# Influence of trees on soil characteristics and maize productivity in small holder farms of western Kenya

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## DECLARATION

This dissertation is my original work and has not been presented in whole or part for award of a degree in Jomo Kenyatta University of Agriculture and Technology or any other institution of higher learning.

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# DEDICATION

To my mother Jenipher and my husband Solomon

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## List of Abbreviations and acronyms

ANOVA –Analysis of variance

CDM – Clean Development Mechanism

CEC – Cation Exchange Capacity

DBH – Diameter at Breast Height

FAO – Food and Agricultural Organization of the United Nations

GDP – Gross Domestic Product

GOK – Government of Kenya

GPS – Global Positioning System

ICRAF – International Centre for Research in Agroforestry (World Agroforestry Centre)

KARI – Kenya Agricultural Research Institute

LM – Lower Midland

UM – Upper Midland

REDD - Reduced Emissions from Deforestation and Forest Degradation

RUFORUM – Regional Universities Forum

SE – Standard Error of mean

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## Abstract

Maize production in Kenya has been decreasing with time, especially in Western Kenya which is one of the main belts of maize production. This is due to low purchasing power for inorganic fertilizers by resource poor farmers. Use of local inputs such as tree and shrub biomass that are easily available in the farms may be a realistic option to improve soil fertility. This study evaluated the effect of four tree species (*Grevillea robusta, Leuceana spp, Markhamia lutea* and *Mangifera indica*) on soil pH, CEC, TOC and on growth and yield of maize. The study was done on pre-selected farmer groups in Bungoma and Siaya by the ongoing Sustainable Intensification of Maize Legume cropping system for food security in Eastern and Southern Africa (SIMLESA) project. A baseline survey was conducted to determine common tree species growing on farms. Farms with common trees growing along the farm boundary were selected. The trees species that were used for the study were *Grevillea robusta, Leuceana spp*, *Markhamia lutea* and *Mangifera indica.* Soil samples were randomly taken at a 1 m radius using a soil auger for three distance intervals, that is, 2, 7 and 12 m distance away on the ground from each of the selected tree and mixed thoroughly to come up with a composite sample for each treatment. This was repeated for two other trees of the same species in the same farm. Sampling was done at two levels, namely 0-15 cm (top soil) and 15-30cm (sub soil).  The soil samples were analyzed for soil pH, soil TOC and soil CEC. Soil pH, CEC and TOC did differ significant ($P>0.05$) at the different distance intervals for all the tree species. Results on maize growth indicated that the crops under the canopies of G. *robusta*, *Leuceana* spp and *M. indica* had suppressed growth compared to those that were few meters away while crops close to the canopies of *M. lutea* performed better compared to those that were some distance away. *Eucalyptus* spp, *Markhamia lutea* and *Grevillea robusta* were the most preferred trees. From the study, it's evident that trees affect the chemical properties of soil,that is TOC, CEC and soil pH and all the trees suppressed plant growth and yield except *M lutea*. Therefore more research on the potential of *M lutea* as an agroforestry tree and how it affects the soil properties since it had a different trend from other trees.

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background

Agriculture remains fundamental for poverty reduction, economic growth and environmental sustainability for agriculture dependent countries. It contributes to economic development in many ways: as an economic activity and leading sector for economic growth, as a source of livelihood, as a provider of environmental services and as a contributing factor to peace and stability by providing food to the growing population (World Bank, 2008). Enhancing smallholder productivity and sustainable economic growth are pre-requisites to achieving the full contribution of agriculture to overall growth and development. Increasingly, developing countries are viewing science and technology as the drivers of economic growth and agricultural research and development is expected to play a significant role in the process.

In Kenya, agriculture is an economic mainstay contributing up to 24% of the Gross Domestic Product (GDP), (World Bank, 2008). About 80% of national employment is linked to agriculture, either directly or indirectly through linkages with manufacturing, distribution of food, and agriculture related sectors. The principal cash crops are tea, horticultural crops, and coffee whereas the major food crops include maize, potato, wheat and rice among other crops.

