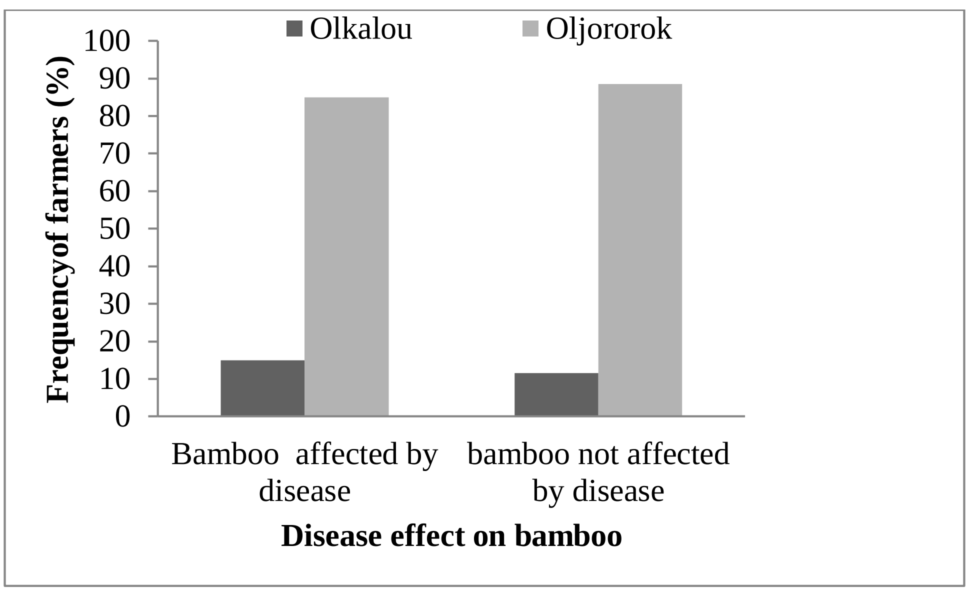

Figure 4.6 Response (%) on any disease or insect affecting bamboo

Majority of the bamboo farmers at 74.4%) strongly agreed that the area they planted bamboo influenced their decision to undertake intercropping. 22% , 2.5 % and 1 % of the bamboo farmers reported to agree, had a neutral stand, and disagreed respectively that the area where bamboo was planted influenced their choice to intercrop. However, the difference was not significance (X^2=2.586 P=0.274) (Table 4.9).

Table 4.9 Response (%) on the influence of zone bamboo is planted on the choice to intercrop

Did the zone where bamboo is planted influence the choice to intercrop	**Sub County**		**Mean**	**Chi^2 value**	**P value**	**Cramers value**
	Olkalou	**Oljororok**				
Strongly agree	70	78.8	74.4	2.586	0.274	0.140
Agree	28.7	15.4	22			
Neutral	1.3	3.8	2.5			
Disagree	0	1.9	1			
Strongly disagree	0	0	0			

Majority of the bamboo farmers (mean=56.3%) strongly agreed that the size of their land influenced their decision to undertake intercropping. 37.6% , 2.8 % ,12.2 % and 1% of the bamboo farmers reported to agree, had a neutral stand, disagreed and strongly disagreed respectively that their land size influenced their choice to intercrop at a significance level of X^2= 6.132; P=0.047) (Table 4.10).

Table 4.10 Response (%) on the influence on land size on adoption of bamboo for agroforestry

Did the size of the land influence the adoption level of bamboo for agroforestry	Sub County		Mean	Chi^2 Value	P value	Cramer's value
	Olkalou	**Oljororok**				
Strongly agree	51.2	61.5	56.3	6.132	0.047	0.214
Agree	42.5	32.7	37.6			
Neutral	3.8	1.9	2.8			
Disagree	2.5	1.9	12.2			
Strongly disagree	0	1.9	1			

Majority of the bamboo farmers (mean=27.8%) agreed that where they sourced information about bamboo farming influenced their decision to undertake intercropping. 21.2% , 19.7 % ,19 % and 12.4% of the bamboo farmers reported to strongly agree, had a neutral stand, disagreed and strongly disagreed respectively that the source of information about bamboo farming influenced their choice to intercrop (Table 4.11).

