A STUDY OF SOME FACTORS INFLUENCING DOMESTICATION AND ADOPTION OF INDIGENOUS TREE "ESWATA" (*Markhamia lutea)* BY COMMUNITIES IN TESO NORTH SUB COUNTY, KENYA

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UNIVERSITY OF KABIANGA

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DECLARATION AND APPROVAL

Declaration

This thesis is my original work and has not been presented for an award of a diploma or degree in this or any other University:-

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DEDICATION

This dissertation is dedicated to my family members for their utmost support and encouragement they gave me throughout the entire research period. Finally thanks to almighty God for his care and guidance in life.

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ABSTRACT

In the 19th century, tropical forests covered approximately 20 % of the dry land areas on earth. By the end of 20th century, this figure had dropped to less than 7 %. This is because more forest land is being converted to agricultural use and exotic forestry. Farmers pay little attention to domestication and adoption of indigenous tree species such as *Markhamia lutea* in agroforestry systems which could be more beneficial compared to exotic species. The study was undertaken with the following specific objectives: i) to determine socio economic factors influencing domestication and adoption of *M. lutea* in the study area ii) to determine the effect of *M. lutea* local provenances on seed germination rates in green house iii) to determine the effect of seedling production method on survival and growth rate of *M. lutea* of local provenance and iv) to evaluate types of soils present in the study area influencing germination and development of *M. lutea*. Structured questionnaire, field experiments and surveys were used to gather primary data. Data was analyzed using descriptive statistics, Chi-square test, analysis of variance (ANOVA) and Least Significance Difference (LSD) test. The study found the socio economic factors significantly influencing domestication and adoption of *M. lutea* in the study area ($p<0.05$) are gender, occupation, education level, household size, land and tree rights. Germination rates were as high as 98.7 % for seed from Kakamega provenance and as low as 93.7 % for seed from Siaya provenance. There was absolute survival rates under container mode and up to 99.0 % under bare root system. The height growth rate were as high as 0.7 cm/week for Kakamega provenance and as low as 0.25 cm/week for those from Siaya provenance under bare mode of production, however there was no significant difference in growth rates among the seed provenances. The population of *M. lutea* was highest in areas with predominantly sand-clay soil type and lowest in areas with loamy-sandy soil. This study has generated new knowledge which can benefit foresters and other stakeholders in quest for domestication and adoption of *M. lutea*.

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LIST OF ABBREVIATIONS AND ACRONYMS

AF	Agroforestry
AFTP	Agro Forest Tree Products
AHT	African Humid Tropics
ANOVA	Analysis of Variance
CRBD	Completely Randomized Block Design
EMCA	Environmental Management and Co-ordination Act
FAO	Food Agricultural Organization
FFS	Farmer Field School
FMNR	Farmer Managed Natural Regeneration
FORIG	Forest research Institute of Ghana
GDP	Gross Domestic Product
GoK	Government of Kenya
HH	Household Head
ICRAF	International Centre for Research in Agroforestry
ISFM	Integrated Soil Fertility Management
ISTA	International Seed Testing Association
IUCN	International Union for Conservation of Nature
LR	Long Rains
LSD	Least Significance Difference
Masl	Meters above sea level
NGO	Non-Governmental Organization
NMK	National Museums of Kenya
NTFP	Non Timber Forest Products
PELIS	Plantation Establishment and Livelihood Scheme.
SCD	Shoot Collar Diameter
SDG	Sustainable Development Goals
SFM	Sustainable Forest Management
SOW-FGR	The State of World’s Forest Genetic Resources
SPSS	Statistical Packages for Social Science

SR	Short Rains
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WUE	Water Use Efficiency

DEFINITION OF TERMS

The following terms were operationalized as follows:

Adoption is an acceptance of a new product or innovation.

Agroforestry is an intensive sustainable land use management system that optimizes the benefits from biological interactions created when trees and shrubs are deliberately combined with crops and /or livestock

Deforestation is the conversion of forest to other land uses or the permanent reduction of the tree canopy cover below the minimum 10% percent threshold (FAO, 2012a).

Domestication is the process of taking a wild species, bringing it into cultivation and then improving the desired characteristics of species.

Dormancy refers to a physical or physiological condition of viable seed, which prevents germination even in the presence of favorable conditions.

Experimental design refers to the framework or structure of an experiment.

Forest degradation refers to the changes in the forest that negatively affects its population capacity which may eventually result in deforestation.

Forest domestication refers to how humans select, manage and propagate trees where the humans involved may be scientists, civil authorities, commercial companies, forest dwellers or farmers.

Germination is the resumption of growth of the embryo and emergence or protrusion of the radicle from the covering structures.

Local provenance is a position maintained by ecologists that suggests that seeds should be planted of local provenance only.

Markhamia lutea is an upright evergreen tree between 10 to 15 meters (m) high, with a narrow, irregular crown and long taproot, bark light brown with fine vertical fissures at maturity.

Pricking Out refers to the process of transferring young and tender seedlings from seedbeds into containers (pots).

Randomization refers to the random determination of a run sequence of experimental units.

Seed provenance refers to the specified area in which plants that produce seeds are located or areas where seeds are derived from.

Treatments refer to the different conditions under which experimental and control groups are put.

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter covers the background of the study, statement of the problem, general objectives, specific objectives, hypothesis, justification, significance, scope, limitations and assumptions of the study.

1.2 Background of the Study

In the 19^{th} century, tropical forests covered approximately 20 % of the dry land areas on earth, by the end of 20^{th} century, this figure had dropped to less than 7 % (FAO, 2010). Tropical forests contain high levels of biodiversity (Brooks *et al.*, 2006). World's forests are important as carbon pools and provide a wide variety of other ecosystem services (Gullison *et al.*, 2007). Tropical forest constitute a vital source of raw materials, both for industry and rural communities that depend on forest products to meet basic livelihood needs.

Globally, planted forests and natural regeneration have increased the forest areas in United States, Europe, China, Chile, Uruguay, Cuba and Costa Rica (FAO, 2010). However, there is continued deforestation in Africa, Asia, the Pacific and tropical countries of Latin America, occasioned by demand for agricultural land, and income generation from logging, charcoal burning and exploitation of the forest products (Rudel, 2013). It is estimated that, the annual loss of forest cover was about 130,000 km^2 per year between 2000 and 2005, almost half of which was offset by activities such as a fforestation, reforestation and re-vegetation (FAO, 2006). The deforestation rate poses adverse effects on the environment and climate change (Burton, Musgrove, Rehfisch and Clark *et al.*, 2010).

In Kenya, deforestation is rampant particularly in villages and among highland farmers where land for cultivation is a priority. Population pressure, improper Government policies and disruption of indigenous traditional land-use practices, have contributed to forest land degradation (Kio and Abu, 1994). This has resulted to a forest cover of less than 1.7% that is below the world recommended cover of 10 %. It is therefore against this background that efforts to improve agro-forestry technologies need be encouraged. The Environmental Management and Coordination Act (EMCA) 1999 came up with measures to encourage the planting of trees and woodlots by individual land users, institutions and community organized groups (Ludeki, Wamukoya, & Walubengo, 2004).

Markhamia lutea is an indigenous tree common in the Lake Victoria belt and highland areas in central Kenya. It is a fast growing and is widely used in agroforestry farming (Van Schaik, 1986). It is used for the production of timber, poles, posts, fuel wood, furniture, tool handles, medicinal, bee forage, shade, mulch, ornamental, soil conservation, banana props, and firewood for tobacco curing (ICRAF, 1992). Its poles are harvested, and used for construction of traditional huts due to its durability, resistance to termite attack and coppicing ability (ICRAF, 1996). It does well in acid heavy clay soil but not waterlogged and prefers red loam soil (Maundu and Tengas, 2005).

In Teso Sub County the most predominant tree species are *Eucalyptus* and *Grevillea robusta* mostly used for firewood, timber and poles. Both of these species are prone to attack by termites and blue gum chalcid. Other indigenous trees on farms are reported to be reducing in population hence a need for sound agroforestry intervention.

Agroforestry farmers prefer indigenous tree species that are not susceptible to termites attack and blue gum chalcid infestation. Domestication of indigenous trees species through agroforestry is one of the major ways of land use transformation in Africa by establishing a better balance between food security and natural resource utilization (Fandohan *et al.*, 2010). This study, therefore seeks to determine the factors influencing domestication and adoption of indigenous tree "Eswata "*Markhamia lutea* in Teso North Sub County, Kenya.

1.3 Statement of the Problem

Due to high rates of population increase, unemployment, the use of forest products (firewood, charcoal, logging, forest encroachment) for subsistence income generation by significant proportion of the population and has resulted in degradation of indigenous forests. Consequently traditional land use systems such as indigenous tree species are facing serious threat of depletion (FAO, 2016). Farmers pay little attention to domestication and adoption of indigenous tree species such as *M. lutea* in agroforestry systems while more attention is given to exotic species such as *Grevillea robusta*, *Melia azediratch* and *Eucalyptus grandis* (Wierisum, 1997).

The socio economic factors influencing domestication and adoption of *M. lutea* have not been well documented in Teso North Sub County. The understanding of the factors involved may enhance its domestication and adoption. In addition there are several provenances of *M. lutea* in Kenya all displaying differences in seed, germination and seedling growth characters and therefore recommending which provenance (s) for where is a big challenge. Therefore understanding seed germination of some provenances is an important step in helping identify which provenances could be proposed for establishment in the study area.

There is also limited information on seedlings survival and growth rate of *M. lutea* local provenances using both bare root and container mode of seedlings production in the nursery. This is because the climatic pattern of Teso Sub County has both wet and dry seasons necessitating use of both methods.

Different types of soils influence germination and development of plants differently and that role of Teso soils on germination and development of *M. lutea* is not known. Determining soil types in the study area will be important when choosing the right tree species to site match the area for maximum growth and development.

1.4 General Objective

To investigate some factors influencing domestication and adoption of indigenous tree; "Eswata" (*Markhamia lutea)* by communities in Teso North Sub County, Kenya.

1.5 Specific Objectives of the Study

The following objectives guided the study:-

i. To determine socio economic factors influencing domestication and adoption of *M. lutea* in Teso North Sub County.
ii. To determine the effect of *M. lutea* local provenances on seed germination rates.
iii. To determine the effect of seedling production method on survival and growth rate of *M. lutea* of local provenance.
iv. To evaluate types of soils present in the study area possibly influencing growth and development of *M. lutea.*

1.6 Hypotheses of the Study

The following hypotheses were formulated:-

$H0_1$. Socio economic factors have no significant influence on domestication and adoption of *M. lutea* in the study area.

$H0_2$. There is no significant effect of *M. lutea* of local provenances on seed emergence rates.

$H0_3$. There is no significant difference on the effects of seedling production methods on seedling survival and growth rates of *M. lutea* of local provenances.

$H0_4$. There is no significant difference between soil types present in the study area that may influence growth and development of *M. lutea.*

1.7 Justification of the Study

Markhamia lutea is an indigenous tree species commonly found along Lake Victoria belt and highland areas of Kenya, where incidences of poverty are high (van Schaik, 1986). This makes diversification of sources that increase food and income in such areas a priority. In Kenya, many of the indigenous tropical tree species such as *M. lutea* have never been deliberately incorporated into plantation or farming systems, instead more emphasis is given to exotic species such as *Grevillea robusta* and *Eucalyptus grandis* which have dominated the tree planting programmes. With the introduction of such fast growing tree species and supposedly economically superior exotic tree species, the growth of *M. lutea* has been ignored and is at the virtue of getting depleted. Overall, there is very little literature or scientific data on domestication and adoption of the species in Kenya so as to guide its utilization and management in different land-use systems. In addition, recommendations for provenance selection for particular sites have rarely been done.

Enhancing the domestication and adoption of the species in study area will likely enable tree farmers to address the challenges of domestication and increase diversification of their income sources.

Domestication and adoption of indigenous species fail due to poor germination, low survival and low growth rates. Manipulating such parameters silviculturally shall lead to better results and therefore increased income to the community. Knowledge of which *M. lutea* seed provenances does well in bare root system of seedling production can be adopted in areas with adequate rainfall and labour less intensive for domestication and adoption.

Poor site matching of tree species in their environment results to their stunted growth, malformation and poor wood quality of undesired traits. With well-known types of soils and their characteristic shall help in programming whether to plant earlier or late during the onset of rainy season and lead to choosing tree species suitable for that particular site. Some soils are known to have high infiltration rates and others low. Once these information is known it shall lead to high germination rates and growth development of tree species in a given area. The benefits of domestication and adoption of *M. lutea* over exotic species in the study area is not documented. Having such knowledge can be an impetus in the species' domestication and adoption.

1.8 Significance of the Study

The research findings shall contribute to an improved domestication and adoption of *M. lutea* in the study area and enhance on-farm forestry development of indigenous species. The study shall also integrate local people's needs, with their valued tree species and the benefits accruing out of certain preferred agro forestry tree species such as *M. lutea*. Further these results shall help communities, stakeholders and policy makers to understand the need for on-farm a forestation not only in the study area but in other regions within the country with similar agro- climatic and soil conditions to enhance farm productivity, contribute towards realizing the 10% forest cover by the year 2030, upscale soil fertility management essential in poverty alleviation and environmental degradation, fulfillment of sustainable development goals (SDGs). Also the study shall be of greater importance in easing pressure on plantations and natural forest as the demand for wood material shall be met at farm level and the effects of deforestation minimized and for future reference.

1.9 Scope of the Study

The study was carried out in Teso North Sub County, Kenya and aim was to investigate some factors that influence domestication and adoption of indigenous tree; *M. lutea* by communities in Teso North Sub County, Kenya.

1.10 Limitations of the Study

The research findings were limited by inadequate funds, time, short term experimentation and the parameters monitored were not exhaustive to the determination of potential of the species for its domestication and adoption in the study area.

1.11 Assumptions of the Study

i. The research assumed that all the responses received from the sampling units were true and representative of the views of the large population.

ii. The daily chores of the respondents did not affect their availability for interview and generation of adequate representative sample of the entire population.

iii. That the seed germination and seedling survival rates in the experimental set up would be a representative of the actual field conditions.

iv. That the juvenile and mature growth characteristics of the species are positively correlated.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This Chapter presents the literature review on challenges towards domestication and adoption of indigenous tree species, their domestication strategies, seed germination rates, seedling survival rates, and growth rate under different nursery production conditions.

2.2 Botanic Description of *M. lutea*

Makhamia lutea is an indigenous tree species commonly known as Eswata (Iteso), Lusiola *(*Luhya), Omubwo (Kisii), Mgambo in Swahili and Markhamia as the trade name. It belongs to *Bignoniaceae* family. It's an upright evergreen growing tree with an average height between 10 to 15 meters (m). It has a narrow and irregular crown with long taproot (Orwa, Mutua, Kindt, Jamnadass and Anthony, 2009). It has a light brown bark with fine vertical fissures, thin and waxy compound leaves existing in bunches. Each leaflet measuring up to 10 cm long. Their flower buds vary from yellow, green to furry (Orwa *et al.*, 2009).

2.2.1 Taxonomy

Makhamia lutea is an angiosperm plant belonging to kingdom (plantae), division (*Tracheophyta*) , Subdivision (*Spermatophytina*), class (*Magnoliopsida*) Sub order (*Asteranae*) , order (*Lamiales*) , family (*Bignoniaceae*), genus (*Markhamia*) , and species (*Markhamia lutea*) (Schmidt and Mbora, 2008).

2.2.2 Ecology and Distribution

According to Orwa *et al.* (2009) the species is common in the Lake Victoria basins and highland areas of eastern Africa .It is a drought resistant species and cannot withstand water logged areas

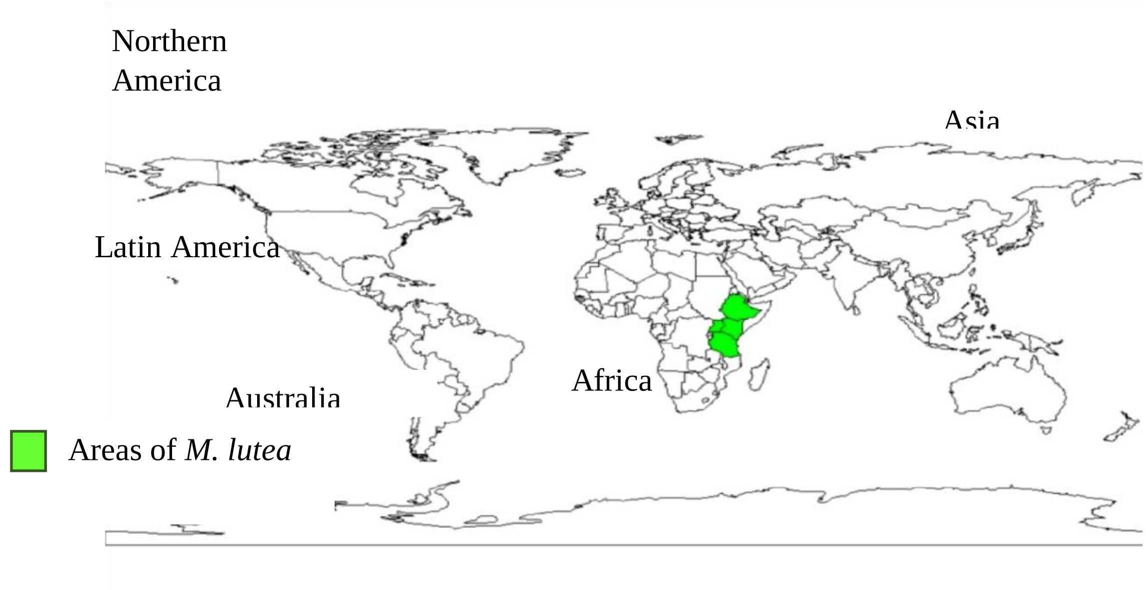

Figure 2. 1: Map showing *M. lutea* Distribution Source: Orwa *et al.* (2009)

2.2.3 Biophysical Adoption of *M. lutea*

Markhamia lutea does well between mean altitudes of 900 to 2000 meters above sea level (masl), Mean annual temperature (12-27°C) and Mean annual rainfall between 800-2000 mm. Orwa *et al*. (2009). It prefers loam soil and can tolerate well-drained, heavy, acidic clay soils (Orwa *et al.*, 2009).

The species flowers for much of the year. In western Kenya, flowering occurs from August to September, followed by seeding in February to March, while areas in the east of Mt Kenya, the flowering period is between December and January and the seeding period July to August. The seeds take six months to develop after insect pollination (Orwa *et al.,* 2009).

2.2.4 Functional Uses and Services of *M. lutea*

The species is good for protective, productive, regulative and accessory functions according to Orwa *et al.* (2009). The species is excellent in Ecosystem conservation, production of commercial timber, firewood, poles, banana props; its woodlots are good for bee foliage and cultural values (Orwa *et al.*, 2009). The large conspicuous yellow flowers make the species popular for ornamental use. It is frequently planted a long roadside or in parks in cities and towns (Schmidt and Mbora, 2008).

The tree species is highly recommended for use in soil-conservation, shade and shelter (ICRAF, 1996). It provides useful shade and acts as a windbreak. It improves soil through mulching, which enhances soil-moisture retention and increases organic matter. It's attractive and worth planting as a screen or background tree for gardens and on golf courses. *M. lutea* poles are used as props in providing support for banana trees (Orwa *et al.,* 2009).

2.2.5 Management of *M. lutea*

Dart, Brown, Simpson, Harrison and Venn (2001) argued that the majority of the smallholder plantings have limited success due to lack of integrated package of tree management practices. In good forest soil the *species* grows fast, and can attain a minimum growth rate of more than 2 m/year according to Djoudi and Brockhau (2011) whom further recommended that the tree should be planted in a deep hole due to its long root characteristics.

Markhamia lutea trees can be pruned and pollarded to reduce shading effect on farm crops. Seeds are harvested from the tree after the Pods turns grey. Across Africa, women care for their families and are responsible for gathering firewood for cooking. Firewood scarcities are likely to increase their burden at a time when men are increasingly migrating to towns and transferring their activities, such as small ruminant herding, to women hence need for proper tree management for sustainable wood products (Djoudi and Brockhaus, 2011).

To safeguard livelihoods and reduce poverty among communities that are dependent on naturally growing plants, it is important that the species they depend on are sustainably managed (Kiptot and Franzel, 2011).