Maize is a major food crop in Kenya, covering approximately15 million hectares. The crop dominates all food security considerations in the country and a decline in maize stock is considered a threat to food security (Ouma and Groote, 2011). It accounts for about 40 percent of daily calories and has per capita consumption of 98 kilograms; this translates to between 30 and 34 million bags (2.7 to 3.1 million metric tonnes) of annual maize consumption in Kenya. The country produces only 28 million bags (2.5 million metric tonnes) yet has a potential of producing up to 3.0 million metric tonnes. The deficit is bridged by imports from neighboring countries. (www.fao.org).

Western Kenya is among the areas in the country with great potential for crop production due to high rainfall (1,740 to 1,940 mm/annum). The soils were fertile in the past and with the low population at that time production levels were capable of meeting demand (Achieng *et al.*, 2001). The increasing population pressure has reduced the size of the land. Coupled with limited use of fertilizers (due to high fertilizer costs and even availability when required, this has led to nutrient mining (Stoorvogel *et al.*, 1993). The area receives bimodal rainfall distribution with long rains from March to June, and short rains from October to December that allows for two cropping seasons per year. The annual staple food crops grown in the two seasons are maize, beans, sorghum, cassava and finger millet (ICRAF, 2010). Maize is the most important crop enterprise in the area (Howell *et al.*, 1999) with current production standing at 1.3tonnes per hectare (t $ha^{-1}$) only against a potential yield of 3.8-4.0 t $ha^{-1}$ (Achieng et al., 2001).

Factors contributing to the gap between production and potential yields include poor soil fertility, poor crop husbandry and use unimproved seeds among others (Achieng et al., 2001). Farmers thus have possibility to use of inorganic fertilizers to improve the yields of maize. However, this has not been adopted widely since a majority of the smallholder farmers are resource poor and cannot afford to use the recommended fertilizer rates

(Achieng, 2001). Alternative but less costly nutrient sources are therefore important in improving maize yields in western Kenya including the use of organic manure and fertilizer trees.

Measures which involve the adoption of sound agricultural practices that are sustainable and aim at improving productivity and the health status of the soil which is the single most important resource for agricultural production should be encouraged. Sustainable agriculture is defined as establishing high, lasting and economic soil productivity, without damaging the soil and the environment, improving quality of life. Ecological, social and economic dimensions must always be considered. In order to keep agricultural production of lands sustainable, Conservation Agriculture based on minimum-till system, organic agriculture and use of trees that can complement crops by supplying nutrients could act as alternative to reconcile agriculture with its environment and overcome the imposed constraints of continuous inputs cost as a result of economic constraints (Ghosh et al., 2010).

Trees growing within croplands are of great importance. They contribute in controlling of soil erosion, providing shade and temperature regulation alongside providing other products like fodder, timber, building materials firewood among other products. Some tree species are known to have beneficial effects to crops by adding nutrients to the soil (Mac Robert *et al*, 2003). These include nitrogen fixing tree species that provide atmospheric nitrogen that can be used by crops. When incorporated in landscapes where maize is grown, such trees can provide an effective solution to reversing the spiral of declining productivity caused by land degradation and extreme environmental conditions.

Planting appropriate trees on farm can help small holder farmers to obtain better yields at lower costs.

In Western Kenya, tree planting is mainly farm-based with a mix of exotic and indigenous trees dominating the landscape. Although trees have previously been planted strictly separate from crops, most trees are currently planted in croplands, either along farm boundaries or intercropped with crops, depending on land size and/or tree species utility (Kituyi *et al*. 2001). Boundary planting is adopted to limit competition with crops, while highly competitive trees such as eucalyptus are often planted in woodlots for households with large land sizes (Kuyah *et al*. 2009). Studies have reported low abundance of trees in smallholder farmlands in western Kenya (Kituyi *et al*. 2001). Farmers in this part of Kenya rarely use trees and shrubs for soil fertility improvement.

Residues from tree on farms are as a source of nutrients to crops (Mureithi, 1999) because upon decomposition, tree residues provide organic matter, nitrogen, phosphorus and other essential nutrients which results in increased yields. For example, *Faidherbia albida*, one of the tree species that is being introduced into the agroforestry system has a reverse phenology in that during the rain seasons, it shades its leaves and the rich organic matter that's formed from these leaves enriches the soil nutrients which are generally responsible for a substantial increase of grain yields under its canopy (GART, 2010). In shading its leaves during the rainy season, the tree does not compete with the crops for light and thus it's an ideal tree for agroforestry parklands.