Table 4.11 Response (%) on the influence of the source of information on bamboo farming on the choice to intercrop or not

Source of information influenced the choice to intercrop?	Sub-County		Mean	Chi^2 value	P Value	Cramer's Value
	Olkalou	**Oljororok**				
Strongly agree	21.3	21.2	21.2	6.367	0.173	0.220
Agree	32.5	23.1	27.8			
Neutral	16.3	23.1	19.7			
Disagree	18.8	19.2	19			
Strongly disagree	11.3	13.5	12.4			

At least 31.6% of the bamboo farmers strongly disagreed that bamboo farming challenges influenced their decision to undertake intercropping. 16.8%, 19.6 %, 9.5 % and 22.4% (p value=0.385)who reported to strongly agree, agree, had a neutral stand and disagreed respectively that bamboo farming challenges influenced their choice to intercrop (Table 4.12)

Table 4.12 Response (%) on the influence of bamboo farming challenges on the choice to intercrop or not

Did bamboo farming challenges influence the Choice to intercrop or not?	Sub County		Means	Chi^2 Value	P value	Cramer's value
	Olkalou	**Oljororok**				
Strongly agree	12.5	21.2	16.8	4.162	0.385	0.178
Agree	20	19.2	19.6			
Neutral	7.5	11.5	9.5			
Disagree	27.5	17.3	22.4			
Strongly disagree	32.5	30.8	31.6			

From (Table 4.13) 33.2% of the bamboo farmers at 33.2% strongly agreed that training on bamboo farming influenced their decision to undertake intercropping. 30.6%, 8.2 %, 10.7 % and 17.1 % of the bamboo farmers reported to agree, had a neutral stand, disagreed and strongly disagreed respectively that training on bamboo farming influenced their choice to intercrop.

Table 4.13 Response (%) on the influence of training on bamboo farming on the choice to intercrop or not

Did training on bamboo farming influence the choice to intercrop or not?	Sub County		Mean	Chi^2 value	P value	Cramer's value
	Olkalou	**Oljororok**				
Strongly agree	33.8	32.7	33.2	6.367	0.173	0.220
Agree	32.5	28.8	30.6			
Neutral	8.8	7.7	8.2			
Disagree	10	11.5	10.7			
Strongly disagree	15	19.2	17.1			

CHAPTER FIVE

5.0 DISCUSSION

This chapter gives brief discussion of the findings as per the specific objectives.

5.1 Agroforestry systems practiced in the selected Sub Counties

Results on agroforestry systems practiced with bamboo revealed that bamboo was mostly planted along the homestead farm (Mean= 33%) followed by along the valley (Mean=24%). Bamboo planting on grazing area was the least (Mean =11%). According to Ogungo (2012) in Kenya bamboo grows on hilly areas and along valleys which could be attributed to massive the growing of bamboo along valleys on the study areas. The bamboo grown on grazing areas was the least maybe since bamboo is good fodder crop thus discouraging planting on grazing areas because the bamboo grown by farmers was commercial. Bamboo is a good fodder crop, good in energy production and a source of food in Kenya (Karanja *et al.*, 2015) and farmers might have shunned away from planting the crop within grazing areas to avoid ravaging by grazers hence deny farmers there commercial purpose of growing the crop.

Bamboo farmers who practiced intercropping were the majority (79.0%) compared with the farmers who did not (21.0%). These results imply that more farmers are adopting bamboo for agroforestry within their farms because of the advantages of planting bamboo alongside food crops. This is in agreement with Nath *et al.*, (2009) that at different heights and growth characteristics, bamboo may be used as shade thereby protecting other agricultural crops systems from effects of excessive sunlight.

Nguyen, (2004) found out that agroforestry systems with bamboo species lead to a sustainable land use option in different countries such as in Northern Vietnam at the Doge catchment. This was in agreement with the results that, utilizing the available land was the main reason for intercropping followed by increasing farm income (mean 34.2% and 32.3% respectively).

Potatoes were the most intercropped crop within the study area (mean=29.7%) while maize was the least crop intercropped with bamboo (mean=4.7%). From the study, the results could be attributed to the observation that potatoes are the main food crop for the residents within the study area and can easily grow close to the bamboo without being affected by the shading. Maize, being an annual crop in study area could have affected the farmers' interest to intercrop with bamboo. Most probable maize was not a suitable intercrop because it might have competed with bamboo for sunlight thus giving low yields. In India, Seshdri (1995) observed that intercropping soya beans with bamboo during the first six years of the crop's growth was economically viable.

According to Nath *et al.,* (2008), it is clear that some crops improve bamboo.. From the results,, may be most farmers had adopted intercropping bamboo with potatoes because potatoes enhance bamboo growth positively by not competing with it for sunlight. Majority of the farmers reported to have intercropped when bamboo crop was less than three years old (mean=57.3%). The results concurred with those of Yeshambel *et al*., (2011) who found out that bamboo was easily intercropped with food crop at its tender ages and that the food crops promotes its culm growth.