2.2.6 Pests and Diseases

Damage from shoot borers of the genus *Hypsipyla ragonot* (*Lepidoptera: Pyralidae*) presents the greatest deterrent to the establishment and cultivation of the high value timber species (Orwa.*et al.*, 2009). The most serious damage to the tree results from the tunneling of the larva in the developing shoots. The boring leads to the death of the terminal shoot and subsequent production of laterals, eventually resulting in a stunted, continuously branched and crooked tree of greatly diminished value for timber production. Growth rate is reduced and death can result from heavy and repeated attacks. Damage has been recorded on trees from age three months old and 50 cm height (Kalshoven, 1926), up to age 14 years and 15 m height (Froggatt, 1923; FAO, 1958; Streets, 1962; Suratmo, 1977). The borer is thus a problem to both nursery and planted stock.

The current criteria for choice of woody plants are largely dictated by the envisaged role of a particular agroforestry system. These criteria are less rigid and relaxed when weight against the potential insect pest problems associated with such undertakings. There is therefore a need for rigorous exercise in choosing woody plants for agroforestry that are resistant to pests and diseases. This exercise should preferably be based on the useful attributes of the woody plants which have been carefully weighed against the potential insect pests associated with the tree species (Janzen, 1969). The control of shoot borers is by either through mechanical, chemical, biological or cultural practices as described by Orwa *et al.* (2009).

2.2.7 Conservation Status

Conservation of indigenous tree species is crucial for restoration of ecosystems and provision of livelihood support functions among rural communities according to Byabashija *et al.* (2004). Rural communities have, for long, relied on indigenous trees for food, medicine and income (Schreckenberg *et al.,* 2006). These species also contribute to a cleaner environment as they sequester more carbon compared to exotics (Abebe *et al.* 2011). Often, collection, processing and marketing of indigenous tree products represent a significant portion of rural household income particularly where farming is marginal (Scoones *et al.,* 1992). With more intensification of agroforestry, exotic tree species have begun to dominate agricultural landscapes. Most tree planting initiatives are promoting exotic species ignoring native species on which populations have for long depended (Sekatuba *et al.,* 2004), leading to neglect of indigenous species which are more adapted to local environments. Also, many indigenous tree species are becoming scarce due to unsustainable land management practices and destructive harvesting methods.

The Forest Policy 2014 has a clause on protection of indigenous forests and it aims at "promoting ex-situ and in-situ conservation of forest genetic resources" as well as "encourage and support land owners to sustainably manage natural and riverine forests. In many farming communities in southern Africa, there is declining of tree genetic resources due to deforestation (Akinnifesi *et al*., 2007). Other drivers such as forest fire, drought and floods are also ravaging the region. According to Bewley and Black (1983), seed conservation has been the most reliable and widely used method for *ex situ* storage. The Forests Act (2005) has recognized the importance of involving stakeholders including local communities in the management of forests.

2.3 Theoretical Framework

Many rainforest tree species are considered economically and socially of high value. For instance, Costa Rica has 150 valuable timber species (Carpio, 1992), most of them native, amongst a total of 1600 tree species. Considerable research has been done on native species in plantations in Costa Rica and Panama (Hall, 2011a, b), particularly on initial growth and behavior in both pure and mixed stands, and on potential for environmental services. However, it appears that few operational plantings have been stimulated as a result of this research, and it remains unclear how best to empower uptake of early domestication research.

Streed (2006) estimated that small scale plantings of native species on the southwest coast of Costa Rica could be profitable within fifteen years after plantation establishment. Piotto

(2010) reached the same conclusion after evaluating silvicultural and economic aspects of pure and mixed plantations in the Atlantic region of Costa Rica, and recorded the best growth after 15–16 years, amongst *Vochysia guatemalensis*, *Virolakoschnyi species*, *Jacaranda copaia*, *Terminalia amazonia* and *Hieronyma alchorneoides*. Where long-term tree improvement programs are not evident for these species, several have been planted at the scale of hundreds of hectares. Indeed (Sollis and Moya, 2004a, b, c) recorded 807 hectares (ha) of *Hieronyma alchorneoides*, 947 ha of *Vochysia guatemalensis*, and 2282 ha of *Terminalia africana* which has long been regarded a premium species throughout its natural range within Mexico, Central America, the Caribbean and Brazil. As is often the case indigenous peoples and colonial foresters were well aware of the desirable properties of this and other native species and the ecology and silviculture of this species are well established (Marshall, 1939). Since this is a long-lived pioneer species it has long seemed a candidate for domestication.

The term ‘Cinderella trees’ (Leakey and Newton, 1994) is now widely accepted as a phrase applicable to traditionally important indigenous species that have been overlooked by science for agroforestry as evidenced by the term used in numerous articles and conference proceedings (Leakey *et al.*, 1996). Similarly, the need to rapidly domesticate the Cinderella trees has been accepted and is now one of the three pillars of ICRAF’s research program. Domestication, however, is not only about selection, as domestication integrates the four key processes of the identification, production, management and adoption of agroforestry tree genetic resources (ICRAF, 1997).

Leakey *et al.* (1996) defined the domestication of trees producing non timber forest products (NTFPs) as ‘a progression from collection and utilization of products, through protection, management and cultivation, which culminates with genetic manipulation.

2.3.1 Strategies for Domestication of Indigenous Tree Species

Domestication is the process of taking a wild species, bringing it into cultivation and then improving its desired characteristics (Nichols and Vanclay, 2012). Despite this history of using trees, little research has been done on the domestication of important native timber species. For example two of ACIAR’s forestry projects in Vanuatu, with a combined investment of $1.2 million over five years, are looking into the growth and management of whitewood and the improved availability of whitewood germplasm. Whitewood is a fast growing hardwood species in the natural forest that is well suited to plantation and agroforestry situations and is able to survive cyclones without major damage. Improved knowledge of whitewood silviculture should enhance the benefits to both the landowners who grow the trees and the processing industries that will utilize them. This special issue deals with a diverse series of insights derived from these ACIAR projects in Vanuatu, covering the constraints (Aru, 2012), establishment (Grant *et al.*, 2012), silviculture (Glencross, 2012; Grant *et al.*, 2012a), genetics (Doran, 2012; Settle, 2012) and marketing opportunities (Viranamangga, 2012).

Recent literature on domestication of forest trees is dominated by research on biotechnology and molecular genetics (Harfouche, 2012), which, although important, is just one aspect of domestication (Leakey, 2012). With much of the earlier literature dwelling on propagation potential. However, Simons and Leakey (2004) offered a more comprehensive assessment addressing 14 aspects of domestication of indigenous trees. He concluded that the prevailing problem is that information is incomplete, and has led to sub optimal tree domestication strategies. While tree domestication work has increased, the documentation of the logic and the approach has been generally scant. Even when results are shared or published, it is typically the positive outcomes that are reported and not the successful processes. A few case studies of tree domestication strategies have been documented (Simons and Leakey, 2004), and decision-frame works have been offered for domestication of agroforestry fruit trees (Leakey and Akinnifesi, 2008), but clear guidance for domestication of forest trees remains scarce. Jamnadass *et al.* (2009) offered useful generalized 'domestigram' (appendix 2) indicating possible pathways for tree domestication. A notable feature of the diagram is the central chain involving identification, production, management and adoption, which is key to the domestication process. A 'whole of chain' approach is essential, and success with the domestication process may depend on the weakest link in this chain.

Kalinganire (2005) observed that over-emphasis on a single aspect may lead to dysfunctional outcomes. For instance, they offer anecdotes highlighting that identification alone is not domestication, because there may be an inability to provide sufficient seeds, and that an over emphasis on management to the neglect of adoption, may result in guidelines that are impractical in a large scale situation, or which produce a yield far in excess of market needs. (Underwood, 2006) is one of the few scientists who has commented on the importance of encouragement: identified incentives must attract investment, resolve technical problems, enhance growth and development and lead to a self-sustaining industry-driven commercial enterprise capable of operating without direct financial input from governments”. The challenge is to ensure that such incentives can be sustained (Enters, 2009).

2.3.2 The Scope for Domestication

Almost 7% of forests worldwide, some 271 million hectares (Ha) are industrial plantations (Carle, 2009), potentially able to supply two thirds of the world’s demand for wood, but at potential risk of pests and disease because of the relatively few species and in some cases, the rather narrow genetic base.

Amongst several thousand tree species in the world only about 30% have been extensively planted. Tropical timber plantations comprise some 50% *Eucalyptus*, 23% *Pinus*, 17% *Acacia* and 10% *Tectona* (Evans and Turbull, 2004). Varmola and Carle (2002) estimated that out of a net area of 56.3million ha of tropical and subtropical plantations, there were approximately 32.3 million Ha in hardwood plantations. (Evans, 2009) argued that the prospects for substantial hardwood plantations in the tropics were “bleak” because of the need for long rotations, the high costs of establishment and maintenance, and potential disease risk. For instance, *Meliaceae* are handicapped by *Hypsipyla* shoot borers (Mayhew and Newton, 1998) and *Dipterocarpaceae* suffer from difficult establishment and erratic growth (Weinland, 1998). The well- known exception for cabinet grade timber is *Tectona grandis* but for the most part tropical plantations are of the fast-growing “industrial” species, in spite of the large number of tropical species with premium timber.

The domestication of agroforestry trees is a technique for the intensification of agroforestry as a low input farming system delivering multifunctional agriculture for the relief of poverty, malnutrition, hunger, and environmental degradation in tropical and subtropical countries (Leakey, 2010, 2012).

For decades there have been calls for native rain forest trees to be domesticated and planted (Evans and Turnbull, 2004; Kanowski and Borralho ,2004) estimated that some 200 tree species have been subject to one breeding cycle and 60 species have been worked on more intensively. Notwithstanding continuing calls for greater diversity in planted forests (Diaci, 2011), current market forces tend to favour single species plantings (Nichols, 2006) and greater diversity and resilience of plantations will not be achieved without domesticating additional species.

General principles to be followed in initiating the selection process are described briefly in (White, 2007). Key aspects of the process include the need for clarity about the traits to be improved (based on best information on probable end use) and for comprehensive sampling of the existing resource.

Harvesting seed from desirable phenotypes can help to avoid poor seed sources (Cornelius, 2011), but such phenotypic selection is not always reliable. For instance, is the domestication aspect of the Indigenous tropical tree *Markhamia lutea* (Eswata) of any benefit to local communities in Teso North Sub County?

Further approaches to improve soil fertility in Africa include farmer-managed natural regeneration (FMNR) of *Faidherbia albida* and other leguminous trees, which since 1985 in Niger alone has led to the ‘regreening’ of approximately 5 million hectares (Sendzimir *et al.*, 2011). FMNR in the Sahel region has resulted in increases in sorghum and millet yields, with greater dietary diversity and improvements in household incomes also observed in some locations (Place and Binam, 2013). Unlike the wide-scale planting of exotic trees in improved fallows, FMNR is based explicitly on indigenous species, which may better support biodiversity and other associated environmental services (Haglund *et al*. 2011). Trees in farmland can also support the conservation of natural tree stands in fragmented forest agricultural mosaics by acting as stepping stone or 'corridors' for pollen and seed dispersal that help to maintain the critical minimum population sizes needed to support persistence and, for managed forests, productivity (Bhagwat *et al.*, 2008). Species-diverse farming systems that provide rich alternative habitat for animal pollinators can support pollination and hence seed and fruit production in neighboring forest, including of seed and fruit that are important NTFPs (Hagen and Kraemer, 2010).

The identification of species preferred by individual households is decisive to tree and other woody species management because farmers will only invest in such species, if the selected trees provide them with clear benefits. However, there are woody species that are threatened but which must be managed by the state or the local governments. These include: 1) species valued by farmers, but for which farmers lack the essential skills and capital resources to manage; 2) species that are important to only a small section of the community, e.g., medicinal plants; and 3) species not highly preferred by farmers but which must be conserved to maintain ecosystem services such as flood control (Diaz, 2006).

Given that participatory domestication involves selection and management of the most highly valued trees and cultivars, prioritization is the first logical step to obtaining premium species. Guidelines for systematic priority setting in different regions involving the participation of local communities and partners have been developed (Franzel, 2007)

2.4 Challenges of Domestication and Adoption of Indigenous Tree Species

Challenges facing tree domestication in an agroforestry set up revolves around social-economic and cultural issues (Makori, 2017). Domestication of agro forestry tree species may be influenced by a number of factors such as economic value of trees is a key factor in farmers' adoption (Gitonga, 2012) and the type of tree species available to the farmers for planting. Farmers in most cases tend to accept multipurpose and fast growing tree species that yield benefits early rather than those that have long maturity periods (Sharma, 1998). Labour shortage has tended to discriminate against categories of farmers (Aboud, 1997), when tree production requires a high input of labour (Kerkhof, 1990), farmers tend to resist.

In Nyeri (Kenya), farmers gave reasons for not planting trees with crops as, trees shade crops and reduce yields, and that farm units were small (Chitere, 1985). In Rwanda, for example in a place called Nyabisindu, farmers noted that the planting and use of *Leucaena leucocephala* and *Calliandra calothyrsus* for fodder increased milk production and dung for manure leading to improved crop production and household income (Kerkhof,1990). Socio-economic diagnosis of traditional as well as commercial agroforestry practices followed by farmers in western Uttar Pradesh carried out by Dwivedi *et al.*(2007) and they found that tree species like *Azadirachta indica*, *Acacia nilotica*, *Dalbergia sissoo* and *Eucalyptus spps* were dominant species in traditional system whereas, *Populus deltoides* and *Eucalyptus spp.* were the main species of commercial agroforestry. Fuel wood (50.6

%) was major driving force for agroforestry adoption followed by additional income (24.4 %) and shade (17.5 %) in traditional agroforestry.

The natural forest resource continues to play a major role in improving the livelihood of rural communities (Tiwari *et al.,* 2017). However, the current levels of deforestation which cause land degradation, soil nutrient depletion, loss of natural habitats and therefore change in structure and composition of the natural woodlands. Improved agroforestry systems bring significant change in the agricultural farming systems among farming communities (Tiwari *et al.*, 2017).

A study on the factors affecting the adoption of an agroforestry practices in Cameroon found that one of the reasons for low adoption of agroforestry practices has been that the fact that studies and information has not covered all geographic areas where unique interventions are needed for specific areas (Nkamleu and Manyong, 2014).

2.4.1 The Socio-economic Factors Affecting Tree Domestication and Adoption

Socio-economic factors are aspects that relate to social and economic conditions in communities and less to the cultural and biophysical environment. These include income, occupation, education level, farm size and family size. These factors variously influence the adoption of farm forestry technologies among farmers (Makori, 2017). Tree species, crops grown, farm size and local planting practices were found to influence tree domestication and adoption in Western Kenya (Kimwe and Noordin, 1994). Level of education as a socio-economic factors influencing adoption of agro forestry development and production system has been found to be controversial (Okuthe *et al.*, (2013). The author argues that the relationship between a farmer's level of Education and farm practice is indirect except where persons learn new practices in school and where this is not the case, education may merely create a favourable mental atmosphere for acceptance of new practices. Rahim *et al.* (2013) found similar results in his studies on the influence of education level in adoption of new agroforestry technologies. According to Adesina *et al.* (2000) farmers with a higher education level are more likely to adopt new innovations compared to less educated farmers. Mekoya *et al.* (2008) also emphasized that agroforestry technologies are knowledge intensive and therefore require high levels of education.

A study by Rahim *et al.* (2013) with an aim to examine social factors which affect farmers' adoption of agroforestry system in Azna, Iran, found out that, educational level of the respondents had a positive correlation with agroforestry adoption (r = 0.560). Majority of the household heads interviewed had a post primary education and least number of respondents had a primary level of education and below. The higher the educational level of the household head, the higher the adoption levels of agroforestry practices (Rahim *et al.,* 2013). The study concludes that; education of the household head plays a crucial role in agroforestry adoption, since education enhances an understanding of new technologies hence the probability of adoption is increased.

Twaha *et al.* (2016) carried out a study, with the objective to assess the socioeconomic factors that affect agroforestry adoption in the eastern agro-ecological zone of Uganda, he reported a positive correlation between education level and agroforestry adoption (r^2=0.671). He stated that, farmers with a secondary level of education and above tends to embrace agroforestry more because education enhances obtaining information as well as promoting awareness on new agroforestry practices, consequently encouraging adoption.

A study by Oino and Mugure (2013) with the objective to assess farmer-oriented factors that influence adoption of agroforestry practices in Kenya, Nambale District, Busia County found that there was a strong positive correlation (r^2 = 0.613) between the household head level of education and the number of trees planted on the farm. The number of trees in the household farm was related to household head level of education. The study further reported that majority of the farmers with less than 10 trees had low level of formal education (below primary school level of education), while those with above 30 trees had higher levels of formal education, i.e., above secondary school level of education. Therefore, the study concludes that; education level of the household head influences decision to adopt agroforestry practices at the household level.

Okoba *et al.* (2013) carried out a study in Laikipia County in Kenya, with an objective of assessing farmers' perception on adoption of conservation agriculture. Found that the level of education of the household heads to be 2% illiterate, 47% primary school, 44% secondary school and 8% tertiary level. The findings revealed that; the level of education of the head of the household had influence on agroforestry adoption among farmers. The results showed that farmers who are more educated are more likely to practice agroforestry and other conservation agriculture practices.

2.4.2 The Socio-Cultural Factors Affecting Tree Domestication and Adoption

A Study by Irshad *et al.* (2011) with an objective of identifying factors affecting agroforestry system in Swat, Pakistan found that farmers' willingness to grow trees on their farms was as a function of their sociological, cultural and economical characteristics. This refers to norms, rules and attitudes that govern the meaning of certain activities for individual and groups. They also govern the organization of activities and behavior of individuals in the course of participation in such groups (Tengnas, 1994); activities that are designed around existing cultural and social structures, taking into consideration local customs, beliefs, values and even taboos, are socio-cultural. For the purpose of this study, socio-cultural factors will include land tenure, traditional beliefs, public awareness and availability of extension services. Farmers' adoption of agroforestry practices also vary with socio-cultural practices of the community and that adoption by an enforced policy frequently may not work (Young, 1989).

The extent of tree domestication and the involvement of the local farmers are directly related to the flexibility of the land tenure system (Adayoju, 1984). This shows that land tenure is crucial in the adoption of agro forestry technologies by farmers (Binswanger, 1980). Most farmers in Kenya find it unacceptable and unattractive to invest in tree planting on land which is not confirmed legally as theirs (Tengnas, 1994).

2.4.3 Traditional Beliefs and Taboos

Cultural beliefs, superstitions and taboos are found in perpetually all cultures throughout the world. This class of informal institutions defines the human behaviour and also guides people's conduct towards the exploitation of the natural resources (Negi, 2010). Certain traditional beliefs are found to be factors that influence farmers' adoption of tree domestication technologies (Issa1 *et al.*, 2016). Among some communities in Kenya, women cannot plant trees because doing so may mean ownership of land (Gichuki and Njoroge, 1989). Sometimes, women are constraint by taboos and beliefs for example if a woman plants a tree she will become barren (Ndei, 2014). In some communities, trees belong to men regardless of who plants them. For example the traditional Fig trees are only planted by men and women are not even allowed to cut branches from such trees ,if they do so they will become barren", communities that hold these beliefs and taboos, traditional land tenure and ownership rights also believed that tree planting decisions in many communities are the domain of male heads of household (Rotich *et al.,* 2017). According to FAO (2011), in Rwanda women have the primary responsibility for food production but custom does not allow them to plant trees.

2.4.4 Farm Size

Farm size refers to the preference of the farmers to grow as much food for their household and the market for sale as possible. When farm size is large and labour availability is low, then farmers may be more ready to adopt agroforestry practices such as woodlots (Edinam *et al.*, 2013).

The high rate of increase in population in Kenya has led to fragmentation of land (Gitonga, 2012). For example in the coffee subsistence zones of Kenya, the land parcels are small and shared by too many people, so that after planting cash and food crops, leave limited space for planting of *M. lutea*. Many agroforestry technologies require reasonable farm size according to Ragland and Lal (1993).

A study carried in Bangladesh found out that tree planting increased with the size of homestead land while the farmers whose main source of income was non-agricultural were more likely to decide to plant trees in their homestead (Salam, Noguchi and Koike, 2000). Households with large farm sizes were willing to plant trees that were compatible with farm crops (Cramb *et al.*, 1999). Similar Amsalu and Graaff (2007) found that in Ethiopia, farmers with large farm sizes were more likely to invest in soil conservation measures as they can take more risks, including relatively high investment, and survive crop failure.