On the other hand, studies have shown that the fertility of soils under trees and *Faidherbia albida* canopies are generally more fertile than those outside the canopy

(Boffa, 2000, GART, 2010). Many of the soil-fertility and nutrient cycling benefits of agroforestry systems are derived from the production and decomposition of tree biomass (Nair *et al.,* 1999). Some trees have shown to complement crops when grown simultaneously by providing nutrients for crops. Such trees are referred to as fertilizer trees. Similarly, fertilizer trees also increase maize yield and reduce production costs (MacRobert *et al*., 2007). Trees can thus be used as a complement to crop residue cover since they are perennial (Jamnadass *et al*., 2011).

Much attention has been given to the role of trees in enhancing food security and contributing to climate change mitigation. Potential benefits have been reported in other parts of southern Africa like Zambia, Malawi and Zimbabwe where fertilizer trees have been adopted widely (ICRAF, 2009).

## 1.2 Problem Statement

Trees in croplands have positive effect on crop performance, but also can show competition when intercropped with crops (Ong *et al*.1999). The choice of what trees should be incorporated within croplands has been a problem. Farmers face challenges in selecting the most appropriate trees for their enterprise. Although the choice of tree species to be planted is determined by the size of land available, the utility of the tree, family needs among other factors, farmers often desire to raise multipurpose trees that can grow with crops without reducing the yield of the later (Kituyi *et al.* 2001). Literature on the selection of tree species for inclusion in crop lands, the effect of these trees on soil properties, as well as consequent effect on growth and yield of maize is lacking. Therefore a study of the prevalent trees and how they affect the soil properties and growth and yield of maize will be beneficial. Studies have shown that inclusion of trees in croplands affect crop productivity through their influence on physical and chemical properties on soil (Sileshi and Mafongoya, 2006a; Beedy, 2008). Some literature exists on trees found in croplands in Western Kenya but there is no synthesis of trees commonly grown in croplands and their effect on growth and yield of maize and soil properties. It is therefore essential to identify the tree species preferred by farmers and determine how the prevalent tree species in Western Kenya influence maize production.

## 1.3 Justification

Maize in western Kenya is grown mainly for subsistence, although some farmers sell surplus for income (Achieng, 2001). Declining land productivity, mainly attributed to soil impoverishment as a result of intense agricultural use and soil erosion (Kiptot et al., 2006), has led to reduced crop yields with the attendant challenges (Kapkiyai et al., 1998). Smallholder farmers in the region rely on organic, or a mix of organic and inorganic fertilizer application for maize production. Growers who do not have access to manure, and cannot afford inorganic fertilizers experience recurrent low yields. Since the majority of farmers lack the finances to enrich their fields with inorganic fertilizers (Muriithi *et al.*, 1994; Kapkiyai *et al.*, 1998), and because the role of trees in enhancing crop production is not well appreciated by most farmers, there is need to assess the beneficial trees in the region, have an integrated approach that incorporates the appropriate trees in cropping systems so as to improve the soil chemical properties thus improving the production of maize. Fertilizer trees have been shown to improve crop production in other countries such as, Malawi, Zimbabwe, and Zambia where increased yields at reduced production cost. Information generated in this study on tree species prevalent in the Western Kenyan croplands, their effect on soil, and their influence on growth and yield of maize will provide a basis for informed agroforestry interventions to enhance maize production.

## 1.4 Objectives

The general objective of the study was to determine the influence of tree species on soil properties and maize yield in croplands of Western Kenya.

The specific objectives of the study were to:

1. Identify the main tree species found within croplands in Western Kenya,
2. Determine the effect of the prevalent tree species on the chemical properties of soils; and
3. Assess the effect of the prevalent tree species on growth and yield of maize.

## 1.5 Research Questions

1. What are the most prevalent tree species in the agricultural landscapes in western Kenya?
2. What effect do the preferred trees have on the chemical properties of soil?
3. How do the preferred tree species affect the growth and yield of maize?

## 1.6 Hypotheses

1. Western Kenya is dominated by different tree species.
2. Dominant tree species growing within croplands affect the chemical properties of soil
3. Maize growth and yield is affected by tree species growing within croplands.

## CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Maize production in Kenya

Maize is produced in most ecological zones in Kenya, and is the preferred food crop, accounting for about 40 percent of daily calorie intake of the Kenyan population (FAO, 2007). While large-scale farmers grow maize for commercial purposes only, the majority of smallholder farmers grow it for subsistence and a source of income when there is surplus. Smallholder farmers contribute more than 70% of the country's maize production (Ouma et al., 2002). Despite efforts to improve production, domestic production has stagnated to between 24 and 28 million bags over the last 10 years (FAO, 2007).

While maize is important in Kenya's crop production patterns accounting for about 20% of gross farm output for the small-scale farming sector (Jayne, *et al*., 2001), production of the crop in Western Kenya is constrained by a myriad of related factors, with the extent of contribution of the various factors differing across the sites. Maize is the most important crop enterprise in the area (Howell *et al*., 1999) with current production standing at 1.3tonnes per hectare (t $ha^{-1}$) only against a potential yield of 3.8-4.0 t $ha^{-1}$ (Achieng et al., 2001).

Soil degradation on smallholder farms has been cited as the major cause of low maize production in Kenya (Sanchez *et al.*,1997). Soil nutrient outflows far exceed inflows in most farming systems resulting in negative nutrient balances (Sanchez *et al.*,1997), which combined with stocks of nutrients in the soil, are widely used as sustainability indicators (Vanlauwe and Giller, 2006). Smaling *et al.* (1993) showed that net average annual mining from the soils in western Kenya was about 42 kg nitrogen per hectare, 3kg phosphorus per hectare and 29kg potassium per hectare. Although soil fertility depletion is often acknowledged as an insidious and slow process (Ervin and Ervin, 1982; Barrios *et al.*,2006), it is important that farmers perceive the problem and associated yield losses before they can consider investing in soil fertility enhancing technologies. In particular, if farmers ignore or underestimate soil fertility losses, they may fail to replenish soil nutrients because they erroneously view such investments as unnecessary or unprofitable or both.

Previous studies have shown that farmers' perceptions of soil fertility decline encourage the adoption of soil conservation practices and land productivity enhancing technologies (Degrande and Duguma, 2000; Mbaga-Semgalawe and Folmer, 2000). In contrast, farmers may perceive the problem but give priority to other problems when deciding how to invest their resources due to situational constraints such as lack of financial resources to buy inputs and lack of technical information (Franzel 1999; Mbaga-Semgalawe and Folmer, 2000). Over the years, population pressure and lack of growth in other sectors have increased pressure on natural resources, resulting in declining soil fertility, productivity and general environment degradation (Mati, 2005).

## 2.2 Trees on farm

The science of growing trees on farm is synonymously known as agroforestry. Agroforestry is a dynamic, ecologically based practice of integrating trees on farm in the agricultural landscape that diversifies and sustains production for increased social, economic and environmental benefits for land user at all levels (Leaky, 1996). It is an old farming system, but traditional agroforestry has been continually improved to increase productivity in limited pieces of land over a short period of time (Nair, 1993). In response to rapidly growing population pressure on agricultural land, agroforestry plays a dual role of sustainably increasing food and biomass resources and improving landscapes by providing services such as carbon sequestration, water and soil conservation and biodiversity conservation (World Agroforestry Centre, 2008). Trees on farm use limited resources (sunlight, nutrients, water and space) to provide a favorable environment for sustained crop production by recycling nutrients, providing shade, improving soil fertility and protecting crops from wind.

Traditional agroforestry was practiced in different societies by leaving naturally occurring trees within landscapes. Some traditional approaches of agroforestry include intermittent gardens in forests or bushes including shifting cultivation, mixed tree gardens, and arboriculture. Due to the challenges of traditional agroforestry modern agroforestry, which includes planting of tree species that are known to complement the growth of crops were introduced (Nair, 1992).

### 2.2.1 Biophysical and socioeconomic impacts of trees on farm

Trees on farm have great impact on biological aspects of land, soils and sunlight utility. According to a research done in western Kenya where agroforestry trees and shrubs were tested against agroforestry systems, it was revealed that, agroforestry technologies (biomass transfer and improved fallows) increased yields due to increasing soil fertility with raised household income and increased food security and ability to mitigate crises as additional benefits (Place *et al*, 2005). Fertilizer tree species increased soil nitrogen and improved soil structure and porosity with better infiltration and soil water retention as a result (Place *et al*, 2005). Trees on farm play a major role in nutrient cycling. They are mostly deep-rooted, thus take up nutrients leached to lower soil horizons and assimilate them, drop leaves, fruits, flowers and branches that later decompose thus providing nutrients to shallow rooted plants which are unable to tap in the nutrient resources of deeper soil horizons. Decomposed materials improve soil structure and deep roots break hard pans thus reducing the amount of surface runoff by increasing infiltration and soil water retention capacity (Norman 1978). Deep roots reduce competition for water with food crops as they utilize ground water.