From the results it is evident that bamboo farmers understood the many uses of bamboo. Majority of the farmers practiced bamboo farming for commercial use and erosion control at a mean of 54.7% and 19.7% respectively) The results agreed with Ogungo (2012), who pointed out that most Kenyan bamboo was embraced for controlling soil erosion while little had been done to utilize the other benefits of bamboo in Kenya.

5.2 Factors influencing the adoption of bamboo for agroforestry in the selected Sub Counties

From the results, it was established that agroforestry systems positively affected the rate of adoption of bamboo for agroforestry (X^2 =14.173; P= 0.007 Cramers v = 0.0457). The results were in agreement with Nath *et al., (*2009) who found out that agroforestry systems favour some crops compared to others. Nath *et al.,* (2009) argued that the results might have behaved so due to allelopathic effects of some agroforestry trees compared to others. Katumbi *et al.,* (2017) also points out that agroforestry practices can be adopted by farmers for various reasons such as fuel wood, shelter and land use maximization. It is due to this uses, that the author establishes that adoption a certain crop for agroforestry can be affected by the agroforestry practice the crop fits in.

The results revealed that more male headed households in Oljororok had adopted bamboo farming at 28% compared to Olkalou. The results are in agreement with findings by Yeshabel *et al*., (2011) who established that land related investments were more adopted by men than women due to land ownership related issues.

According to Yeshabel ea al., (2011) more farmers aged between 30 and 40 had adopted bamboo farming (mean=34.1%, p value= 0.000) in comparison to other age brackets. It was also evident that farmers earning a monthly income above ksh. 20,000 had adopted bamboo farming (29.0% and 23.0%; p value= 0.021 and 0.000). The results are in agreement with Loesvinsohn *et al*., (2013) who established that income per house hold influenced the rate of adoption of new agricultural technologies. The results could have been attributed to the high cost of acquiring seedlings and land preparation for bamboo growing.

Bamboo farmers received information about bamboo farming from extension officers, Media, and neighbors. The source of the information on bamboo farming however affected the rate of adoption of bamboo (P Values 0.014 and 0.021). Kinyanjui (2012) established that the source of information on agricultural production greatly affects the rate of adoption of such technology. The result might have been so because farmers tent to trust more on reliable sources of agricultural information such as government officers and registered nongovernmental organizations. According to Challa, (2013) the known institutions have cumulative data which reduces ambiguity about a technology performance and can change farmers assessment from skewed to purpose.

The gender of the household head also influenced the rate of adoption of bamboo for agroforestry ($p<0.001$). The gender of household head could have influenced the rate of adoption of bamboo for agroforestry because often in the Kenyan tenure system, most lands are owned by the men. Most men headed households could have adopted agroforestry as owners of the farms and since men are mostly involved in mega projects which are associated with more income generation (Muchiri, 2013)

Results on farmers' training and source of training as predictive variables for agroforestry adoption (ability to intercrop bamboo with food crops) show that both training (Chi-square test value = 3.772, p = 0.022) and (Chi-square test value = 2.343, p = 0.026) for Olkalou and Oljororok Sub Counties had a great association with the rate of adoption of bamboo for agroforestry. The results agreed with Nath *et al.,* (2009) who concluded training on use of new agricultural practices influences its adoption by farmers.

Consequently, training on bamboo farming could have increased farmers' knowledge on the benefits of bamboo agroforestry which led to more farmers adopting the new farming practice. The source of information on bamboo farming influenced farmers' bamboo agroforestry adoption maybe due to reliability and affordability. For instance, majority of farmers relied on NGOs more than the other sources probably because NGOs offer subsidized or free services.

According to Nath *et al.,* (2009) it was established that farmers land size influences the type of agroforestry system practiced by the farmers. This was in agreement with the results of this study, which found out that land size directly influenced the rate of adoption of bamboo for agroforestry as well as the type of agroforestry system (Cramer's v = +0.942 and +0.720).

5.3 Challenges faced by farmers cultivating bamboo in selected Sub Counties

Atleast 27.5% and 40.4% from Olkalou and Oljorork respectively of the bamboo farmers faced challenges on where to source planting materials. This problem could have been associated with the high cost of seedlings.The knowledge on bamboo propagation vegetatively required a training which could was also costly from Olkalou and Oljororok, at 23.5% and 40.3% respectively.