Maluki *et al.* (2016) carried out a survey targeting smallholder households in the semi-arid Makueni County, Kenya. The objective of the survey was to ascertain the various agroforestry practices adopted and the extent of adoption. Roughly 234 respondents were interviewed. Adoption of agroforestry was positively correlated with size of landholding (r^2 = 0.507). The bigger the land, the higher the likelihood to invest in agroforestry technologies suitable in the semi-arid areas and that the farmer can plant in parts of the land deemed suitable without restrictions. 23% of the respondents own less than 3 acres, 59% own between 3.1-6 acres and 18% own above 6.1 acres. The studies failed to recognize that farmers with a small size of land are likely to adopt agroforestry technologies to improve soil fertility, through intercropping fertilizer trees with crops.

Geremew (2016) carried out a study in Mecha rural district, found in Amhara National Regional State in the Northwest of Ethiopia. The objective of the study was to investigate the factors that influence the agroforestry adopting decisions of the farm households and its effect on farmland productivity. The findings show that; farm size has a positive correlation with agroforestry adoption (r^2 = 0.834). The study records that as farm size increased by one hectare, the probability of adopting agroforestry of that household would rise by 28.2% units. The study concludes that, where there is surplus farmland the household can be motivated to allocate the additional farmland for cash generating agroforestry practices. Kassa (2015) also found similar findings.

These studies have failed to indicate how the sizes of the farm influence the farmers' decision to plant or not to plant trees. Therefore this study seeks to fill this gap by, finding out the various farm factors that play a role in the farmers' decision making to adopt or not to adopt agroforestry.

2.4.5 Constraints to Farmers Influencing Tree Domestication Technologies

The importance of trees, need to retain and remove them have always conflicted with the need for agricultural land (FAO, 2000). Tree planting generally coincides with agricultural activities which are always given first priority. The need to provide food through agriculture is a first priority all over the world while the need to conserve forests is to ensure sustainability of the global ecosystem (Sharma, 1992). International and National forest policies have had detrimental impact on small holder farmers' decision to plant trees. The policies immediate intention is to prevent indiscriminate felling of trees (ICRAF, 1992), which makes farmers uncertain as to why they should plant trees that they cannot cut for their needs without approval from forest authorities.

A study by Matata *et al.* (2010) on socioeconomic factors influencing adoption of improved fallow practices among smallholder farmers in western Tanzania found that farmers face a number of constraints that hinder them from establishing and using improved fallows. Such constraints included lack of awareness and poor knowledge on improved fallow, lack of interest to plant trees, the long time it takes to realize benefits from trees, as farmers have to wait for two years before getting benefits from improved fallow and lack of seeds or seedlings. Similar study carried out in Zambia revealed that the major constraints to planting an improved fallow were lack of awareness, lack of seeds or seedlings and unwillingness to wait for two years before realizing of the benefits of the technology (Ajayi *et al.*, 2003).

2.4.6 Land and Tree Tenure Rights

Land tenure refers to the possession and rights to use land. Agroforestry production systems that involve the local farmers will directly be related to the flexibility of the land tenure system (Rotich *et al.,* 2017). Land tenure has long been considered a critical factor in determining the adoption and long-term maintenance of agroforestry technologies (Mercer, 2004). Tenure in agroforestry concerns both land tenure and tree tenure. Because of the long term nature of agroforestry systems, security of land tenure is important for adoption of agroforestry system (Matata *et al*., 2010). Access to land on which the farmer has the right to plant trees; rights over trees must be sufficient to justify the effort of planting them and the right to harvest and utilize trees must be exclusive enough to give a return on investment. If the farmer does not have the security that the land will be his for a longer time, then he will not be interested in activities to improve the soil (Glover, 2011).

In Kenya, most farmers find it unacceptable and unattractive to invest in tree production on land, which is not legally theirs (Tengnas, 1994). In Kitui County, Kenya, it was found out that secure tree, land tenure, relative freedom to harvest trees and sell products were an incentive for farmers to adopt tree planting (Makindi, 2002). Bruce and Fortmann (1988) state that land tenure systems which do not guarantee continued ownership and control of land are not likely to be conducive to the adoption of long-term practices such as agroforestry.

Ehrlich *et al*. (1987) stated that secure land rights have proven pivotal in determining whether the benefits of agroforestry reach the intended beneficiaries. Mercer, (2004) reviewed agroforestry adoption research from the tropics and found that in studies which tenure was significant variable, secure land tenure was positively associated with adoption. Property rights to land shape farmers" expectations of whether and how they will be able to appropriate long-term benefits from investing in tree planting and management (Meinzen, 2006).

Thangata *et al*. (2007) reported that farmers in Southern Malawi with small land holdings resorted to adoption of maize tree intercrops of species like *Gliricidia sepium, Sesbania sesban, Leucaena* species and pigeon peas. In addition land tenure is crucial in adopting agroforestry as farmers are very willing to invest on land whose security is guaranteed. Farmers feel that if they do not own the land then they cannot own the trees planted on that land (Chitakira & Torquebiau 2010; Kabwe, 2010). This is in agreement with findings by Place and Otsuka (2011) where they report that even in matrilineal societies of Southern Malawi where land tenure is under the women, the decision making power of women regarding tree planting is not guaranteed.

2.4.7 Seed Germination and Germplasm Management

Many tree species of economic potential are propagated by seeds, but in some seed germination formation is limited due to inadequate research (Mng'omba *et al.*, 2007). This frustrates genetic conservation, ecosystem restoration, and domestication and biodiversity efforts. Seeds are better sown fresh, while after extraction for high germination rate (Mng'omba *et al.*, 2007). Seeds can be dried in the sun to 5-10% moisture content. Mature and properly dried seeds can be stored in hermetic storage at $3^{0}{}_{C}$ for several years with no loss of viability. On average, there are about 75 000 seeds/kg of *M. lutea* (Orwa *et al.*, 2009). According to Schmidt and Mbora (2008), good germination result is achieved when seeds are sown directly on the surface without covering them with soil and it's greater than 50 % under optimal conditions.

The Kenyan Forest Seed Centre has been unable to meet the demand for seed of *Markhamia lutea* since 1990. The shortfall amounted to about 1.5 million seeds in 1994 (ICRAF, 1996). Biological diversity for tree species is now becoming a priority, and hence robust germplasm conservation programs are needed. Seed germination is defined as the emergence of the embryo from the seed and the germination process is triggered by a variety of anabolic and catalytic activities (Bewley and Black, 1983). Many tropical and subtropical tree species are known to produce recalcitrant seeds (Berjak and Pammenter, 2004), but there is still limited knowledge on the germination behavior of such tree seeds, especially wild tree species. Variations in seed morphological characteristics, germination and seedling growth among provenances of the same species have been reported for many forest trees including *Faidherbia albida* (Dangasuk, Seurei and Gudu, 1997). Variation among the provenances might be attributed to genetic differences caused by the adaptation of different provenances to diverse environmental conditions (Ginwal *et al.*, 2005) and soil types (Elmagboul *et al*, 2014).

2.4.7.1 Seedlings Growth and Survival Rates in Bare Rooted and Container Mode

Tree growth refers to quantitative biomass change occurring during development, defined as irreversible change in the size of cells or organs or the whole organism (Sievänen *et al.*, 2000). Gregorio *et al.* (2004) revealed that nursery operators' lack of knowledge on appropriate nursery cultural practices and their limited access to sources of high-quality germplasm have led the production of low-quality planting stock in most tree nurseries. Moreover, lack of information on site and species combination and narrow species base have resulted in planting of most species in unsuitable sites resulting in poor growth performance of planted trees.

Seedlings survival rates and the factors influencing mortality are unaccounted for in many restoration projects (Sullivan *et al.*, 2009). Compared with direct seeding or assisting natural regeneration, planting container-grown seedlings (e.g. one year-old plants) may reduce the time required to achieve canopy closure (Bergin and Gea, 2007).

There are, however, drawbacks associated with using container-grown seedlings for a forestation. For example, planting potted seedlings raised in nurseries is more expensive and labour intensive than direct seeding or assisting natural regeneration (Douglas *et al.*, 2007). Understanding plant mortality is a complex process, and is highly context-dependent and species-specific (Holzwarth *et al.*, 2013). Mortality of seedlings, however, generally decreases over time and can become negligible in as little as 2 years after planting (Ledgard and Henley, 2009). Kureel (2006) reported that the container or polythene bag method of seedling production gave inferior seedlings as compared to the bare rooted system.

2.4.7.2 Tree Provenances

Studies have shown that the success of forest tree plantations in the tropics does not depend only on the choice of species, but also on the seed source (provenance) of the species being planted. Shu *et al.* (2012) stated that plantations in developing countries often fail because of lack of research on provenances or because of lack of tree improvement programmes in general. A number of studies are available on provenance variation as related to the growth performance of tree species. Of the species thoroughly studied in this respect and utilized in Ghana, *Tectona grandis* and *Gmelina arborea* (Lauridsen *et al.*, 1987) can especially be mentioned. Recently, there has been an initiation of Iroko (*Milicia excelsa*) provenance trials in Ghana by Forest Research Institute of Ghana (FORIG) with the aim of providing information that could enhance selection and subsequent domestication of the species (Appiah *et al.*, 2001). In a recent literature review based on more than 400 publications, Leakey, (2012a) assessed the progress that had been made in agroforestry tree domestication over the last ten years in comparison to the decade before. In the first decade, there was a focus on assessing species potential and the development of propagation techniques, more emphasis was placed on new techniques for assessing variation, on product commercialization, adoption and impact issues and lastly suggest that a major challenge worldwide will be to scale up successful agroforestry tree domestication approaches.

Takuathung *et al.* (2012) also noted that selection of the best provenance of a species for a given site or region is necessary to achieve maximum productivity in agroforestry. A major decision in forest management is the selection of seed sources for reforestation to ensure a successful crop (Shu *et al*., 2012). This decision could be assisted by seed zone and seed transfer rules, by determining the size of seed zones thereby reducing the risk of planting poorly adapted trees (Hamann *et al.*, 2000) and ensuring the use of well-adapted planting stock (Ibrahim *et al.*,1997). Koech *et al.* (2014) also observed a higher variability between Eastern African provenances than Southern African provenances of *F. albida* and attributed it to high variability in environmental conditions within the regions.

2.4.8 Influence of Soil Types on Tree Seed Germination and Development

Successful germination and seedling establishment are crucial steps for maintenance and expansion of plant populations and recovery from perturbations (Böhlenius *et al.*, 2016). Studies by Abdalla and Hassan (2013) showed that survival of seedlings in arid and semi-arid zones is strongly affected by water availability and soil type. Studies show that *Jatropha* grows on well drained soils with good aeration and is well adapted to marginal soils with low nutrient content (FACT Foundation, 2006). Soil texture and drainage are two of the most important factors for successful poplar plantation establishment and growth (Baker & Broadfoot, 1979). Poplars are generally considered to prefer well drained alluvial soils with sufficient moisture and nutrients and an intermediate soil texture (sand/loam) (Baker & Broadfoot, 1979).

In northern climates, sandy soils can favor the growth of Populus x wettsteinii (hybrid aspen) as these soils warm earlier in spring, but this advantage may be offset by the risk of drought conditions later in the growing season (Tullus *et al.*, 2011). Heavy soils with clay, clay loam, and silty clay loam textures are considered less favorable for poplar growth (Stanturf *et al.*, 2001). However, once established, high growth of poplars can occur on heavier soils (Johansson & Karačić, 2011). Based on these background the study further tries to find out the best soils that can support the growth of *M. lutea* in Teso North Sub County, Kenya.

2.5 Conceptual Framework

The concept envisaged throughout this study is that, there exists a complex linkage between agro-climatic indices, seed provenances, socio-economic factors, seedling production technologies and soil productivity that greatly impacts on domestication and adoption *M. lutea* (Figure 2.2).

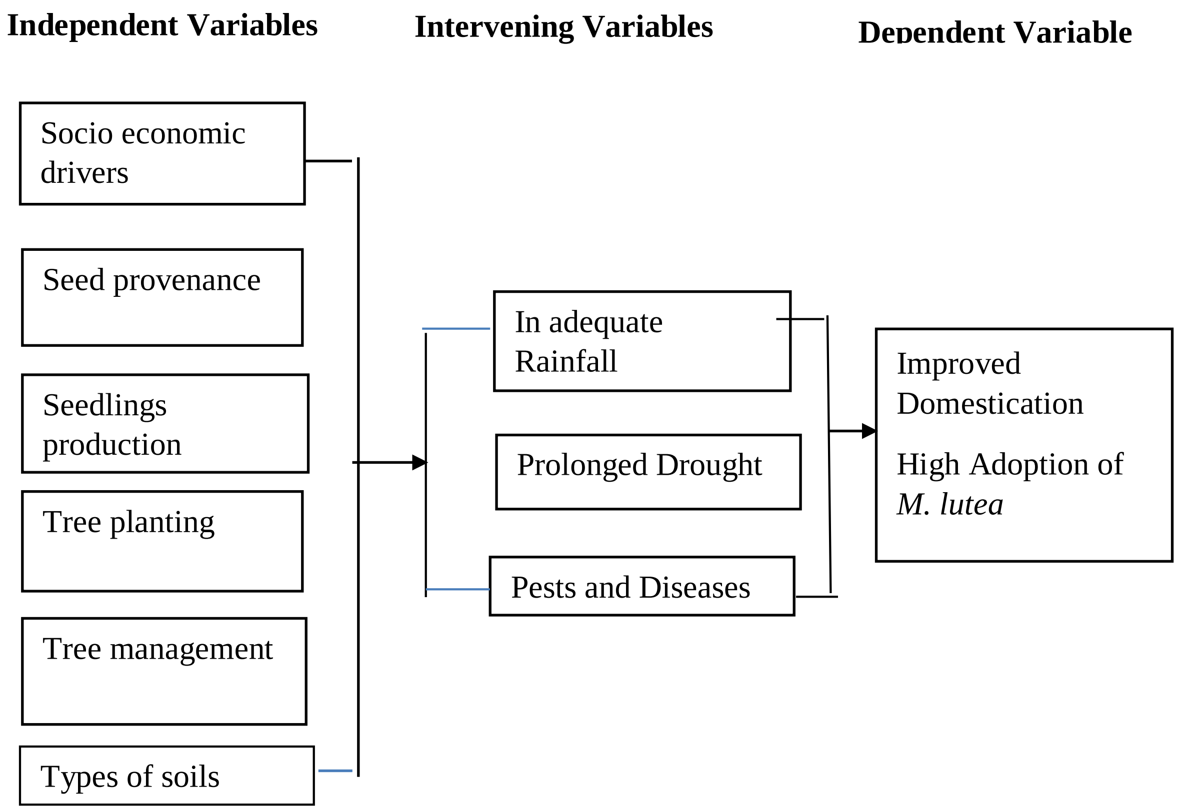

Figure 2.2: Conceptual Framework of Factors Influencing Domestication and Adoption of *M. lutea*

Source: Author (2017)

The arrow points to the dependent variable (improved domestication and adoption of *M. lutea*) from the independent variables. Farmer's decision to domesticate and adopt *M. lutea* would be determined by socio economic factors and intervening variable such as in adequate rainfall, prolonged drought and pest and disease outbreak.

2.6 Identification of Knowledge Gap

About 200 tree species are commonly planted for timber and other purposes, such as food, shelter, and beautification, around the world (Evans, 1992). Like plants, animals have also been domesticated for agriculture and for pleasure. In both plants and animals, the proportions that have been domesticated out of the total number of species are small (Leakey and Tomich, 1999). However, if the potential for domestication is limited to higher plants (*angiosperms, gymnosperms and pteridophytes)* of which there are some 250,000 species (Wilson, 1994). The proportions go up to 0.5 % and 6.6 % respectively (Leakey and Tomich, 1999). This indicates that agroforestry is not making full use of the diversity of species available. Domestication of more indigenous tree species for timber and non-timber forest products is required as a means to reduce farmers' reliance on subsistence food production, and to promote food and nutritional security, alleviate poverty and enhance environmental resilience (Leakey, 2010, 2012a). This study therefore seeks to fill these by providing information that will improve domestication and adoption of *M. lutea* in the study area.

In many developing countries, especially in Africa, farmers have been introduced to agroforestry with little consideration for the markets for trees and tree products aside from potential productivity gains to food crops. It is now being recognized that expanding market opportunities for smallholders particularly in niche markets and high value products is critical to the success of agroforestry innovations. Forest policy, physical and social barriers to smallholder participation in markets, the overall lack of information at all levels on markets for agroforestry products, and the challenges to outgrowing schemes and contract farming inhibit the growth of the smallholder tree product sector in Africa outside of traditional products. Notwithstanding these constraints, there are promising developments including contract fuelwood schemes, small-scale nursery enterprises, charcoal policy reform, novel market information systems, facilitating and capacity building of farmer and farm forest associations, and collaboration between the private sector, research and extension.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter covers sections on the study area, methodology, research design, target population, sample size, sampling techniques, data collection instruments, reliability, validity, data collection procedure, data analysis, methods of presentation of results and ethical consideration.

3.2 Research Design

The study adopted both descriptive survey and experimental design. Descriptive research design is a scientific method that involves observing and describing the behavior of a subject without influencing it in any way (Shuttleworth, 2008). This design was used to obtain most recent, relevant and in depth information about challenges towards domestication and adoption of tree species under study (Mbonyane and Ladzani, 2011). Kothari and Garg (2014) describes descriptive research design as the state of affairs as it exists in nature.

A survey is a method of collecting information by interviewing subjects, respondents or administering a questionnaire to a group of individuals who constitute the sample that provide data useful in evaluating present practices and improving the basis for further decisions. For the purpose of this study, the descriptive survey design was suitable for data collection since it assisted the author to gather qualitative and quantitative data from the target population.

Experimental design on the other hand is the process of planning a study to meet specified objectives. Planning an experiment properly is very important in ensuring that the right type of data and a sufficient sample size and power could be available to answer the research questions of interest as clearly and efficiently as possible (Mugenda and Mugenda, 2012). The study adopted complete randomized block design (CRBD) since the design was useful for comparing treatments means, easy to construct, simple to analyze data and its usefulness in accommodating a number of treatments in a number of blocks.

3.3 Location of Study

The study was conducted in Teso North Sub County of Busia County. Teso North Sub County borders the Republic of Uganda to the West, Teso South Sub County to the South, Mt Elgon Sub County of Bungoma County to the North and East.

According to Busia county Development profile (GoK, 2013), the Sub County covers an area of 261 Km^2, eighty one percent (81%) of the land is arable and the sub county has two administrative divisions namely; Amagoro and Angurai. Teso North lies at an altitude of between 1130 -1500 m above sea level (asl) above sea level. The sub-county has a population of 117,947 persons with a population density of 452 persons per Km^2 with an average farm size less than 2.1acres (Osumba, 2011). The map in figure 3.1 below represents the description of the study area.

Figure 3.1: Map of Teso North Sub County.

Source: KNBS, (2010).

3.3.1 Climate of the Study Area

It has an annual mean temperature range of 26° – 30° average annual rainfall of between 800 – 1600 mm. The rainfall is bimodal with long rains (LR) from late March to late May and short rains (SR) from August to October (Osumba, 2011). The Sub County is drained by Malakisi and Malaba rivers. Dark clay soils are predominant in the Sub County while, other soil types include sandy clay and clay. The major economic activities include subsistence farming of maize, sorghum, sweet potatoes, cassava, ground nuts, finger millet and the newly introduced upland rice, while cash crops include tobacco, cotton and pineapples (Busia County Strategic Plan, 2014 – 2018).

In the past the region had predicable weather patterns however this has since changed with time and may be attributed to inadequate forest cover at 3%, destruction of water catchment areas, land degradation, and global climate change among others (Busia County: Strategic Plan, 2014 – 2018). Other causes of change in weather patterns include deforestation due to population pressure and termite attack on young trees, yet there is a secure tenure system on land ownership but underscore in tree cover due to inadequate information on the tree domestication aspects (Osumba, 2011). The situation can however be addressed by deliberate efforts of the government to initiate a forestation and proper land use practices (Busia County: Strategic Plan, 2014 – 2018).

3.4 Target Population

This study targeted farmers within the study area who are engaged in both domestication and adoption of tree farming in agroforestry setups. Consequently, these farmers were the main actors, beneficiaries and decision makers with regard to on farm tree domestication and adoption practice.

3.5 Sample Size and Sampling Procedures

3.5.1 Sample Size

The sample size was determined using the formulae advanced by Gomez and Jones (2010).

$$n = \frac{N}{(1 + N(e)^2)}$$

Where (n) is the Sample size of household farmers

N is the Population size of farmers

e is the Level of Precision at 95% Confidence level.