The litter produced by trees provides energy to soil fauna which enhance soil porosity and infiltration. In five separate experiments conducted in eastern Zambia, the number of invertebrate orders per sample and the total macro fauna (all individuals per square meters) recorded were higher when maize was grown in association with tree legumes than under fertilized monoculture maize. Similarly, densities of earthworm and millipede were also higher than under monoculture maize (Sileshi and Mafongoya, 2006a, b). Cumulative litter fall, tree leaf biomass, and re-sprouted biomass under legume species appeared to explain the variation in macro fauna densities (Sileshi and Mafongoya, 2007). Litter transformer populations were higher under gliricidia, which produced good quality organic inputs, than among the other fallow species. On the other hand, a higher population of ecosystem microbes was found under trees that produce poor quality organic inputs (Sileshi rand Mafongoya, 2006a, b).

Fertilizer trees also affect maize production though their influence on striga species which parasitize on maize. The effect of fertilizer trees on weeds and soil insect has been studied in eastern Zambia (Sileshi and Mafongoya, 2003; Sileshi et al., 2005, 2006). Abundance of *Striga asiatica* was significantly influenced by the quantity and the interaction effect of quantity and quality of biomass. Species that produce low to medium quantities of slow-decomposing biomass tended to reduce *striga* abundance in maize, while fast-decomposing ones did not (Sileshi *et al*., 2006). Similarly, in East Africa, reduction of another witch weed species (*Striga hermontica*) by legume fallows depended on the rate of decomposition and nitrogen mineralization of organic residues, which in turn was determined by quality in terms of carbon to nitrogen + polyphenol ratios (Gacheru and Rao, 2001). This indicates that the mechanism by which legume fallows influence striga is much more complicated than just by soil fertility improvement. Among the legumes tested, *Sesbania* appeared to be the best in reducing striga infestation in maize in eastern Zambia (Sileshi *et al.,* 2006). Fertiliser trees have also reduced arable weed problems (Sileshi and Mafongoya, 2003; Sileshi *et al*., 2006).

Previous studies (Kuntashula et al., 2004) have shown that biomass transfer using fertilizer tree species is a more sustainable means for maintaining nutrient balances in maize and synchrony between nutrient release and crop uptake can be achieved with well-timed biomass transfer. In addition to increasing yields of vegetables such as cabbage, rape, onion and tomato, and maize grown after vegetable harvests, biomass transfer has shown potential to increase yields of other high-value crops such as garlic (Kuntashula et al., 2004, 2006).

Agroforestry trees provide firewood and charcoal, the major fuel sources for rural households and fodder. Woodlots, for example, have been found to be good sources of fuel wood, wood, poles and rafters for domestic and commercial purposes. In Kenya, species known for wood are *Eucalyptus spp, Markhamia lutea* and *Casuarina equisitifolia* among others (Kiptot and Franzel, 2011). They fetch a good price in the market following the presidential ban on exploitation of Kenyan gazetted forests that left forestry as the only alternative to satisfying wood demand (Kenya Forest Service, 2007). Some trees that are used in agroforestry are good sources of fuel for rural households.

Agroforestry plays a great role in increasing food security, which is a major challenge in sub- Saharan Africa. Most people in this region live below the poverty line, with women and children being the most affected. From studies carried out, indigenous fruits and vegetables are easily available, rich in nutrients and are income sources for many rural livelihoods (World Agroforestry Centre, 2008). Tree species such as *Moringa olifera,* are multipurpose; the leaves are used as vegetables, the bark has medicinal value and the fruits are edible.

Through agroforestry, indigenous fruit trees and vegetables are domesticated and properly managed to increase amount and quality of produce, reducing the duration of production. A case study in Zimbabwe by Akimifesi et al., (2008), showed that wild fruits represent 20% of the wood resources used by rural households. These fruits and vegetables are collected, consumed fresh or processed and sold, increasing income sources for rural residents (Kiptot and Franzel., 2011).