Land preparation and seedling trasportation was also a challenge as per the respondents (Mean=23.3%). Results obtained from the study area revealed that majority of the bamboo farmers did not encounter bamboo diseases or insects affecting the crop (mean=86.7%). This can be attributed to good bamboo farming practices that farmers learned from training on bamboo farming. Less than 10% percent of farmers within the study area reported to have experienced crop diseases and pests within their farms. Cost of land preparation and limited information on where to source planting materials was a major challenge to bamboo farmers within the study area which could have been the reason for poor adoption rates of bamboo for agroforestry (Kinyanjui *et al.,* 2015).

The results established that the challenges encountered by farmers were not related to the training they received ($p < 0.096$). The results could have been so mainly due to availability of some nongovernmental organizations willing to educate farmers on best farming practices regardless of their educational level. The results were not in agreement with Mignouna *et al.,* (2011)and Doss, (2013) who established that the problems encountered by agricultural farmers is directly influenced by the training undertaken by the farmers concerning farming techniques. The findings could have been so may be because the problems encountered were not related to the trainings undertaken by the farmers.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the results it was concluded that bamboo home gardens, intercropping, farm boundaries, Hedgerows and agrosilvopastoral (bamboo grown in grazing areas) were the agroforestry practices in both the sub counties. Bamboo home gardening was majorly practiced. Bamboo along valleys was commonly practiced for reduction of soil erosion while farm boundary bamboo farming was used as wind break. Regardless of the fact that bamboo crop is a grass; the farmers knew the benefit of maximizing the available land by intercropping bamboo with other food crops.Bamboo for agroforestry farming was found to be economically viable agricultural venture. Maximum utilization of the available land resources and increasing farm income were the major reasons why bamboo farmers embraced agroforestry. Farmers within the study area planted bamboo mainly for commercial use and erosion control.

Demographic factors such as monthly income from crops intercropped with bamboo, gender of house hold head, house hold size, age of the bamboo farmers of bamboo and land sizes significantly influenced the rate of adoption of bamboo. Similarly, agroforestry systems practiced by farmers were also factors influencing the rate of adoption of bamboo for agroforestry. Differently, education level, did not significantly influence the rate of adoption of bamboo for agroforestry.

Correspondingly, training in bamboo farming significantly influenced the rate of adoption of bamboo for agroforestry. It was evident that challenges faced by farmers during land preparation and planting was not influenced by training and therefore, it would be concluded that challenges encountered during bamboo growing was not influencing the rate of adoption of bamboo for agroforestry. Contrarily, the source of bamboo information did not affect the rate of adoption of bamboo for agroforestry. It was established that, cost of land preparation, harsh weather conditions, and high cost of planting materials were the major challenges faced by bamboo farmers in the study area.

6.2 Recommendations

Since the bamboo cropping has proven important to improved land utilization, the Ministry of Agriculture should encourage bamboo for agroforestry.

Extension officers in the Ministry of Agriculture and Non-Governmental Organizations should continue providing information on agroforestry practices available for bamboo as well as regular trainings on the entire value chain from bamboo planting to harvesting and marketing.

Investors willing to venture in to bamboo value chain can provide subsidies to farmers like providing bamboo seedlings to farmers willing to venture in bamboo growing. The incentives will reduce the effects of farmers being affected by the costs incurred during bamboo growing and thus increasing bamboo production.

To increase the supply of bamboo seedlings there is need for more trainings to the farmers on seedling production techniques.

Research institutions such as Kenya Forestry Research Institute and Kenya Agricultural and Livestock Research Organization should undertake more researches to establish the best crops for intercropping with bamboo for maximum production.

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APPENDICES

Appendix 1 questionnaire

Questionnaire for head of households

My name is Damaris Mwikali I am a Climate Change and Agroforestry Masters student at South Eastern Kenya University. The research that I am currently conducting is part of my degree program. My goal is to identify the factors influencing the adoption of bamboo for agroforestry in selected sub-counties of Nyandarua. My humble request is that you kindly answer the questions provided in this questionnaire. All information will be kept confidential.