Given the population size N (117947), then sample size (n) was obtained using the formulae given above.

$n = 117947 / ((1 + 117{,}947(0.05)^2)) \cong 400$

3.5.2 Sampling Procedures

A sample size of 400 households was used. Purposive and simple random sampling technique was used in gathering the information on socio economic factors influencing domestication and adoption of *M. lutea*.

In purposive sampling, the author relied on his own judgment and experience when choosing members of the population to participate in the study as described by Saunders, Lewis and Thornhill, (2012). Key informants who were knowledgeable people with information on the area of study were selected to provide an in depth understanding on most of the issues of concern. These key informants included; four leading farmers with exemplary woodlot activities, one Sub County agricultural officer, one representative of Non-governmental organization, one Sub County administrator, four chiefs and two Kenya forest service officers working in the study area.

In simple random sampling technique all the members of the target population were given an equal chance of being selected to participate in the study. The researcher sought the assistance of the local administration and the village heads who came up with a list of household heads. Respondents were randomly chosen from the list and the name of the household head chosen was marked until the entire sample size (n) of 400 respondents required was exhausted. The selected household units were administered with the questionnaire for information capturing (Saunders *et al.*, 2012).

3.5.3 *Markhamia lutea S*eed Germination Experiment

Forty (40) grams each of pure *M. lutea* seeds from the 3 provenances (refer 3.6.2.1) were assessed for percent germination rates. One kilogram *M. lutea* has approximately 75000 pure seeds (Schmidt and Mbora, 2008). Hence 40gms of seeds has approximately 3000 seeds.

3.5.3.1 *M. lutea* Seed Provenances

Sources of *M. lutea* seeds for the study were from Teso local (Ml1), Kakamega Tropical rain forest (Ml2) and Kenya Forest Research Institute (Siaya) referred as Ml3.

3.5.3.2 Pre Testing of *M. lutea* Seed Viability

The viability of the three seed provenances were tested for purity, moisture content, and seed weight per kg at Kenya Forest research Institute (KEFRI) Maseno following methods described by FAO (1985). A small sample of seeds were randomly selected from the 3 provenances of *M. lutea*. The seed coats were removed and the seeds were cut into half and placed in a container of Triphenyltetrazolium Chloride solution (TTC) incubated in warm water (30°C) for one hour. After incubation period, decant off the liquid. Rinse seed halves with distilled water until water is clear. Blot seeds on dry towel without crushing the seeds, then observe color. Highly viable seeds will be uniformly red, while seeds of reduced vigor will be white.

3.5.3.3 Bare Root and Container Seedbeds Preparations

Bare root were constructed using locally available materials and filled with forest soil in preparedness for pricking in of experimental samples. On the other hand the polythene tubes of sizes “3 x 1.5” open at both ends for free drainage were filled with forest soil and arranged in groups of hundreds as described by Munjuga *et al.*(2008).

3.5.3.4 Nursery Soil Collection

Forest soils were used in both treatments according to Mbora, Lillesø and Jamnadass, (2008). Forest soils were preferred for the study because of its rich in organic matter that will ensure soil fertility for the seedlings health.

3.5.3.5 Care of *M. lutea* Seedlings

Experimental seedlings were nurtured following normal nursery maintenance procedures pertaining to watering, weeding and protection against pests and diseases as described by Jamnadass *et al.(*2013); Munjuga *et al.*(2008). Watering was done in early in the morning and late in the evening when the temperatures were low using watering with fine nozzle cans. The seedlings were carefully monitored against any pest and disease attack.

The experiment took 2 months after plant emergence as described by Okello (2012).

3.5.3.6 Disinfection and Germination of seeds

The seeds from 3 provenances were surface sterilized against fungi and bacteria using 1% sodium hypochlorite (NaOCl) for 10 minutes under agitation on a shaker. Excess NaOCl was removed by rinsing the seeds with sufficient quantities of sterile distilled water before they were germinated (Matonyei, 2014).

Moist sand was used as the substrate for germination of seed from the 3 provenances and marked as Ml1, Ml2 and Ml3 with a permanent marker and mounted on germination trays. Clean and pasteurized sand was packed into deep bottomed plastic trays arranged in rows with three replicates in the greenhouse. Sand was used since it is endowed with adequate drainage. The sand tray had equidistant holes to drain off excess water in the substrate. Seed spacing of 2cm was used. One seed was placed in each hole, covered with fine sand fine spray watering was done so as not to dislocate the seeds. The seeds were left to germinate. Germination were monitored from day two up to 14 days or until no more germination was noticed from the previous two consecutive counts (Rao *et al.,* 2006).

3.5.3.7 Nursery Experiment of *M. lutea* Seedlings

Germinated seedlings from three (3) provenances were separately pricked out after attaining the first two juvenile leaves as described by Mbora *et al.*, (2008). The seedlings were transferred into seedbeds laid out in split plot experimental design, where the entire experimental block was split into two portions for each treatment (Swazilandbed and container) method **(**Figure 3.3). Inside each plot the seedlings from Ml1,Ml2 and Ml3 were presented in a complete randomized block design (CRBD) as described by Grant (2010) with 3 replications. Each replication had a total of 100 seedlings.

The experiment was set up in an open environment and subjected to normal weather conditions of the test site, however watering was done as described by Mbora *et al.* (2008) when rains are not sufficient enough. Growth characteristics of selected parameters (height and shoot collar diameter) from the seedlings were monitored and their measurements taken after every two weeks for two months. % seedlings survival in both treatments were taken from the same experiment.

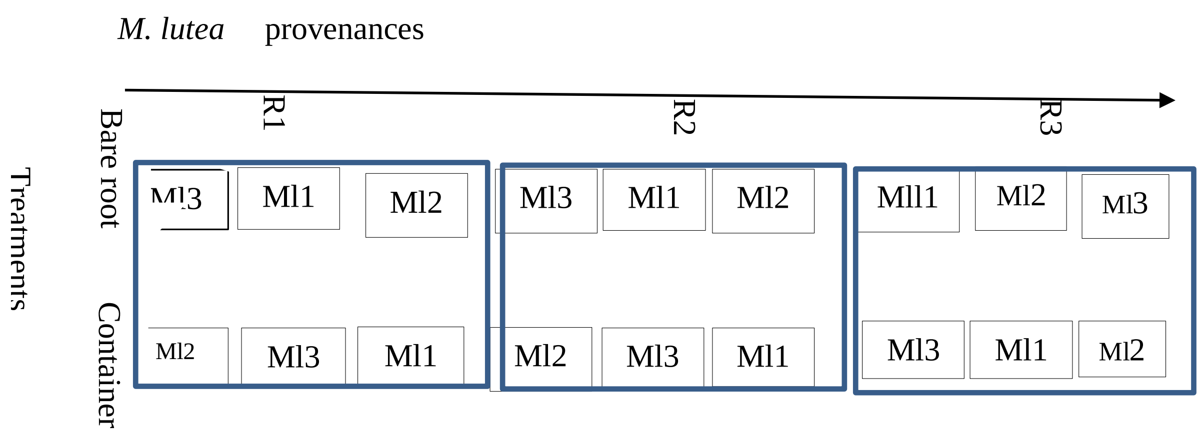

Figure 3.2: Experimental layout

Source: Author (2017)

3.5.4 Determination of Types of Soils

The study area was divided into two blocks (Amagoro and Angurai divisions). The blocks were further subdivided into small sampling units or cells as described by Manitoba Agriculture, Food and Rural Initiatives (2001). Fifty soil samples from each block where *M. lutea* population was examined growing were randomly collected for evaluation as described by North Dakota State University (1998) and as briefly as follows; two teaspoons of soil was placed in the hand and sprayed with water from a spray bottle to moisten it enough to form a ball. Then the procedures in the soil texture feel test key (Appendix 12) were followed. The evaluation process began at a point marked "start" until all soil samples were positively determined.

3.6 Data Collection Instruments

The instruments used for data collection included structured questionnaire, field observations, interviews and field experiments.

3.6.1 Validity

Validity of the research instrument was ascertained after pre-testing of data collection tools, as follows; structured questionnaire were first pretested using a few of selected households and necessary adjustment made. Secondly using calibrated tools eg tape measure, dial caliper.

3.6.2 Reliability

In this study reliability referred to the extent in which selected samples represented all the entire population targeted for the study and to the extent the questionnaire and field experiment yielded consistent data.

3.7 Data Collection Procedures

3.7.1 Socio Economic Factors Influencing Domestication and Adoption of *M. lutea*

A questionnaire with both open and closed ended questions was administered to the sampled population (Appendix 1). The questionnaire schedule was used to gather information on socio economic factors influencing domestication and adoption of indigenous tree species (Eswata) *M. lutea*, that included age, gender, household size, farm size ,education level, land and tree tenure rights, household contact with the extension agents, challenges of tree planting and general information on *M. lutea* tree species.

3.7.2 Determining Germination Rate of *M. lutea* Local Provenances in Greenhouse

Percentage germination of *M. lutea* seed provenances were measured daily after the second day of sowing in the greenhouse. All germinated seeds were counted and removed on a daily basis for avoiding double counting. A seed was considered as germinated when the radicle has penetrated out from the seed coat and clearly appeared visually or when the hypocotyl hook was evident above the soil surface as stated by Fandohan *et al*. (2010). The daily germination count continued until no more seed germination occurred.

Germination % was calculated as follows;

$$\text{Germination } \% = \frac{\text{G}}{\text{X}} \text{ X } 100$$

Where:
G = number of seed germinated
X = number of seed sown using quantity according to Orwa *et al*. (2009).

3.7.3 Determination of *M. lutea* Survival rate

Number of *M. lutea* survived after pricking out were counted after every one week for a period of two months in all the three provenances in each treatment and survival rate determined using the formulae below;

$$\text{Survival } \% = \frac{\text{Total germination} - \text{Dead seedlings}}{\text{Total number of seedlings germinated per provenance}}$$

3.7.4 Determination of *M. lutea* Growth Rate

After completion of seed germination, observation of the transferred seedling growth performances (shoot collar diameter and shoot height of the plant) in container and bare root mode of seedlings production were measured for a period of two months. The collar diameter was measured at collar region where root and shoot separate slightly above the ground level using dial caliper and was expressed in millimeters (mm).

The height of the seedling was measured from the collar to the growing tip at 7, 21, 36, 60, 74 and 88 days after transplanting from 10 seedlings and average taken and expressed in centimeters (cm) as described by Okello (2012).

3.7.5 Determining Soil Types

Soil samples were collected randomly from the area were *M. lutea* was growing. A palm full soil sample was sprayed with water to wetness and rolled to form a ball shape. The ball shaped wet soil was then placed in between the fore finger and the thumb, pressed and released. Soil ball that collapses on release is classified as sand soil. If it does not collapse when squeezed then the next level of soil analysis procedures in soil texture flow chart key (Appendix 12) is followed step by step until all fifty soil samples are positively identified. From each block soil type percent distribution was determined.

3.8 Data Analysis and Presentation

Statistical package for social science (SPSS) software version 16.0 was used to analyze the collected data. Socio economics data of *M. lutea* was analyzed using descriptive statistics (frequency and percentages). Chi square of independence was used to determine the significant relationship between the socio economic factors (variables) affecting domestication and adoption of *Markhamia lutea* in the study area. In addition data on seed germination, seedling survival rate and early seedling growth parameters (height and shoot collar diameter) were subjected to one way Analysis of Variance (ANOVA) test at 95 %

Confidence interval and multiple comparison of Least Significance difference (LSD) to show significance difference of variables within the treatment and mean separation between variables. Results were presented in form of tables, cross tabulation, figures, graphs, photographs and charts**.**

3.9 Ethical Issues

Denscombe (2002) describes ethics as what ought to be done and what ought not to be done in a research. The author sought a research recommendation from University of Kabianga and research permit from National commission for science, technology and innovation (NACOSTI) (Appendix15). Respondents were guaranteed confidentiality of the information given during and after the research period.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussions on socio-economic factors influencing domestication and adoption of *M. lutea*, demographic information of households, comm. Tree species, and general information on *M. lutea*, germination, survival and growth characteristics of three *M. lutea* provenances in bare root and container mode of seedlings production and the soil evaluation in the study area.

4.2 Socio-economic Factors Influencing Domestication and Adoption of *M. lutea*

These are aspects that relate to social and economic conditions in communities and less to the cultural and biophysical environment.

4.2.1 Demographic Information of the Households

Table 4.1 reports the distribution of gender in the study area. Out of the 400 respondents 65.2% were male headed household and 34.8% were female. The high percentages of male headed households are that in the African culture men are considered the most productive compared to female headed families according to FAO (2011). The low percent of female headed household was either unmarried, single women or they were widows. Although the female headed households constituted a smaller percentage, they showed interest in domestication and adoption of trees including *M. lutea*, though their decision purely relied on the male's acceptance. The results confirm that farmer's adoption and domestication of *M. lutea* depended on gender, however it was observed that females are not permitted to make decisions to adopt agroforestry technologies such as planting of *M. lutea* without consulting their husbands. This observation is similar to the findings of Scherr (1995).

Table 4.1

Social characteristics of the households

Characteristics	Description	No of HH respondents	% response
Gender	Male	261	65.20
	Female	139	34.80
	N	400	100.00
Age bracket (yrs)	16-25	2	0.50
	26 -35	28	7.00
	36 – 45	115	28.80
	Above 45	255	63.80
	N	400	100.00
Marital status	Married	340	85.00
	Single	16	4.00
	Windowed	42	10.50
	Divorced/ Separated	2	0.50
	N	**400**	**100.00**

Source: Author (2017)

The Chi square test (Appendix 4) showed that gender to have a significant influence on domestication and adoption of *M. lutea* in agroforestry systems of the study area ($p<0.05$). However these results disagree with the findings of Ragland and Lal (1993) who found gender to have no significant influence on the adoption of agroforestry technologies.

Sex of household head is related to household decisions; gender is an important factor influencing adoption of agroforestry practices with the probability of adoption higher in male headed household than in female (Negatu and Parikh, 1999).

4.2.1.1 Age Distribution in Households

Sixty three point eight percent (63.8%) of the respondents were above 45 years and this was found to be the most active group in practicing agroforestry related activities. The age group bracket between 16-25 years formed the lowest age group 0.5% (Table 4.1).

Household heads (HH) were adults and only few cases where both parents were deceased persons young men of age range between 16- 25 years assumed the household heads. This age structure indicate a situation where there are more adult members heading households meaning that more quality labour would be available for planting and domestication of agroforestry trees (Rotich *et al.*, 2017). According to Olujide and Oladele (2011) age is significantly related to knowledge of agroforestry. However this result disagrees with the findings of Mwase *et al.* (2015).

Eighty five percent (85%) of respondents were married, while 0.5% were either divorced or separated (Table 4.1). The high percentages of married headed families observed in the study suggest that participation of farmers in domestication and adoption of *M. lutea* depends on the perception of technology by the male members of the community since most of the women did not own land. This is in agreement with Matata *et al*. (2010) who found that proportionately more men planted improved fallow than women primarily because married women need consent of their husbands. The results are in line with the findings of Anyanwu (2006); Akinbile and Salimonu (2007) who found that the active participants in farming activities were over 51 years. The findings are in agreement with results by Rotich *et al.* (2017) on socio economic perspectives influencing availability, preference and utilization of agroforestry trees in Kapsaret, Kenya, where majority of respondents were in the age brackets of 41-50 years and the least were youths aged 21-30 years.

The age was not significant ($p>0.05$) appendix 4 and therefore does not seem to influence the domestication and adoption of *M. lutea* in the study area. Similar studies done elsewhere by Gockowski and Ndoumbe (2004) found age to have no significant influence on the adoption of agroforestry practices. The results are also in agreement with the findings of Ayuba and Helen (2012) where there was no significant statistical relationship between demographic characteristic and farm participation in afforestation.

The findings differs with the results of Muneer (2008) on factors affecting adoption of agroforestry farming system as a mean for sustainable agricultural development and environment conservation in arid areas of Northern Kordofan state, Sudan that showed a high percentage of the respondents were of young age (≤ 40 years) compared to about one fifth who were over 60 years of age. According to the adoption theory this represents a good ground for the success of extension campaigns and programs that aim at dissemination and adoption of any agricultural innovations, particularly those intended for environment conservation and natural resource sustainable management, as young farmers have been found to be more innovative than their older counterparts (Rogers, 1993).

4.2.1.2 Education Level of the Household Respondents

Out of 400 respondents 38.28% had primary education, 31.5% had attained secondary education, 17.75% of the respondents had none, 7.25% had obtained university education and 5.25% had obtained tertiary education (Table 4.2).

Table 4.2

Education level of respondents

Education Level	Number of respondents	% response
None	71	17.75
Primary	153	38.28
Secondary	126	31.50
Tertiary colleges	21	5.25
University	29	7.25
Total	**400**	**100.00**

Source: Author (2017)

The majority of respondents had primary education this is because that most people dropped out of school at an earlier age and opt for boda boda business within the Kenya Uganda boarder (Oprong, 2016).

The level of education of respondents had significant influence on domestication and adoption of *M. lutea* in the study area ($p < 0.05$). When farmers are educated they have better access to information and innovations which help them to make quick decisions to adopt the cultivation of agroforestry trees including *M. lutea.* The findings are in tandem with Aliu (2012) who found that demographic characteristic such as education level has effect on farmer adoption of afforestation (Adesina *et al.*,2000) farmers with a higher education level are more likely to adopt new innovations compared to less educated.

Mekoya *et al.* (2008) emphasized that agroforestry technologies are knowledge intensive and therefore require high levels of education. On the other hand studies by lionberger (1960) argues that the level of education as a socio economic factor influencing adoption of agroforestry development and production systems has been found to be controversial, he further holds that the relationship between the level of education and farm practice is indirect except where persons learn new practices in school and where this is not the case, education may merely create favorable atmosphere for acceptance of new practices. His arguments were echoed by Misiko (1976) who shared the same thought.

The research findings are also in agreement with Lapar and Ehui (2004), Okuthe *et al.* (2013), Rahim *et al.* (2013) and Twahu *et al.* (2016) who stated that in many studies, education significantly influences adoption of improved soil agroforestry technologies. Some of agroforestry practices are knowledge intensive and thus do not diffuse as quickly as other technologies as described by Place *et al.* (2012). Consequently the result differs with the findings of Wireko (2011) who found that the level of education to have no significant influence on the adoption of agroforestry practice in Ghana. The study findings agree with those of Rahim *et al.* (2013) whose study examined social factors, which affect farmers' adoption of agroforestry system in Azna.

The study reveals that, the higher the educational level of the household head, the higher the adoption levels of agroforestry practices. This is alluded to the fact that, education enhances an understanding of new technologies hence the probability of adoption is increased. Okuthe *et al.* (2013) analyzing the socio cultural determinants of adoption of integrated natural resource management technologies by small scale farmers in Ndhiwa division, agrees that there is a strong relationship between education level of the household head and the agroforestry adoption levels. He explains that, a well-educated farmer can easily understand and interpret the information conveyed to them by an extension officer or from any other source. The implication on the influence of the level of education varies from region to region, that is when comparing results of different researchers on adoption of an agroforestry practice

4.2.1.3 Size of Households

Thirty two percent (32%) of the respondents had the highest HH size between 5- 6 persons, while 4.75 % had the least HH between 1-2 persons (Table 4.3).

Table 4.3

Household size of the respondents

Household sizes(No)	Number of respondents	% respondents
1 – 2	19	4.75
3 – 4	108	27.00
5 – 6	128	32.00
7 -8	85	21.25
>9	60	15.00
Total	**400**	**100.00**

Source: Author (2017)

The household size plays an important role in domestication and adoption of *M. lutea* where family members are used as a source of labour in tree planting activities (Joel *et al.*, 2013). Consequently a large number of household sizes affect the demand for more production to feed family members (Joel *et al*., 2013).

Chi square test ($p<0.05$) appendix 4 shows that there is significant influence of HH size in domestication and adoption of *M. lutea*. This means household size is an important determinant influencing domestication and adoption of *M. lutea* in the study area. These findings are in line with studies carried out by Adedayo and Oluronke (2014). Similar results were found by the studies according to Rajasekharan and Veeraputhran (2002) who mentioned the availability of family labour (household size) as one of the variables influencing the adoption of agroforestry technologies in India.

According to Nkamleu and Manyong (2014) household size is positively and significantly related to farmers' adoption of live fencing and apiculture. This indicates that larger families with an increased labour supply are more likely to adopt the technologies than smaller households. The effect is positive according to Amsalu and Graaff (2007). However, large household size lead to the changes in land use, where more land is put under agriculture, mainly for food production to feed the growing population (Mugure *et al.,* 2013; Muneer, 2008).

4.2.1.4 Occupation of Respondents

Majority 79.75% of respondents were farmers and the least 0.5% were students who practiced farming as a secondary occupation (Table 4.4).

Table 4.4

Occupation of the respondents

Occupation	Number of respondents	% response
Others	39	9.75
Farmer	319	79.75
Civil Servant/Teachers	19	4.75
Business	16	4.00
Student	2	0.50
Driver	5	1.25
Total	**400**	**100.00**

Source: Author (2017)

It is true that most of the respondents were farmers, who were involved in small scale production of a variety of staple food crops and tobacco on small portions of land. However due to the prevailing economic hardship in the area, some households were forced to work on their neighbours farm, others sold tree products in order to get money so as to meet other household needs.

The few respondents who were employed by the government were mainly working within and outside the Sub County. For those in business were engaged in small business like brick making and bicycle (boda boda) transport. Those who were involved in driving were engaged in motorcycle (boda boda) transport. The results implied that households were involved in formal employment and business activities that supplement household income than on farm tree production. This is in agreement with the findings by Wafuke (2012).

The study also observed that women do their farming work in the morning hours and then later in the day they go to market places to sell foodstuffs like fish, vegetables among other goods on small scale. Men on the other hand do activities like maize roasting and charcoal burning which involve tree products. It was found from the studies that occupation had significant ($p<0.05$) influence on the domestication and adoption of *M. lutea* in the study area (Appendix 4).

Indeed it was noted that most of the community members whose occupation was outside their home area had little time to attend tree farming activities, hence contributed to low domestication and adoption of *M. lutea*. These results are in agreement with the findings by Oino and Mugure (2013) who found that farmers' occupation significantly influenced the adoption of agroforestry practice in Nambale, Kenya.

4.2.1.5 Land Sizes of Respondents

The study found 52.5% of the respondents had land sizes between 1-5 acres while few 10% of respondents had above 10 acres of land (Table 4.5).

Table 4.5

Land sizes

Land sizes (acres)	Frequency of respondents	% response
< 1	70	17.50
1 – 5	210	52.50
5.1 – 10	80	20.00
>10	40	10.00
Total	**400**	**100.00**

Source: Author (2017).

Land sizes of respondents in the study area ranged from < 1 to 10 acres.

The small land sizes in the study area could be a contributing factor of low domestication and adoption of *M. lutea*. Farmers could not risk planting *M. lutea* in their small sizes of land used for agricultural production due to its long period it takes to mature. According to studies by Ragland and Lal (1993) and Mwase *et al.* (2015) domestication and adoption of *M. lutea* required reasonable farm sizes.

The small farm sizes are shared among many family members so that after planting cash crops, there is limited space for planting trees (Bradley, 1991). The effect of farm size on domestication and adoption of *M. lutea* in the study area was found to be significant ($p<0.05$) therefore can influence the domestication and adoption of *M. lutea*. This result is in tandem with (Orisakwe and Agomuo, 2011; Kabwe *et al.*, 2009; Maluki *et al.*, 2016; Geremew, 2016).

Households with large land sizes are willing to invest their land into planting of compatible trees with farm crops such as *M. lutea* as suggested by Cramb *et al.* (1999) that farmers who have large farm sizes are more likely to adopt *M. lutea* planting.

Studies by Amsalu and Graaff (2007) in Ethiopia found out that those farmers with large land sizes were more likely to invest in soil conservation measures such as tree planting. However these results differ with the findings by Adadeyo and Oluronke (2014) who found out that land size do not have significant influence in adoption of agroforestry practice in studies carried in Osun, Nigeria ($p > 0.05$).

This implies that the significant influence of land size on adoption and domestication of *M. lutea* in agroforestry practice varies from region to region. According to various researchers (Mugure *et al.*, 2013), small scale farmers depend on land for their livelihoods and its ability to sustain production of food, fiber and other wood products. Even though the concept of agroforestry and its importance was well understood among the respondents, the size of the land available to the farmers, served as a limiting factor. Land is one of the most important resources in Kenya (Kinyanjui, 2005). Many farmers still prefer agriculture for food production over growing of *M. lutea* and are therefore less willing to avail much land for forestry purposes (Mugure *et al.*, 2013).

Agroforestry technologies that require larger piece of land such as tree-crop fallows would be a barrier to adoption by small holder farmers with land of less than 1 hectare (Mwase *et al.*, 2015). Thangata *et al.* (2007) reported that farmers in Southern Malawi with small land holdings resorted to adoption of maize tree intercrops of species like *Gliricidia sepium*, *Sesbania sesban*, *Leucaena* species and pigeon peas.

Fifty eight percent (58%) of the respondents had the view that land size has no influence in decision to plant *M. lutea*, while 42% believed it had influence (Table 4.6).

Table 4.6

Influence of the land size on decision to plant *M. lutea*

Influences	Frequency of respondents	(%) response
Yes	168	42.00
No	232	58.00
Total (N)	**400**	**100.00**

Source: Author (2017)

The majority of respondents who believe that land size do not have any significant influence in deciding to plant *M. lutea* proposed that whatever the size of the land available for planting *M. lutea* is to supplement income from the sale of other farm produce. Those who hold the view that land size has influence preferred having perennial crops to *M. lutea* that take long period to start realizing the benefits. The implication of these findings is that the decision to plant *M. lutea* does not depend on land size but on individual perceptions.

Approximately 35.25% of the respondents perceive that the land size was too small to accommodate *M. lutea*, while 3.5% believe that land was too big and *M. lutea* was naturally growing (Table 4.7).

Table 4.7

Factors influence *M. lutea* farming

Factors influencing *M. lutea* farming	Number of respondents	% response
The land was too small to accommodate trees	141	35.25
Big land and trees are naturally growing	14	3.50
The land was used for cereals production	79	19.75
Tree interfere with arable crops	121	30.25
Trees can supplement income on small land	45	11.25
Total	**400**	**100.00**

Source: Author (2017).

The largest percentage of the respondents gave reason that the land was too small to accommodate *M. lutea*. This is attributed to the fact that farmers prefer food crops that take short period of time to realize the benefits and hence they could not engage in planting *M. lutea* that take long to reach maturity. Indeed farmers could not risk 5 to 10 years waiting for *M. lutea* to mature for benefit realization and incase of eventuality of disease or pest outbreak farmers are likely to lose everything and incur losses, hence they prefer annual crops.

4.2.1.6 Land and Tree Tenure Rights

The study showed that land ownership is predominantly by male (83%), female (15.75% land children (1.25%) Table 4.8.

Table 4.8

Land ownership

Land ownership	Number of respondents	% response
Family	0	0.00
Husband	332	83.00
Wife	63	15.75
Children	5	1.25
Husband and wife	0	0.00
Total	**400**	**100.00**

Source: Author (2017).

Most of the decision to plant trees rest on the land owners leaving the rest less likely to have authority on the said matter.

Males (husbands) in the African customs are considered to own land that they inherit from their parents. Women are not supposed to own land. The children with the right of land ownership are the ones who are orphans and have inherited the parents land (Laurel, 2008).

Land ownership is an important socio- economic characteristic, which does not only refer to one having the title deed of that land but also having powers to control the use and disposal of the land. Therefore land ownership has a bearing on one's productivity especially in farming communities. Adedayo (2004) showed that land ownership plays an important role in the adoption of alley cropping among local farmers in Akure Local Government area of Ondo State, Nigeria. He further noted that tenant farmers are not usually allowed to plant trees as such they cannot adopt agroforestry practice since it involves tree planting. In addition land tenure is crucial in adopting agroforestry practice as farmers are very willing to invest on land whose security is guaranteed. Farmers feel that if they do not own the land then they cannot own the trees planted on that land (Chitakira & Torquebiau, 2010; Kabwe, 2010).

Results on *M. lutea* ownership showed husband (70.75%), wife (12%), both husband and wife (14 %), family (3.25%) and children (0.25%) Table 4.9.

Table 4.9

Who owns *M. lutea*

Tree ownership	Number of respondents	% response
Family	13	3.25
Husband	283	70.75
Wife	47	11.75
Children	1	0.25
Husband and wife	56	14.00
Total	**400**	**100.00**

Source: Author (2017)

Most of the trees on the farmland are owned by husband leaving the rest less likely to have authority over the usage of *M. lutea.* The studies revealed that both the husband and wife had the right to own and use *M. lutea* in their farm. In absence of the husband the wife takes full control of tree rights. The research revealed that male children could access both land and tree rights especially when both of their parents have died. This negatively affected the children's participation in domestication and adoption of *M. lutea* in Teso North Sub County. It was also revealed by the respondents that forest policies inhibit tree user rights. For instance during tree harvesting and marketing one requires an approval from Kenya Forest Service (KFS). Charges on timber movement permit contributed to loss of interest by farmers to domesticate and adopt *M. lutea* in close associate with food crops (Kenya gazette supplement No. 16, 2016).

Adoption and domestication of *M. lutea* in agroforestry systems depends on people's rights to plant and use trees, rights which in turn depend on the prevailing systems of land and tree tenure. Tree tenure is often distinct from land tenure, but they affect each other. Tree tenure comprises rights over trees and their products, which may be held by different people at different times. These rights include, right to own or inherit trees, the right to plant trees, the right to use trees and their products, the right to sell trees and the right to deny others from the use of trees and their products (Mugure *et al.*, 2013).

The study found that the head of household owned most of *M. lutea* within the farm land through sale of wood products for income generation. The findings are in line with Detlefsen and Scheelje (2011) on farm forest user rights in Honduras, Nicaragua and Panama where very strict regulations for timber harvesting in agroforestry system resulted in the loss of interest of farmers to associate trees with crops and pastures This is in line with Tengas (1994) who stated that most farmers in Kenya find it unacceptable and unattractive to invest in tree production on land which is not legally theirs. Makindi (2002) also found out that secure tree, land tenure, relative freedom to harvest trees and sell products were incentive to farmers to domesticate and adopt tree planting. Mugure *et al.* (2013) had similar findings. Regardless of the overall land security of farming households, in general, women’s rights to land and trees are almost always inferior to those of males. This was found to be the case in studies done in Uganda, Burundi, and Zambia by Place (1995). Even in inheriting or determining descent through the female line societies, the decision making power of women viz tree planting is not guaranteed, such as in Malawi (Hansen *et al.,* 2005). Also the results are in agreement with the findings by Ndei (2014).

The results on whether the respondents had or did not have title deeds showed that majority of respondents 72% had title deeds , 47% of these were males and 25% were female, however 28% did not possess title deeds (Table 4.10).

Table 4.10

Land ownership in Teso North Sub County

Title deeds	Sex	Number of respondents	% response
With	Male	188	47.00
	Female	100	25.00
Without	Male	73	18.25
	Female	39	9.75
Total	Male	261	65.25
	Female	138	34.75
Total		**400**	**100.00**

Source: Author (2017)

Most of the land was owned by men who had the authority over usage leaving the rest with minimal authority over land utilization.

Studies elsewhere have shown that by 2004 in Kenya, only 1% of land titles were held by women and 5-6% was owned jointly and the rest by men in Kenya according to International Women Human Rights (2008). This form of gender inequality undermines economic growth and social development (Institute of Economic Affairs, 2008). Moreover, discrimination against women in land ownership presents itself in customs and traditions of most ethnic groups in Kenya. These has led to poor domestication and adoption of *M. lutea* in the study area by women who did not have right to make decisions on the use of land.

Out of 400 respondents 64.25% believe husbands were the main decision makers on *M. lutea* harvesting, while 0% believed that children and entire family combined had no role to decide when to harvest *M. lutea* (Table 4.11).

The study found that the head of household had the right to use and utilize *M. lutea* within the farm land through sale of its products for income generation.

Table 4.11

Decision to harvest *M. lutea*

Family members involved	Number of respondents	% response
Husband	257	64.25
Wife	45	11.25
Children	0	0.00
Husband and wife	98	24.50
Entire family	0	0.00
Total	**400**	**100.00**

Source: Author (2017)

The findings are in line with Detlefsen and Scheelje (2011) on farm forest user rights in Honduras, Nicaragua and Panama where very strict regulations for timber harvesting in agroforestry system resulted in the loss of interest of farmers to associate trees with crops and pastures. This biasness on the species harvest decision making will deter the other section of family members from investing in domestication and adoption of *M. lutea* with expectation of income generation. This is in line with (Tengas, 1994; Makindi, 2002; Hansen *et al.*, 2005; Mugure *et al.*, 2013; Ndei, 2014).

There is significant influence of tree and land tenure rights on domestication and adoption of *M. lutea* in the study area ($p<0.05$) appendix 4. This also shows that land and tree tenure rights have a crucial role in influencing the domestication and adoption of *M. lutea*.

4.2.1.7 Extension Services

The results showed that 64% of the respondents had no contact with extension officers for knowledge sharing on *M. lutea*, while 5% would interact once a year (Table 4.13).

The contact of farmers with forest extension officers were low, hence the farmers could not access knowledge and information about domestication and adoption of *M. lutea.*

Table 4.12

Farmers access to forest extension services

Contact with farmers	Number of respondents	% response
Not at all	256	64.00
Once a month	26	6.50
Yearly	20	5.00
Rarely	54	13.50
Weekly basis	44	11.00
Total	**400**	**100.00**

Source: Author (2017)

This resulted low adoption rate of *M. lutea.* These implied that information on knowledge of forestry extension was lacking among farmers in the study area.

There was significant influence of forest extension services on domestication and adoption of *M. lutea* in the study area ($p<0.05$). Poor extension services are a major cause of problems hindering domestication and adoption of *M. lutea* in the study area. The findings are similar to the outcome of studies done by Adedayo and Oluronke (2014) in Osun state, Nigeria. Evidence of extension efforts in other countries have yielded fruits in influencing the adoption process of agroforestry practices (Chitakira and Torquebiau, 2010; Masangano and Mthinda, 2012; Mutua, Muriuki, Gachie, Bourn and Capis, 2014; and Kennedy, Amacher and Alexandre, 2016). The study also agrees with work of Matata *et al.* (2010) who argued that extension contact is a key variable in developing a favourable attitude among farmers towards adopting a technology.

4.2.1.8 Traditional Beliefs and Taboos on *M. lutea*

The results in Table 4.13 reveals that 66.5 % of respondents indicated that women should not plant *M. lutea* on family farm, 66.25% don’t allow women to cut the tree for any purpose and 64.25% indicated women should not own land and should not cut any trees they planted and tendered. Similarly, 58.25% indicated that women should not plant any trees.

The overall results of the respondents reveal that women are highly restricted in the participation of tree planting, cutting trees and ownerships of land in the study community.

Table 4.13

Beliefs affecting *M. lutea* tree planting

Beliefs affecting *M. lutea* tree farming	Number of respondents	% response
Some trees should not be planted by women	266	66.50
Some trees should not be cut for any purpose by women	265	66.25
Women should not own land and should not have a right to use any of the trees they plant and tend	257	64.25
Women should not plant trees	233	58.25
Total	**400**	**100.00**

Source: Author (2017)

The findings are supported by studies by Kiptot and Franzel (2011) that showed that beliefs avoids planting of *M. lutea* led to low on farm tree planting. Bankole *et al.* (2012) reported that in some parts of Kenya for example among the Luhya community, women are prevented from planting trees as this was considered a curse.

There was significant influence of traditional beliefs in determining the domestication and adoption of *M. lutea* in the study area ($p<0.05$). The results are in line with the findings by Sahilu (2017).

A study by Kiptot *et al.* (2014) found that women are constrained by customary norms and practices on user rights on agroforestry products thus causing significant negative influence on adoption of *M. lutea.* Cultural beliefs, superstitions and taboos are found in perpetually in all cultures throughout the world (Negi, 2014). This class of informal institutions defines the human behaviour and also guides people's conduct towards the exploitation of the natural resources (Negi, 2010). African societies have taboos that prohibit women from undertaking certain activities, which may limit their participation in developmental interventions such as domestication of *M. lutea* (Kiptot and Franzel, 2011).

4.2.1.9 Constraints of Respondents in Adopting *M. lutea*

Forty three percent (43%) of respondents lacked information on socio economic benefits of *M. lutea,* while 0.75% believed that there were other constraints influencing its domestication and adoption (Table 4.14).

Table 4.14

Agroforestry constraints in adopting *M. lutea*

A/Forestry constraints	Number of respondents	% response
Lack of information	172	43.00
Small land sizes	57	14.25
Harbor pests and diseases	41	10.25
Termites	24	6.00
Conflicts with neighbours	23	5.75
Extension systems	21	5.25
Lack of quality seedlings	15	3.75
Lack of desired species	15	3.75
Competition with farm crops	13	3.25
Shade	8	2.00
Property rights	8	2.00
Others	3	0.75
Total	**400**	**100.00**

Source: Author (2017)

Lack of information on socio-economic importance of *M. lutea* is the greatest challenge the farmers are facing in the study area. Bearing in mind tree planting is a long term enterprise that takes a long period to realize the benefits compared to annual crops. Farmers fear investing heavily on *M. lutea*. These findings are in line with that of Dudi (2011) and Chowdhury and Ray (2009).

Farmers constraints in domestication and adoption of *M. lutea* in the study area was significant (p = 0.000) appendix 4. Studies from several countries in Africa have shown that sustainable land management practices such as agroforestry are not sufficiently known by extension agents and much less likely to be disseminated to farmers (Chitakira and Torquebiau, 2010; Banful *et al*., 2010). This creates an information bias towards other types of land use practices. In some places, long term rights to land are insufficient to motivate long term investments such as domestication and adoption of *M. lutea*. The respondents identified property rights (2%) as a constraint influencing domestication and adoption of *M. lutea* whereby the respondents revealed that forest policies inhibit tree growing on farms by regulating harvesting, cutting or sale of tree products and certain tree species (Tree harvesting moratorium, 2018). Although sometimes well intentioned, such protective policies, when applied to agricultural landscapes, discourage farmers from planting and protecting new seedlings that emerge.

Lack of quality seedlings 3.75% serves as another constraint to the adoption of *M. lutea* in the study area. The Kenya Forestry Services (KFS), which initially provided free seedlings for planting to farmers, no longer provide such inputs. The findings are in agreement with the findings of Sangeetha and Ann (2015) who found that lack of seedlings was the most critical constraint faced by famers in adoption of agroforestry species.

4.2.2 Common Tree Species

The results showed that the common tree species planted by the households in the study area included *Eucalyptus species* 67%, *Grevillea robusta* 65%, *Melia azederatch* 24.5%, *Jacaranda mimosifolia* 12.8% and *Markhamia lutea* 1.5% and *Grevillea* and *Eucalyptus* were the most planted tree species as reported by respondents (Table 4.15).

Table 4.15

Common tree species

Popular tree species	Number of respondents	% response
Terminalia brown	1	0.30
Syzygium cuminii	1	0.30
Albizia gumifera	8	2.00
Tarmarindus indica	6	1.50
Acacia seyal	4	1.00
Markhamia lutea	6	1.50
Melia azederatch	51	12.80
Eucalyptus grandis	98	24.50
Grevillea robusta	16	4.00
Syzygium guajava	28	7.00
Mangifera indica	260	65.00
Jacaranda mimosifolia	51	12.80
Eucalyptus grandis	268	67.00

Source: Author (2017)

The results showed that *M. lutea* planting in the study area was low (1.5%). *Eucalyptus grandis* and *Grevillea robusta* were the most predominant tree species adopted by the respondents because they were fast in maturing and equally the returns were high (Kuria, 2013).

It was noted that indigenous tree species were getting depleted from their farms. Little attention was given to the domestication of indigenous species and these was attributed greatly to lack of knowledge. The results implied that the preferred tree species were generally exotic. Respondents gave reasons for such big disparities as short rotation age, realization of benefits over relatively short time and multiple benefits over the indigenous species. Similar results were reported in Central Kenya by Githiomi, Mugendi and Kung'u (2012).

4.2.3 General Information on Awareness of *M. lutea* by Respondents

Eighty nine percent (89%) of the respondents were aware of the species, while relatively a small number 11% were not aware (Table 4.16).

Table 4.16

Respondents awareness of *M. lutea*

Familiar with *M. lutea*	Sex	Number of respondents	% response
Knows	Male	232	58.00
	Female	124	31.00
Don't know	Male	29	7. 25
	Female	15	3.75
Total		**400**	**100.00**

Source: Author (2017).