QUESTIONNAIRE SERIAL NUMBER…………………………………………………………

Date of distribution

County

Sub-county

Questionnaire number

Name of Enumerator

Socio-demographic information (tick the appropriate answer)

1. Gender

a. Male b). Female

2. Age of the respondent?

a. 18 to 30 d). 30-40

b. 41 to 50 e). 51- 60

c. 61 and above

3. Educational status

a. Never attended school c) Secondary

b. b) Primary d) Tertiary

4. Occupation

a. Farmer

b. Businessman/ woman (c) Farming and business (d) Teacher

e) Others………………………

5. Household size

a. 1-3 c. 7-9

b. 4-6 d. 10+

6. Income earned monthly (Ksh)

a. <10,000 c. 20,000 - 30,000

b. 10,000- 20,000 d. 30,000+

SECTION A

To investigate the agroforestry systems in which bamboo is cultivated in the selected sub counties of Nyandarua County.

1) Which part of your farm have you planted bamboo?

i). Cultivated area (ii) Homestead farm (iii)Farm boundary

iv) Grazing area (iv) Along the valley

2). If you plant bamboo in a cultivated area, along the valley, or homestead, do you do intercropping?

i). Yes (ii) No

3). a). If your answer above is yes, which crops do you plant together with bamboo?

i). Maize only (ii) Beans only (iii) Potatoes only (IV) Peas

v) Maize and potatoes only (vi) Beans and potatoes only

vii) Maize, beans, peas and potatoes

b). How much do you earn from crops planted with bamboo per year?

i). <10,000

ii). 10,000-20,000

iii). 20,000-30,000

iv). More than 30,000

4). Up to what age of bamboo cultivation do you intercrop?

i). <3 years

ii). 3-5 year

iii). throughout bamboo cultivation

5). a). Why do you intercrop bamboo?

i). To fully utilize the available land

ii). For humus

iii). To encourage weed control during bamboo growth

iv). To increase farm income

v) Fodder

b). Please rank your reasons of intercropping in a). above

5). For what use have you planted bamboo?

i). Wind break

ii). Erosion control

iii). Sale

iv). Firewood

v) Fencing

vi) Cleaning and increasing water flow

3). Please rank the choices in (2) above starting with 1 as most important

Use	Rank
Wing break	
Erosion control	
Sale	
Firewood	
Fencing	
Cleaning and increasing water flow	

To establish the factors influencing the adoption of bamboo for agroforestry in selected Sub Counties of Nyandarua County

1. How did you know about bamboo planting?

i). Neighbours

ii). Media

iii). Extension officers

v). others specify) ____________

2. Have you received any training on bamboo?

i). Yes

ii). No

If the answer to the question above is yes,

a). Who trained you?

i). Ministry of agriculture

ii). NGOs

iii). Online training

Other (Specify)

b). which areas of bamboo planting and management were you trained on?

i). Seedling raising

ii). Bamboo planting

iii). Management

iv). Harvesting

v). Marketing

vi). Other (Specify). ____

To examine the problems faced by farmers cultivating bamboo in selected sub counties of Nyandarua.

1) Did you experience any problem before assessing bamboo seedlings?

i). Yes

ii). No

b) If yes, what kind of problem was it?

i) Transport

iii) Information on where to get planting materials

iv) Cost of seedlings

c) Please rank the above problems in order of priority

Problem	Rank(use 1,as the highest rank)
Transport	
Information	
Cost of seedlings	

1. a) Did you encounter any problem during land preparation and planting of bamboo?

i) Yes

ii) No

b) If yes what problem was it?

i) Seedling wilting

ii) The land preparation being costly

iii) Was unable to get enough humus

iv) Expensive management

v) Others (specify)

c). Rank the above problems in order of priority

Problem encountered	Rank(Use 1,as the highest in priority up to 5 as the lowest)
Harsh weather conditions	
Land preparation cost	
Source of manure	
Expensive management cost	
Others (specify)	

2. a) Have you identified and insect or disease affecting your bamboo?

i) Yes

ii) No

SECTION D

On this section, reply with **(a) = strongly** to (**e) = strongly disagree,**

1. The area that I have planted my bamboo influences my choice to intercrop or not

   (a)Strongly agree (b) Agree (c) Neutral (d) Disagree (e) Strongly disagree

2. The size my land influenced my decision to intercrop

   (a)Strongly agree (b) Agree (c) Neutral (d) Disagree (e) Strongly disagree

3. The source through which I got information about bamboo farming influence my interest to intercrop

   (a) Strongly agree (b) Agree (c) Neutral (d) Disagree (e) Strongly disagree

4. Bamboo farming has many problems that influence my intercropping interest.

   (a)Strongly agree (b) Agree (c) Neutral (d) Disagree (e) Strongly disagree

5. The choice of intercropping was influenced by the training that a I got about bamboo farming

   (a)Strongly agree (b) Agree (c) Neutral (d) Disagree (e) Strongly disagree