Though a large number of respondents knew the species yet they could not cultivate the tree. This was attributed to lack of information on the socio economic importance of *M. lutea* among the households. This significantly influenced the domestication and adoption of *M. lutea*. The results are similar to findings by Chitakira and Torquebiau (2010); Takele *et al.* (2014); He *et al.* (2015).

Majority of the respondents (91.5 %) believe that they could access *M. lutea* seeds for propagation from natural regeneration, while 0 % believe that they can access seeds from private nurseries (Table 4.17). The results showed that the respondents had challenges in getting the quality seeds for planting in their farms as the relied only from collection from wild trees. Since for any successful woodlot establishment seed source of known (Provenance) is of paramount importance as the traits of genetically desired characteristics are required (Leakey, 2012). These findings are in line with Kabwe, Bigsby and Cullen (2016) who reported that availability, sufficient amounts of and good quality seed were constraining the widespread uptake of improved fallows.

On the other hand 91.5% of respondents believe that they could access *M. lutea* seedlings from natural regeneration, while 0.5% believes that private tree nurseries could be a good source of *M. lutea* seedlings for planting. In addition, the quality of seedlings was a concern as it was reported by a large number of respondents. Furthermore, the good attributes associated with *M. lutea* seen to be not appreciated by the local communities that included; being resistant to pests and diseases attack and high socio-economic and environmental values. The responses are tabulated in Table 4.17

Table 4.17

Source of *M. lutea* seeds and seedlings and benefits

Characters	Source description	Number of respondents	% response
Seeds	KFS nurseries	0	0.00
	Private nurseries	5	1.25
	Own farm	1	0.25
	Wildings	28	7.00
	Regenerations	366	91.5
Seedlings	KFS nurseries	6	1.50
	Private nurseries	2	0.50
	Own farm	6	1.50
	Wildings	20	5.00
	Natural Regenerations	366	91.50
Benefits	Timber	124	31.00
	Building materials	248	62.00
	Medicinal use	134	33.50
	Banana props	44	11.00
	Firewood	352	88.00
	Cultural values	20	5.00
	Shade	28	7.00
	Bee foliage	143	35.8
	Ornamental	0	0.00
	Not aware	228	57.00

Source: Author, (2017)

4.2.3.1 Benefits of *M. lutea* in Teso North Sub County

Majority of the respondents (88%) acknowledged firewood as a major use of *M. lutea*, while (5%) believed that it was for cultural use (Table 4.17).

The study showed that *M. lutea* has a wide range of benefits. The findings are therefore in line with studies by Takele *et al.* (2014) who found out that multipurpose tree species provided divergent benefits such as fodder, fuelwood, timber, mulch and human food.

He *et al.* (2015) in North Korea found out that the choice of a tree species for domestication was based on a single criterion, economic or environmental benefits. Elsewhere studies by

Weyerhaeuser and Kahrl (2006) found similar results. He *et al.* (2015), Ikerra *et al.* (1999) further found out that the awareness of uses and benefits of *Gliricidia sepium* in Malawi had made the farmers to intercrop *G. sepium* with farm crops to increase crop yields. Practicing of Agroforestry systems that incorporates tree farming can improve crop productivity according to Ajayi and Catacutan (2012).

Results on pole characteristics of *M. lutea*, 93% of respondents acknowledged that the tree was crooked while 7% perceived that it was straight (Table 4.18).

Table 4.18

Pole characteristics of *M. lutea* in Teso North Sub County

Pole characteristics	Number of respondents	% response
Straight	28	7.00
Crooked	372	93.00
Total	**400**	**100.00**

Source: Author (2017)

The species is disliked by the majority because of its crookedness. The implication here is that its pole shape prevents it from being adopted by the households.

4.2.3.2 Management of *M. lutea* in Teso North Sub County

Majority 37.25% adopted planting espacement of 10 m by 10m and above, while 9.75% believed planting espacement of 7 x 7 to 9 x 9 m (Table 4.19).

Planting espacement for *M. lutea* was not uniform. Traditionally silviculturists have always been clear that where timber production is an important objective of management or where new woodlots are created on bare land (Cicek *et al.*, 2016) for broad leaved trees species spacing of not more than (3.0 by 3.0) m is recommended. In conclusion *M. lutea* is rarely planted in plantations, hence wide spacing or scattered is the norm.

Table 4.19

Planting space of *M. lutea*

Espacement sizes (M)	Number of respondents	% response
1M x 1M – 3M x 3M	75	18.75
4M x 4M – 6M x 6M	52	13.00
7M x 7M - 9M x 9M	39	9.75
10M x 10 M and over	149	37.25
Random	85	21.25
Total	**400**	**100.00**

Source: Author (2017)

4.2.3.3 Rotation Age of *M. lutea*

Majority 52.3% believed that the rotation age of *M. lutea* was between 11 to 15 years, 1.5% believed to be less than five years (Table 4.20).

Table 4.20

Rotation age of *M. lutea*

Rotation age (Yrs)	Number of respondents	% response
< 5	6	1.50
5 – 10	35	8.80
11 – 15	209	52.30
> 15	30	7.50
Not aware	120	30.00
Total	**400**	**100.00**

Source: Author (2017).

This implies that the species rotation age lies between 5 to 10 years. The results are similar to the findings by Orwa *et al.* (2009).

Ninety percent of respondents (90%) were not aware whether *M. lutea* products require pretreatments, while 10% of the respondents acknowledged that the species products require treatment before use (Table 4.21).

Table 4.21

Response on treatment sawnwood of *M. lutea* products

Treatment	Number of respondents	% response
Requires treatment	40	10.00
Does not	360	90.00
Total	**400**	**100.00**

Source: Author (2017)

The implication here is that knowledge, awareness creation was missing. Treatments of wood products will increase its dimensional stability and resistance to biological degradation (Sandberg, 2016).

Farmers had significant market challenges of *M. lutea* products. The results showed that low prices (45.25%) was the greatest challenge farmers were facing, while 0.25% believed that scarce resources of *M. lutea* products was affecting its market opportunities. Thus leading to low domestication and adoption of the species (Table 4.22).

Table 4.22

Challenges in marketing of *M. lutea* products

Challenges	Number of respondents	% response
Short sizes of timber	79	19.75
Low demand	40	10.00
Low prices	180	45.00
Lack of market information	21	5.25
Scarcity	2	0.50
Not aware	78	19.50
Total	**400**	**100.00**

Source: Author (2017)

The short timber sizes were as a result of crookedness of the merchantable bole that resulted in small timber lengths. The low prices contributed to its poor domestication and adoption. Lack of market information also leads to its poor rate of domestication and adoption in the study area.

The results agrees with Rotich *et al*. (2017) who found sixty-three percent (63%) of farmers in Kapsaret strongly believed that access to reliable market for agroforestry tree products directly affected its adoption. For many agroforestry tree products, markets are poorly structured and coordinated (Roshetko *et al*., 2012).

4.3 Germination Rates of *M. lutea* Provenances

Percent germination experiment was conducted to know the germination across different geographical sources of seed provenance. The results showed a slight variation in germination percentage of the three provenances. Kakamega tropical forest provenance registered high germination percentage (98.7%) followed by Teso with 95.7% and lastly Siaya provenance with 93.7 % (Table 4.23). Overall germination was good.

Table 4.23

Germination results of *M. lutea* provenances

Provenance	Codes	Qty sown (g)	Number of germinates	% germination
Teso	Ml1	4	2,871	95.7
Siaya (KEFRI) Maseno	Ml3	4	2,811	93.7
Kakamega tropical forest	Ml2	4	2,961	98.7

Source: Author (2017)

The result indicated that Kakamega tropical forest could give a better germination rate than other sources.

However, there was no significant difference in germination rate (p = 0.920). These implied that there was no significant difference among provenances in seed germination rates ($p>0.05$). These findings differs with those of Shu *et al.*(2012) who found significant difference among provenances in seed germination percentage in a study carried on variation on seed and seedling traits among fifteen Chinese provenances of *Magnolia officinalis* in China. The results were however similar to the findings of Tinsae *et al.* (2014) who found no significant difference (p>0.05) in germination of *Tamarindus indica* among the provenances under considerations. Also the results agrees with the findings of *(*Dangasuk *et al.*, 1997; Loha *et al.*, 2006; Lopez-Upton *et al.*, 2005). In most plant species, seeds vary in their degree of germination between and within populations and between and within individuals (Mkonda *et al.,* 2003; Loha *et al.*, 2006). Causes of such variability might generally be attributed to either (a) genetic characters of source of population/plant (Shu *et al.,* 2012), or (b) impact of mother plant environment (Singh *et al.,* 2010). Gutterman (2000) stated that germination of seeds can be influenced by maternal factors, such as position of the seed in the fruit/tree, the age of the mother plant during seed maturation, as well as environmental factors such as day length, temperature, light quality, water availability and altitude. The high percentage germination results are in agreement with FAO (2014) who stated that the international regeneration standard for a viably collected seeds should be above eighty five percent (85%).

The value of the mean daily germination (MDG) varied significantly among the different geographical sources of *M. lutea* (Figure 4.1). The mean daily germination varied significantly in all the seed sources studied. The germination performance of *M. lutea* provenances showed Kakamega tropical forest (Ml2) gave better results compared to other provenances.

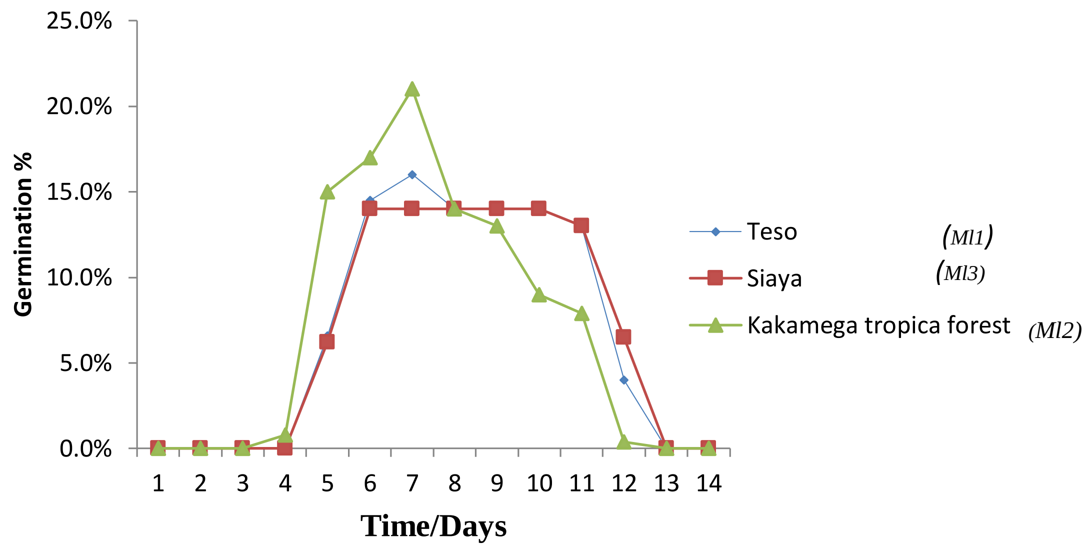

Figure 4.1: Germination % of *M. lutea* provenances per day

Kakamega tropical forest gave the highest germination rate during the seventh day of sowing and it germinated earlier compared to other two provenances. By the twelfth day all its seeds had germinated. These implied that there were slight variations in seed germination rate among three provenances. These results are similar with the findings of (Moya *et al.*, 2017; Kumar, 2003; Rawat *et al.*, 2006; Krishnan and Toky, 1996) who observed variation in germination among twelve seed sources of *Albizia lebbeck* from India. The results are also similar to the findings of Bhat and Chauhan (2003). Equally germination test was conducted to study the performance of *Pongamia pinnata* seeds collected from different locations and found that there was average germination per cent (84%) in all provenances as described by Sudhir (2003). Indeed the results agree with the findings by (Sameer and Siddiqui, 2008; and Hembrom *et al.*, 2010). However the result disagrees with the findings of Nawah (2008) who found germination variation in seed sources of *Albizia lebbeck* lied from 62.80 % to 96.36 %.

4.3.1 Seedlings Survival Rates in the Nursery

There was absolute survival of all seedlings raised via container mode in all the three provenances. On the other hand, the seedlings survival rate in the bare root was best for Kakamega Tropical Forest (99%) and worst for Teso 90% (Table 4.24).

The long-term yield of plantation per unit area can be affected by the survival rate of seedlings (Girma *et al.*, 2012). Therefore, in the nursery container mode of seedlings production from the three provenances gave better results compared to bare root mode. The result further implies that Kakamega tropical forest provenance (Ml2) performs better in both mode of seedlings production. The results are inconsistent with the findings by Moya *et al.* (2017).

Table 4.24

Survival Rate of *M. lutea* seedlings in container and bare root

Provenance	No of seedlings		No of deaths		% survival rate	
	Containers	Bare root	Containers	Bare root	Containers	Bare root
Teso (*Ml1)*	300	300	0	10	100	90.00
Kakamega tropical forest (*Ml2)*	300	300	0	3	100	99.00
Siaya (KEFRI) (*Ml3)*	300	300	0	8	100	97.30

Source: Author (2017)

4.4 Growth Rate of *Markhamia lutea* Seedlings

Kakamega tropical forest provenance (Ml2) registered the highest mean height growth of 8.0 cm, while Siaya (Ml3) had the least mean height growth of 6.0 cm in bare mode of seedling production (Figure 4.2).

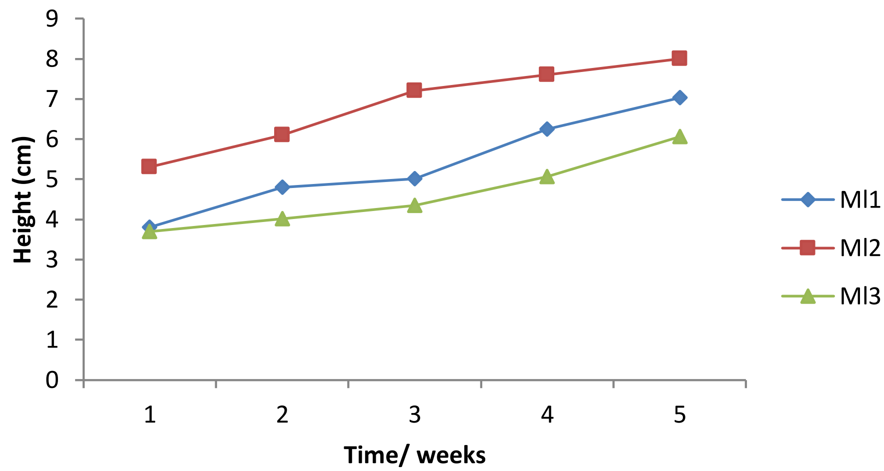

Figure 4.2: Mean seedling height in bare root

Markhamia lutea seedlings from Kakamega tropical forest provenance (Ml2) performed better in bare root mode of seedling production compared to other sources.

On the other hand the mean seedlings height growth performance of provenances in container mode of seedlings production was almost uniform with Kakamega tropical forest provenance (Ml2) exhibiting the highest mean height growth of 10.0 cm, while Siaya (Ml3) registered the least (9.0 cm) (Figure 4.3).

These results are in line with the findings of Ombati *et al.* (2017).

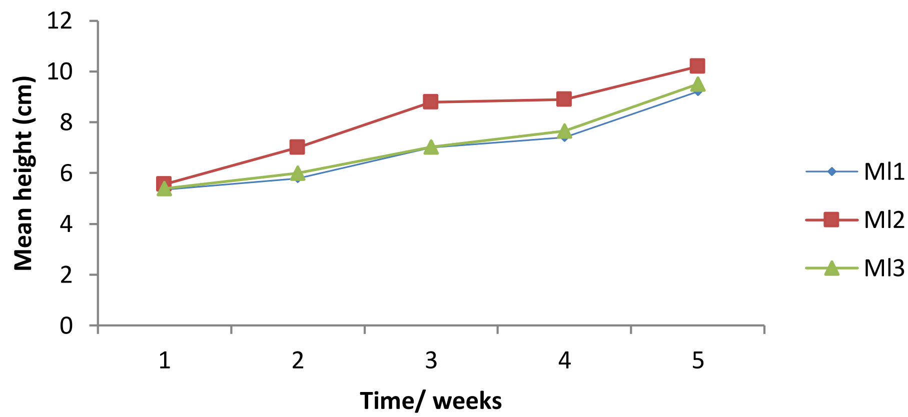

Figure 4.3: Mean height of *M. lutea* seedling in containers

The importance of fast growth rate of seedlings to farmers is that; seedlings takes short time in the nursery to reach plantable size, production of healthy seedlings, they suppress weeds hence a reduction of maintenance cost in terms of labour inputs and mass production of seedlings within a relatively short period that can be used for afforestation programs by the farmers. On the other hand slow growth rate takes long time in the nursery and has high maintenance cost (O'Reilly *et al.*, 2002).

Statistically there was significance difference in mean growth height from different *M. lutea* provenances in bare root mode of seedlings production ($p = 0.002$). The results further showed no significance ($p>.05$) difference in growth height performance of various provenances in container mode of seedling production. These results are similar to the findings by Moya *et* al. (2017) who found no significant effects on the growth of the *Nothofagus glauca* seedlings in terms of diameter and height. These results also agree with the findings of Munendrappa *et al.* (1997); and Kundu *et al.* (1997).

4.4.1 Shoot Collar Diameter

Teso provenance (Ml1) registered the highest mean shoot collar diameter of 0.044 mm, while Siaya (Ml3) had the least 0.036 mm (Figure 4.4).

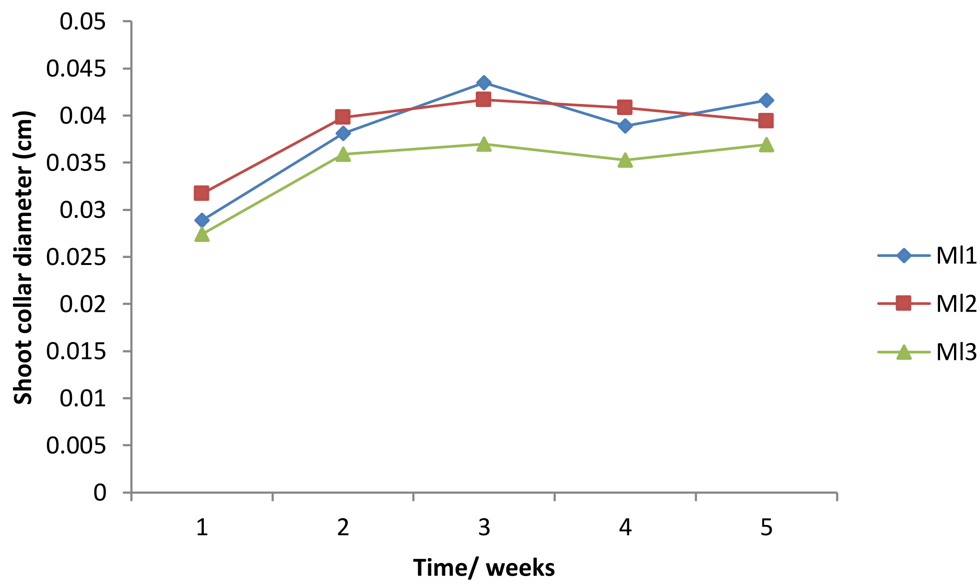

Figure 4.4: Mean shoot collar diameter in bare root

The results indicated that Teso provenance (Ml1) was statistically better than other two provenances in bare root mode of seedlings production.

In container mode of production the mean shoot collar diameter was uniform (0.05 mm) for both Teso (Ml1) and Kakamega tropical forest provenances (Ml2). Siaya (Ml3) registered the least 0.047mm (Figure 4.5). The findings are similar to that of Ombati *et al*. (2017).

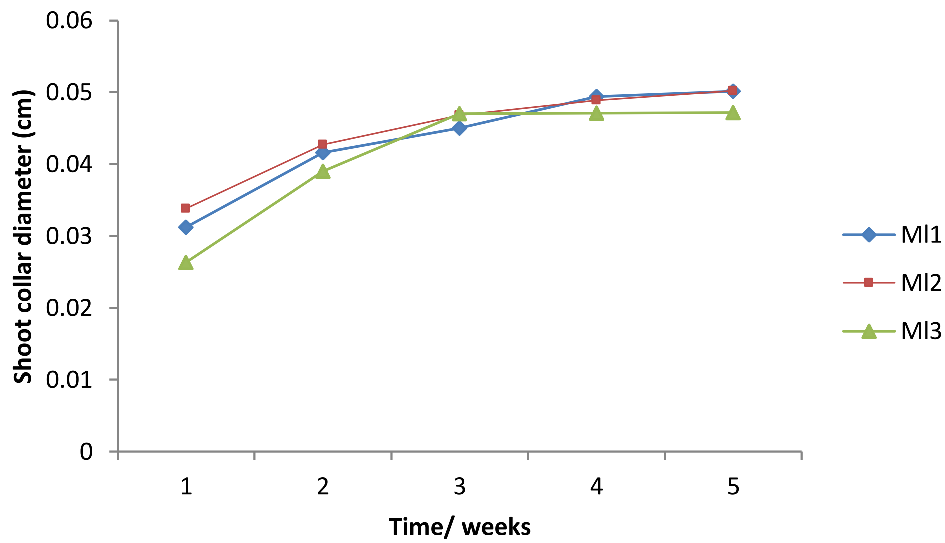

Figure 4.5: Mean shoot collar diameter growth in container

There was a significant difference ($p<0.05$) in mean shoot collar diameter among the three provenances in bare root mode of seedling production. On the other hand there was no significant difference ($p>0.05$) in mean shoot collar diameter among the three provenances in container mode of seedling production (Appendix 9).

The study showed variations in shoot collar diameter of seedlings of three provenances in different treatments. The findings are inconformity with Shu *et al.* (2012) and Dangasuk *et al.* (2001) who also observed variation in seedling diameter for *F. albida* Provenance at the nursery stage for 3 months. Bhat and Chauhan (2002) conducted an experiment to evaluate different seed sources of *Albizia lebbeck*. They found that the sources of Rajapura and Nauni sources of Himachal Pradesh performed better with respect to seed and seedling traits. This study is in line with the results obtained by Bala and Singh (1995) and Sudhir (2003) in *Jatropha curcus*.

4.5 Types of Soils in Teso North Sub County

The highest population of *M. lutea* in Angurai division was growing on sandy clay soils (56%), while 8% was growing on loamy sand soil. On the other hand *M. lutea* in Amagoro division were most observed growing on sand clay soil type (60%) and least observed (6%) on loamy sand soils (Table 4.25).

Table 4.25

Soil types on which *M. lutea* was observed growing

Block	Soil type	Frequency	% proportion of soil type
Angurai Div	Sand	7	14.00
	Clay	11	22.00
	Loamy sand	4	8.00
	Sand clay	28	56.00
Amagoro Div	Sand	5	10.00
	Clay	12	24.00
	Loamy sand	3	6.00
	Sand clay	30	60.00

Source: Author (2017)

The result shows that the study area can be a good site for planting *M. lutea* as it performs well in clay soils. The result agrees with the findings of Van Schaik (1986).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of research findings, conclusions, recommendations and suggestions for further research.

5.2 Summary

Domestication and adoption of *M. lutea* in Teso North Sub County was significantly influenced by households, education level, land size and tree tenure rights, extension services, traditional beliefs and taboos. 38.28% of households had primary level of education, 21.25% with household size of 7-8 members, 79.75% being farmers and 52.5% with land sizes of 1-5 acres, 42% of respondents believe that land size influence the decision to plant *M. lutea*, while 35% land size is too small to accommodate trees. Eighty three percent (83%) of respondents believe that *M. lutea* trees and land is owned by husbands hence this discourages the others from participating in its domestication and adoption.

Sixty four point two five percent (64.25%) of respondents that believed that the decision and rights to harvest *M. lutea* lies with the husband discouraged its domestication and adoption in addition to inadequate of extension support services (64%). 66% of the community believed that traditional taboos such as trees should not be cut or planted by women significantly affected the domestication and adoption of *M. lutea*.

Constraints that influenced domestication and adoption of *M. lutea* included sources of seedlings used for regeneration (91.5%), low market prices (45%), lack of information and awareness on its importance (43%) and small land sizes (14.25%).

The respondents reported that the main use of *M. lutea* included firewood production (88%), construction (62%) and timber production (31%).

Germination of *M. lutea* local provenances from Teso and Kakamega tropical forest was greater than 95%, while Siaya (KEFRI) was less than 95% for 13 days in green house.

On pricking out and transplanting gave a survival rate of greater than 90% in container and bare root for all the provenances. Growth rate of 4 cm in height after 5 weeks in bare root and shoot collar diameter of 0.04mm after 5 weeks for all provenances. There was no significant difference in early growth performance among the provenances under consideration in container mode of seedlings production, suggesting that these factors were not important in domestication and adoption of *M. lutea.*

The population of *M. lutea* was highest on sand clay soil type (56%) as compared to other soil type of the study area.

5.3 Conclusions

i. Domestication and adoption of *M. lutea* was significantly influenced by gender, households' size, education level of households, limited farm sizes, land and tree tenure rights, inadequate extension services, traditional beliefs.

ii. Germination of *M. lutea* local provenances from Teso and Kakamega tropical forest was greater than 95%, while Siaya (KEFRI) was less than 95% for 13 days in green house.
iii. Survival rate of *M. lutea* was greater than 90% in container and bare root method for all the three provenances.
iv. The population of *M. lutea* was highest on sand clay soil type (56%) as compared to sand (14%) and loam sandy (6%) suggesting that the study area has good soil type's ideal for the growth of *M. lutea*.

5.4 Recommendations

In view of the identified factors influencing the domestication and adoption of *Markhamia lutea* in the study area, the following recommendations can help to solve the problem to a greater magnitude.

i. Domestication and adoption of *M. lutea* in the study area can be possible if the socio-economic factors (gender, education level, Household size, land sizes, cultural beliefs) influencing its domestication and constraints in its adoption can be addressed.
ii. Need for further investigation as to why seed sources from Kakamega tropical forest was had better germination results, seedlings growth performance and high survival rates in all mode of seedlings production.
iii. Container mode of seedlings production at nursery level should be encouraged for better growth characteristics and uniformity of seedlings in terms of shoot collar diameter and shoot height.

iv. The observed variations on growth parameter in different treatments will enable selection of provenance with desired traits characteristics for tree improvement and recommendation of specific provenances for seed source.

v. Sand clay soil type is ideal for *M. lutea* growth in the study area.

5.5 Suggestions for Further Research

Silvicultural management of *M. lutea* provenances in the field so as to conclusively conclude the best provenance with desired traits for market characteristics is required.

Progeny test should be undertaken from the three provenances over a longer period of time so as to obtain more information on genetic characteristics on specific growth traits with clear straight pole characteristic for timber production and less crown cover. Selection and breeding research to improve for high product quality, high commercial value and high profitability that will lead to intensive domestication and adoption of *M .lutea* in the study area.

There is need to carry out a study on the soil types in Kakamega and Siaya to provide more insight on growth and development in those provenances.

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APPENDICES

Appendix 1: Questionnaire for households

I am a student at University of Kabianga undertaking a Master's Degree in Forestry (Tropical Forestry, Biology and Silviculture). Currently I am undertaking a research study on "**Towards domestication and adoption of *Markhamia lutea* in Teso North Sub County, Kenya".**You have been identified as one of the key respondent in providing the information required for the successful conclusion of the study. All information that you provide shall be treated with utmost confidentiality and will be used for the purpose of this study only. Remember all answers given are correct.

SECTION A: BACKGROUND INFORMATION

Respondent Number…………………………………………………………..

Division………………………………………Date of visit ………………………………

Sex (1) Male (2) Female, Age … (use √ in giving the correct entry)

Age: (1) 16 – 25 ( ), (2) 26 – 35 ( ), (3) 36 – 45 ( ) and (4) above 45 years ( ).

Marital status: (1) Married,(2) Single, (3) Widowed, (4) Divorced/ separated.

SECTION B:

Information on socio –economic factors influencing domestication and adoption of *M. lutea* in the study area

Education Level

I. What is your level of education?(1) None (2) Primary , (3) Secondary , (4) Tertiary (5) College/University
II. Does your level of education influence *M. lutea* tree-planting activities (1) Yes (2) No
III. If yes, how? ……………………………………………………………………….

Household size

i. What is the size of the household?
ii. (1) 1 and 2, (2) 3 and 4, (3) 5 and 6, (4) 7 and 8 (5) 9 and more
iii. Does your household family size affect your tree (*M. lutea)* planting options? (1) No (2) Yes.
iv. If yes, how ……………………

Occupation of Households

i. What is your **occupation**? (1) Employed (2) Farmer (3) Civil Servant/Teacher (4) Business Man/Woman (5)Other, Specify.---------------------------
ii. Does your occupation affect your tree planting activities in any way (1) Yes (2) No.
iii. If yes, how ………………………………………………………….

Land size

i. **What is the size of your farm?** (1) Less than 1acre, (2) 1.5 -5 acres, (3) 5.1-10 acres, (4) Over 10 acres.
ii. Does size of your farm influence your decision to plant/not to plant trees?(1) No (2) Yes
iii. If yes how? ------chose the most appropriate from choices given below;

a) The farm is too small to accommodate trees,
b) The farm is too big and trees are naturally growing,
c) The farm is used for cereals production
d) Trees interfere with arable crops
e) The farm is small hence trees can supplement income
f) Others, specify,---

Land and Tree Tenure:

i. Who owns this land? (1) Husband (2) Wife (3) Daughter/Son (5) Leased (6) Others, Specify ---
ii. Do you have a title deed for this land? (1) No (2) Yes
iii. If no, does it affect the planting of *M. lutea?*. (1) No (2) Yes
iv. Who owns the trees (1) Family (2) Husband (3) Wife (4) Children (5) Husband and Wife

Extension Services:

i. How often are you visited by the Kenya Forest Service extension staff? (1) Not at all, (2) Once in a month, (3) Yearly, (4)Rarely, (5) weekly basis
ii. How often do you visit the KFS extension officers/offices? (1) Not at all, (2 Once in a month), (3) Yearly, (4)Rarely, (5) weekly basis
iii. Does extension officers provide seedlings (1) No, (2) Yes
iv. If no, what is the source of your tree seedlings? (1) From on-farm nurseries (2) Bought from private nurseries (3) Borrow from friends (4) Others, specify ---------------------------

Traditional Believes and Taboos

i. Do you believe that some trees should not be planted by women (1) Yes (2) No
ii. Do you believe that some trees should not be cut for any purpose by women (1) Yes (2) No
iii. Do you believe that women should not own land and should not have a right to use any of the trees they plant and tend? (1) Yes (2) No
iv. Do you believe that women should not plant trees or you do not belief at all? (1) Yes ( ), (2) No
v. Do you have any traditional beliefs concerning trees and tree growing? (1) No (2) Yes
vi. If yes, does it affect the planting of *M. lutea?* (1) No (2) Yes

Constraints of planting *M. lutea*

i. Are there **constraints** to tree planting in Agro forestry production systems?
ii. If yes what are these constraints specify. ---------------------------------

Common tree species of the study area

i. Do you plant trees in your farm? ...... (1) Yes........... (2) No...................
ii. If yes which species…

Types of tree species
1.
2.
3.

General information on *M. lutea*

i. Do you have tree nursery? (1) Yes (2) No.

ii. If (yes) where do you get tree seeds from……………

iii. .if (no) where do you get tree planting materials (seedlings)from?......(1) KFS Nurseries ( ), (2) Private nurseries ( ) (3) individual ( ) (4) Wildings (5) Others ( ) specify………

iv. Do you know *M. lutea (Eswata)?* ---- *(1) Yes ( ) (2) No ( )*

v. Do you plant *Markhamia lutea (Eswata*)? (1) Yes ( ) (2) No ( ).If yes, where do you get seeds from?...........what is the source of seedlings?...1 buy ( ). 2. Wildings ( ), (3) Free issue by KFS, (4). Natural regeneration ( ).

vi. What are the benefits of *M. lutea?*(1) Timber ( ), (2) Firewood ( ), (3) Building ( ), (4) Medicinal ( ), (5) shade ( ), (6) Others ( )

vii. What planting espacement to you use and why …………………

viii. How long does it take to mature for production? (1) 5-10 Yrs ( ) , (2) 11-15yrs( ), (3) 16 -20 years( ), (4) Over 25 years , (5) Not aware ( ).

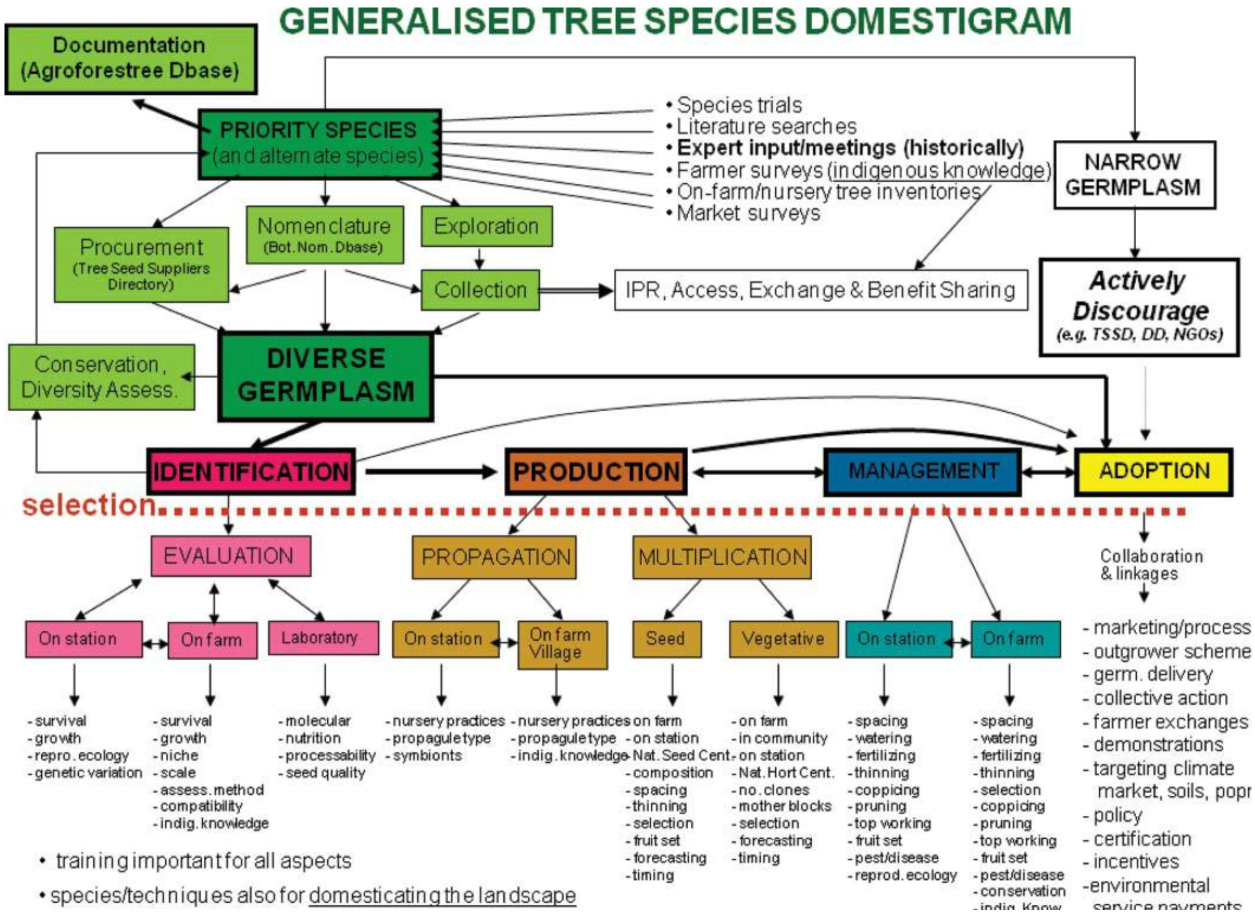
ix. Is the pole straight? (1) Yes ( ) (2) No ( ).

x. Does the crookedness of *M. lutea* affect its domestication and adoption? (1) Yes ( ) .(2) No ( )

xi. Do you treat *M. lutea* materials before use?(1) Yes (2) No--------

xii. What market challenges do you face in marketing *M. lutea* products?

Appendix: 2 Generalized Tree Domestigram



(Jamnadasset al. 2009).

Appendix 3

Demographic Summary of the Respondents

Demographic characteristics	Frequency	Percent
Male	261	65.2
Female	139	34.8
Total	400	100.0
16 - 25 years	2	.5
26 - 35 years	28	7.0
36 - 45 years	115	28.8
Above 45 Years	255	63.8
Total	400	100.0
Married	340	85.0
Single	16	4.0
Widowed	42	10.5
Divorced / Separated	2	.5
Total	400	100.0

Source: Author, (2017)

Appendix 4

Chi-square Test Summary

characters		**values**	**df**	Asymp. Sig. (ch2-sided)	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Gender	Pearson Chi-Square	35.798[a]	1	0.000		
Age	Pearson Chi-Square			0.981		
Land size	Pearson Chi-Square	1.363 E2[a]	1	0.000		
Household size	Pearson Chi-Square	32.615[a]	4	0.000		
Education level	Pearson Chi-Square	37.898[a]	8	0.000		
Occupation	Pearson Chi-Square	74.852[a]	5	0.000		
Land ownership	Pearson Chi-Square	1.524 E2[a]	1	0.000		
Traditional beliefs	Pearson Chi-Square			0.000		
Constraints	Pearson Chi-Square			0.000		
land and Tree rights	Pearson Chi-Square			0.000		
Extension services	Pearson Chi-Square			0.000		
Other land uses	Pearson Chi-Square			0.028		
M. lutea bole Form	Pearson chi-square			0.433		
Rotation age of *M. lutea*	Pearson chi-square			0.080		
Other land use activities	Pearson chi-square			0.028		

*** Significant difference (P<0.05)**

Appendix 5
Descriptive Analysis of Seedlings Height Growth of *M. lutea* Provenances

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Bare root	Teso	60	9.1083	1.90248	.24561	8.6169	9.5998	4.00	12.00
	Kakamega Tropical Forest	60	9.9750	1.54707	.19973	9.5753	10.3747	7.00	13.00
	Siaya (KEFRI)	60	8.8417	2.03464	.26267	8.3161	9.3673	4.00	13.00
	Total	180	9.3083	1.89256	.14106	9.0300	9.5867	4.00	13.00
Replicate	Teso	60	2.0000	.82339	.10630	1.7873	2.2127	1.00	3.00
	Kakamega Tropical Forest	60	2.0000	.82339	.10630	1.7873	2.2127	1.00	3.00
	Siaya (KEFRI)	60	2.0000	.82339	.10630	1.7873	2.2127	1.00	3.00
	Total	180	2.0000	.81877	.06103	1.8796	2.1204	1.00	3.00
Containers	Teso	60	1.5000	.50422	.06509	1.3697	1.6303	1.00	2.00
	Kakamega Tropical Forest	60	1.5000	.50422	.06509	1.3697	1.6303	1.00	2.00
	Siaya (KEFRI)	60	1.5000	.50422	.06509	1.3697	1.6303	1.00	2.00
	Total	180	1.5000	.50139	.03737	1.4263	1.5737	1.00	2.00

Appendix 6

Multiple Comparisons of Seedlings Height Growth of *M. lutea* Provenances

LSD

Dependent Variable	(I) Provenances	(J) Provenances	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
bare root	Teso	Kakamega Tropical Forest	-.86667*	.33587	.011	-1.5295	-.2038
		Siaya (KEFRI)	.26667	.33587	.428	-.3962	.9295
	Kakamega Tropical Forest	Teso	.86667*	.33587	.011	.2038	1.5295
		Siaya (KEFRI)	1.13333*	.33587	.001	.4705	1.7962
	Siaya (KEFRI)	Teso	-.26667	.33587	.428	-.9295	.3962
		Kakamega Tropical Forest	-1.13333*	.33587	.001	-1.7962	-.4705
Replicate	Teso	Kakamega Tropical Forest	.00000	.15033	1.000	-.2967	.2967
		Siaya (KEFRI)	.00000	.15033	1.000	-.2967	.2967
	Kakamega Tropical Forest	Teso	.00000	.15033	1.000	-.2967	.2967
		Siaya (KEFRI)	.00000	.15033	1.000	-.2967	.2967
	Siaya (KEFRI)	Teso	.00000	.15033	1.000	-.2967	.2967
		Kakamega Tropical Forest	.00000	.15033	1.000	-.2967	.2967
Containers	Teso	Kakamega Tropical Forest	.00000	.09206	1.000	-.1817	.1817
		Siaya (KEFRI)	.00000	.09206	1.000	-.1817	.1817
	Kakamega Tropical Forest	Teso	.00000	.09206	1.000	-.1817	.1817
		Siaya (KEFRI)	.00000	.09206	1.000	-.1817	.1817
	Siaya (KEFRI)	Teso	.00000	.09206	1.000	-.1817	.1817
		Kakamega Tropical Forest	.00000	.09206	1.000	-.1817	.1817

*. The mean difference is significant at the 0.05 level.

Appendix 7

ANOVA of Seedlings Height Growth of *M lutea* Provenances

		Sum of Squares	df	Mean Square	F	Sig.
bare root	Between Groups	42.133	2	21.067	6.225	.002
	Within Groups	599.004	177	3.384		
	Total	641.137	179			
Replicate	Between Groups	.000	2	.000	.000	1.000
	Within Groups	120.000	177	.678		
	Total	120.000	179			
Containers	Between Groups	.000	2	.000	.000	1.000
	Within Groups	45.000	177	.254		
	Total	45.000	179			

Appendix 8

Descriptive Analysis of Shoot Collar Diameter of *M. lutea*

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Bare root	Teso	60	.04575	.011459	.001479	.04279	.04871	.022	.072
	Kakamega Tropica Forest	60	.04330	.012454	.001608	.04009	.04652	.004	.075
	Siaya (KEFRI)	60	.03887	.012384	.001599	.03567	.04207	.001	.065
	Total	180	.04264	.012374	.000922	.04082	.04446	.001	.075
Containers	Teso	60	1.50	.504	.065	1.37	1.63	1	2
	Kakamega Tropica Forest	60	1.50	.504	.065	1.37	1.63	1	2
	Siaya (KEFRI)	60	1.50	.504	.065	1.37	1.63	1	2
	Total	180	1.50	.501	.037	1.43	1.57	1	2
Replicate	Teso	60	2.00	.823	.106	1.79	2.21	1	3
	Kakamega Tropica Forest	60	2.00	.823	.106	1.79	2.21	1	3
	Siaya (KEFRI)	60	2.00	.823	.106	1.79	2.21	1	3
	Total	180	2.00	.819	.061	1.88	2.12	1	3

Appendix 9

ANOVA Test for Seedling Shoot Collar Diameter

		Sum of Squares	df	Mean Square	F	Sig.
Bare root	Between Groups	.001	2	.001	4.983	.008
	Within Groups	.026	177	.000		
	Total	.027	179			
Containers	Between Groups	.000	2	.000	.000	1.000
	Within Groups	45.000	177	.254		
	Total	45.000	179			
Replicate	Between Groups	.000	2	.000	.000	1.000
	Within Groups	120.000	177	.678		
	Total	120.000	179			

Appendix 10

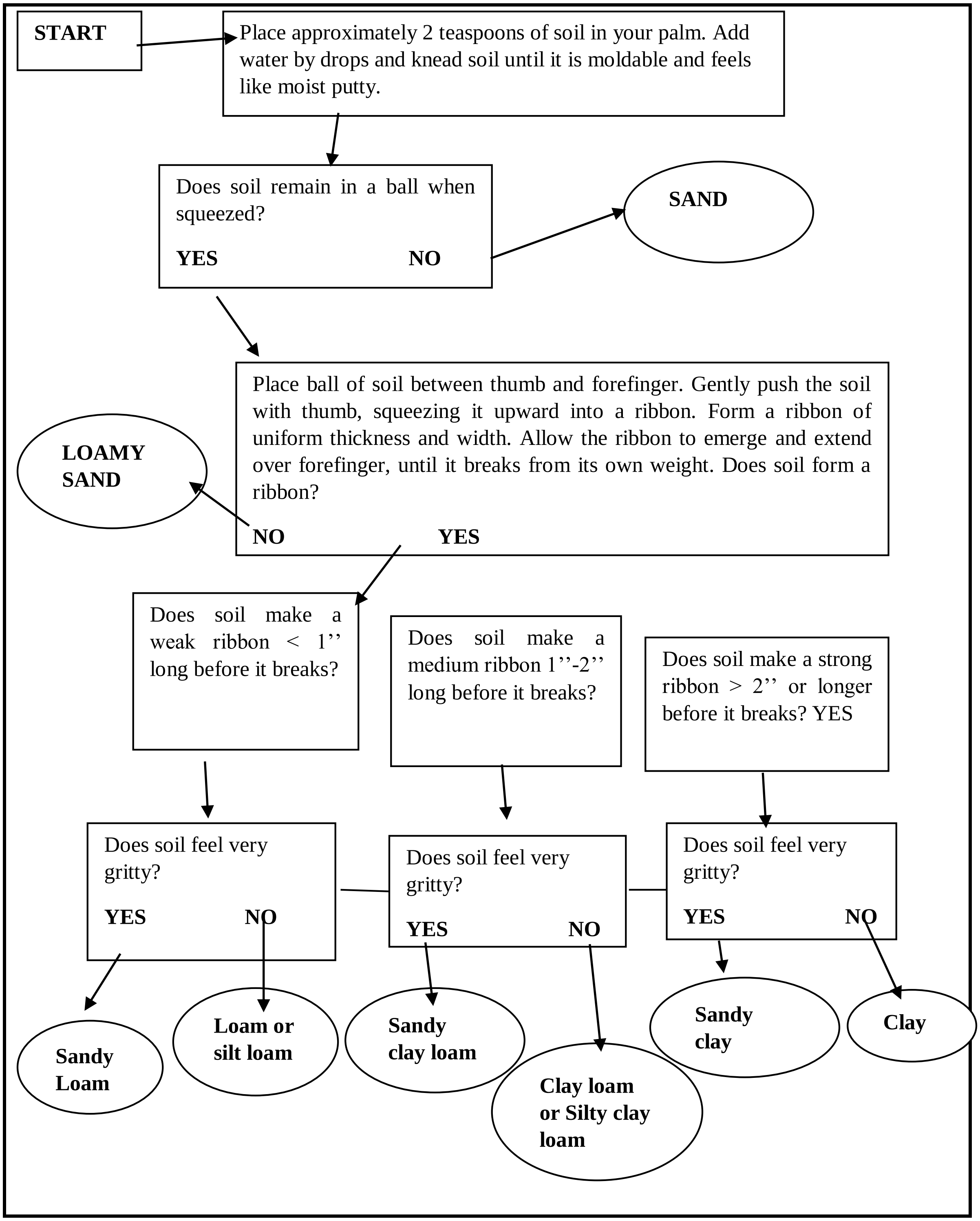
Multiple Comparisons of Shoot Collar Diameter of *M. lutea* Provenances

LSD

Dependent Variable	(I) Provenance	(J) Provenance	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Bare root	Teso	Kakamega Tropica Forest	.002447	.002211	.270	-.00192	.00681
		Siaya (KEFRI)	.006883*	.002211	.002	.00252	.01125
	Kakamega Tropica Forest	Teso	-.002447	.002211	.270	-.00681	.00192
		Siaya (KEFRI)	.004437*	.002211	.046	.00007	.00880
	Siaya (KEFRI)	Teso	-.006883*	.002211	.002	-.01125	-.00252
		Kakamega Tropica Forest	-.004437*	.002211	.046	-.00880	-.00007
Containers	Teso	Kakamega Tropica Forest	.000	.092	1.000	-.18	.18
		Siaya (KEFRI)	.000	.092	1.000	-.18	.18
	Kakamega Tropica Forest	Teso	.000	.092	1.000	-.18	.18
		Siaya (KEFRI)	.000	.092	1.000	-.18	.18
	Siaya (KEFRI)	Teso	.000	.092	1.000	-.18	.18
		Kakamega Tropica Forest	.000	.092	1.000	-.18	.18
Replicate	Teso	Kakamega Tropica Forest	.000	.150	1.000	-.30	.30
		Siaya (KEFRI)	.000	.150	1.000	-.30	.30
	Kakamega Tropica Forest	Teso	.000	.150	1.000	-.30	.30
		Siaya (KEFRI)	.000	.150	1.000	-.30	.30
	Siaya (KEFRI)	Teso	.000	.150	1.000	-.30	.30
		Kakamega Tropica Forest	.000	.150	1.000	-.30	.30

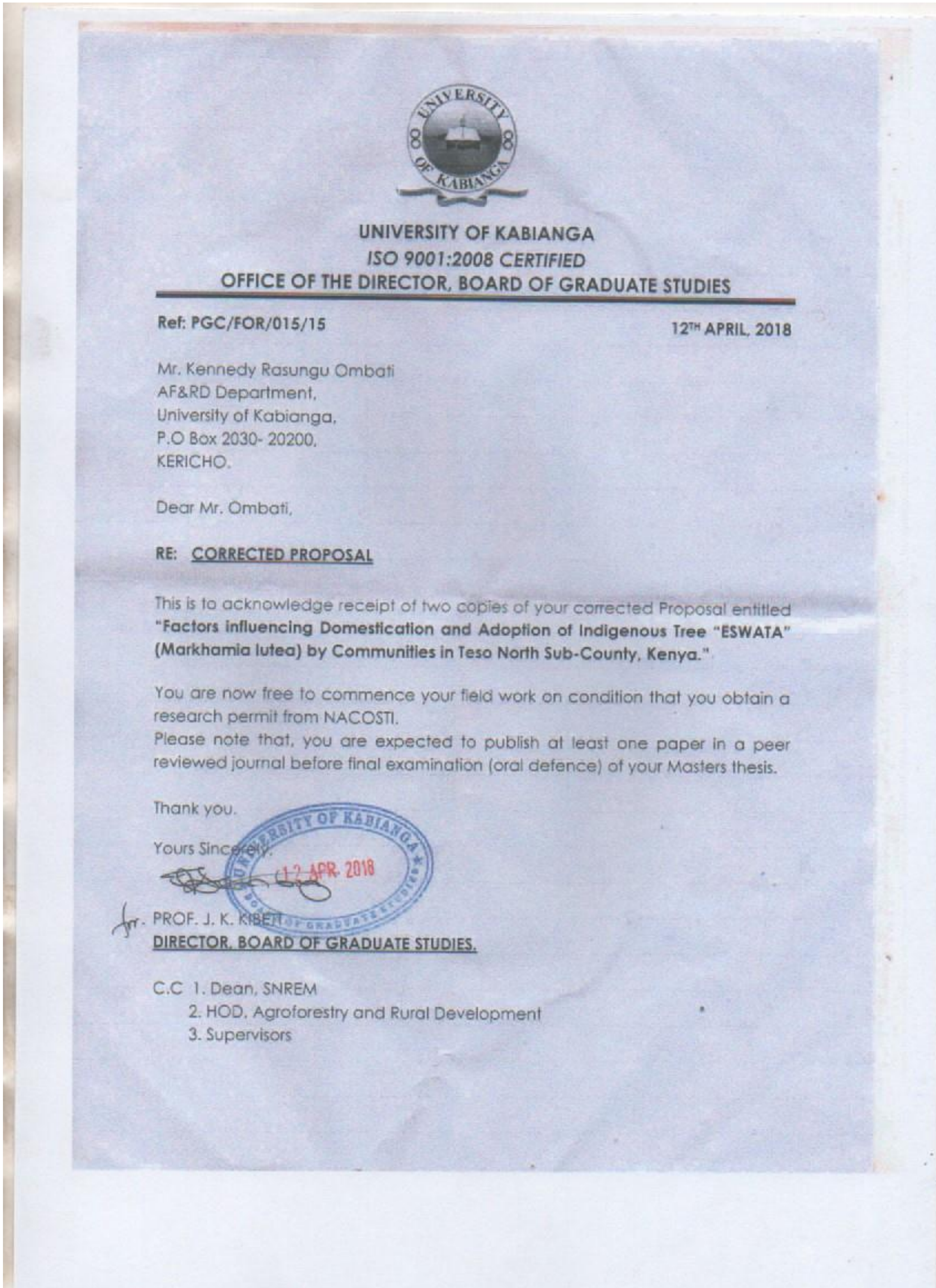
*. The mean difference is significant at the 0.05 level.

Appendix 11: Soil Texture Feel Test Key



Source: Adapted from Thien, (1979).

Appendix 12: Research Authorization from University



UNIVERSITY OF KABIANGA
ISO 9001:2008 CERTIFIED
OFFICE OF THE DIRECTOR, BOARD OF GRADUATE STUDIES

Ref: PGC/FOR/015/15 **12TH APRIL, 2018**

Mr. Kennedy Rasungu Ombati
AF&RD Department,
University of Kabianga,
P.O Box 2030- 20200,
KERICHO.

Dear Mr. Ombati,

RE: CORRECTED PROPOSAL

This is to acknowledge receipt of two copies of your corrected Proposal entitled **"Factors influencing Domestication and Adoption of Indigenous Tree "ESWATA" (Markhamia lutea) by Communities in Teso North Sub-County, Kenya."**

You are now free to commence your field work on condition that you obtain a research permit from NACOSTI.
Please note that, you are expected to publish at least one paper in a peer reviewed journal before final examination (oral defence) of your Masters thesis.

Thank you.

Yours Sincerely,

12 APR 2018

for. PROF. J. K. KIBETT
DIRECTOR, BOARD OF GRADUATE STUDIES.

C.C 1. Dean, SNREM
2. HOD, Agroforestry and Rural Development
3. Supervisors

Appendix 13: Research Authorization from NACOSTI

NACOSTI

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: 020 400 7000, 0713 788787,0735404245
Fax: +254-20-318245,318249
Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref No. **NACOSTI/P/18/58626/22313**

Date: **25th April, 2018**

Kennedy Rasugu Ombati
University of Kabianga
P.O.BOX 2030,20200
KERICHO.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Factors influencing domestication and adoption of indigenous tree "Eswata" (Markhamia Lutea) by communities in Teso North Sub - County, Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Busia County** for the period ending **23rd April, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Busia County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Busia County.

The County Director of Education
Busia County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified

Appendix 14: Research Permit

THIS IS TO CERTIFY THAT:
MR. KENNEDY RASUGU OMBATI
of UNIVERSITY OF KABIANGA, 0-50244
AMAGORO,has been permitted to
conduct research in *Busia County*

on the topic: *FACTORS INFLUENCING DOMESTICATION AND ADOPTION OF INDIGENOUS TREE "ESWATA" (MARKHAMIA LUTEA) BY COMMUNITIES IN TESO NORTH SUB - COUNTY, KENYA*

for the period ending:
23rd April,2019

Permit No : NACOSTI/P/18/58626/22313
Date Of Issue : 25th April,2018
Fee Recieved :Ksh 1000

Applicant's Signature

Director General
National Commission for Science, Technology & Innovation

CONDITIONS

1. The License is valid for the proposed research, research site specified period.
2. Both the Licence and any rights thereunder are non-transferable.
3. Upon request of the Commission, the Licensee shall submit a progress report.
4. The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.
5. Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.
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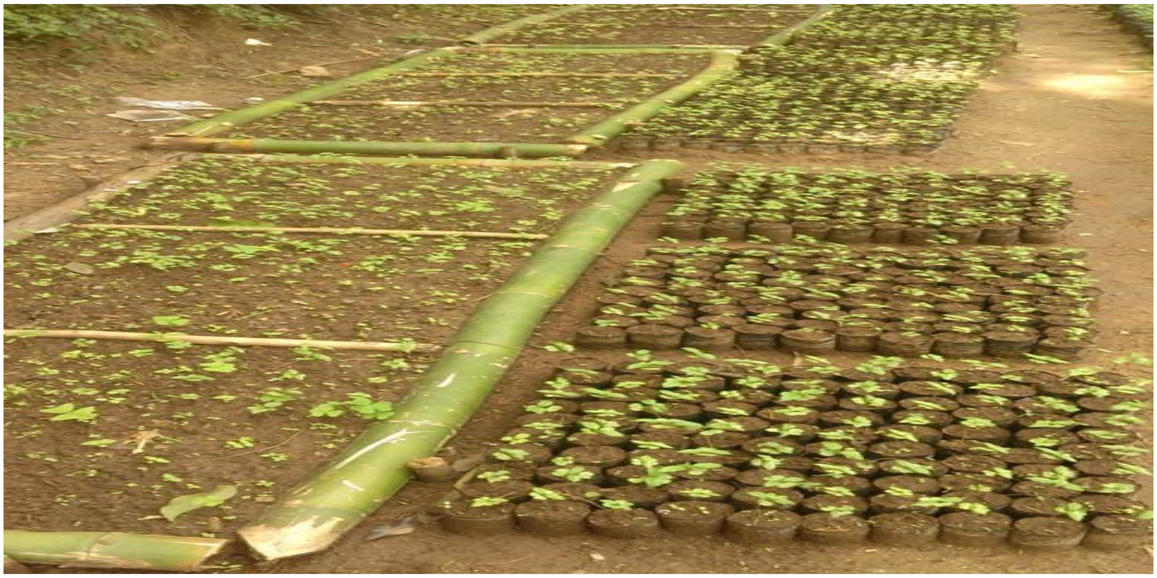

Plate 1: Container and swaziland mode of seedlings production.

Source; Author, (2017)

Plate 2: *Markhamia lutea* bole characteristics
Source; Author, (2017)

Plate 3: Seedlings of *M. lutea* provenances in two mode of production
Source; Field experiment (June – August 2017).

Plate 4: *Eucalyptus species* woodlot
Source; Field survey (June – August 2017)

Plate 5: Woodlot of *Eucalyptus species*
Source: Author, (2017)

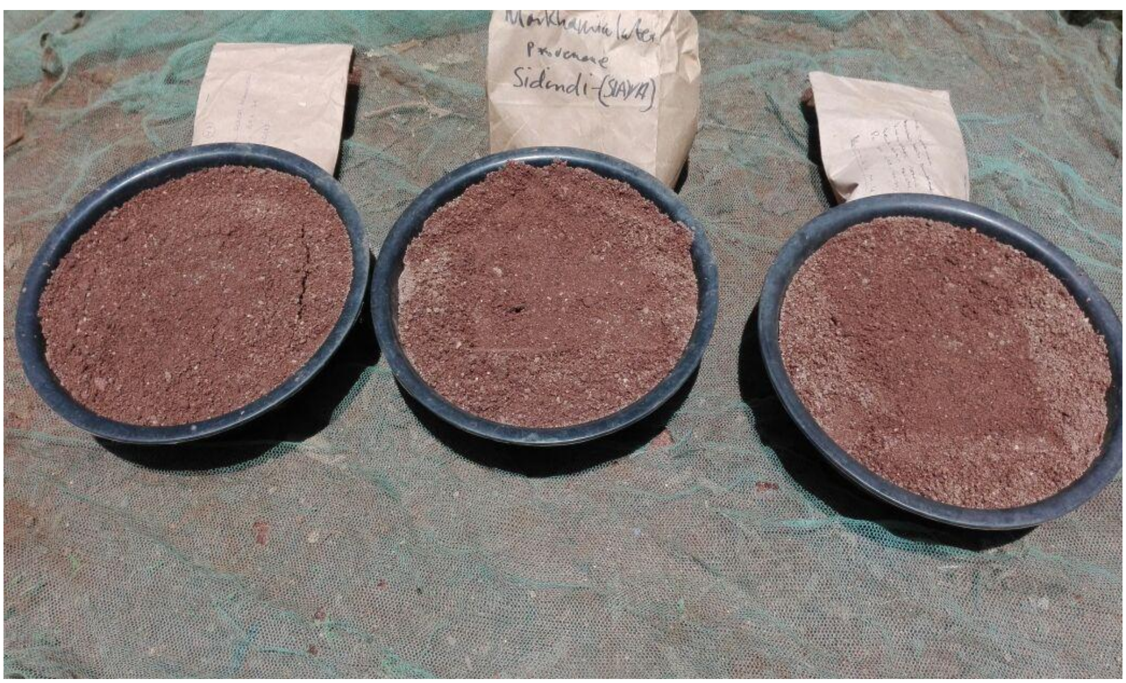

Plate 6: Trays for seed germination
Source: Author, (2017)

Plate 7: Germination experiment
Source: Author, (2017)

Plate 8: Germination of *M. lutea provenances*
Source: Author, (2017)

Plate 9: Electric weighing of pure seeds of *M. lutea* provenances

Publication 1: Towards Domestication and Adoption of *M. lutea*

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Towards Domestication And Adoption Of Eswata (*Markhamia Lutea)* In Teso North Sub County, Kenya

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