In a case study in Cameroon, domesticating and improving varieties of wild fruit trees, through marcoting and grafting has transformed the society of central Cameroon from abject poverty to sustained economic independence. Through processing and marketing of wild fruits, farmers are able to meet most of their financial needs without much strain. Besides increasing income, domestication of wild fruits has resulted to transformed landscapes, reduced soil erosion and improved fertility (Smith, 2010)

### 2.2.2 Influence of trees on crop production

Trees can show complementarity and competition when intercropped with crops. They affect productivity of crops due to aspects such as competition for available nutrients, water and shading. There are many studies that have been done to test the effects of agroforestry trees and systems on productivity of food crops with most studies indicating mutual interaction where crop productivity is higher in agroforestry systems than in monocultures. For instance, fertilizer tree systems involve soil fertility replenishment through on-farm management of nitrogen-fixing trees and shrubs (Mafongoya et al., 2006). They represent a new paradigm because they use a completely different approach to land-use management by smallholder farmers.

In a long-term trial in Makoka, gliricidia intercropping with maize increased maize yield in the range of 100 to 500%, averaging 315% over a ten-year period (Akinnifesi et al., 2006). Increase in yield is more apparent from the third year after tree establishment and onwards (Akinnifesi et al., 2006). The unfertilized plots not amended with gliricidia had steadily declining yield, and amendment with N and P could not sustain high maize yield over time. In Western Kenya, the use of *Tithonia diversifolia, Senna spectabilis*, *Sesbania sesban* and *Caliandra calothyrus* planted as farm boundaries, woodlots and fodder banks has proven to be beneficial as a source of nutrients and improving maize production (Palm et al., 2001)

The potential of *Faidherbia albida* for improvement of soil fertility and crop yields has been demonstrated in many parts of Africa (Saka et al., 1994; Kang and Akinnifesi, 2000). This species has a unique phenology in that it sheds its leaves during the wet season and resumes leaf growth during the dry season. This makes it possible to grow crops under its canopy with minimum shading on the companion crop. About 20 to 30 mature trees are needed to completely cover one hectare of land and maintain optimum crop response (Kang and Akinnifesi, 2000). Several studies in Africa showed yield benefits when crops were grown under the canopy of Faidherbia. Saka et al. (1994) reported 100–400% increase in maize yield in the Lakeshore plain of Malawi. Improved fallows have been widely tested on farmers' fields in Zambia and this technology has now spread to other parts of southern Africa (Kwesiga et al., 2003). Several studies reviewed by Akinnifesi et al. (2008) showed that planted fallows of sesbania (*Sesbania sesban*) in Zambia, Malawi and Zimbabwe had doubled or tripled maize yield after the fallow period compared with control plots.

In Kenya, a research carried out to investigate the effects of *Grevillea robusta* on maize production in semi- arid areas showed that, although competition for nutrients was prevalent, maize performed better under the trees in the first 600 days after planting and total productivity of maize in the agroforestry system was higher than in mono- cropped farms. This was attributed to provision of shade during dry periods, minimizing total evapotranspiration. The study revealed that agroforestry systems in semi-arid regions of

Kenya stabilized soil moisture, providing a good environment for crop growth unlike mono- cropping (Onga et al, 2000).

The performance of agroforestry species differs between agroforestry systems due to different modes of tree crop interactions. Trees enhance the production of crops where they create more favorable soil fertility and soil moisture conditions, and more favorable microclimate. Trees also compete with crops for the same resources, with negative impacts on crop production. The outcome of the positive and the negative interaction depends on tree spacing and management.

### 2.2.3 Challenges of trees on farm

Despite research and documentation of success of agroforestry, there are factors hindering its full adoption. Lack of natural sources of fast growing timber trees has led to establishment of plantations of alien invasive species, particularly eucalyptus and pines (Le Maitre, 2002). An estimated area of 6000 ha in Kenya is under eucalyptus (Ong, 2006). In such a scenario, trees are expected to have a great impact on the hydrological balance and the socio-economic status of a place. Competition for water, light and nutrients between trees and crops is a major constrain in agroforestry system. High demand for water by deep-rooted exotic trees like eucalyptus may be a concern to farmers in semi-arid regions. For instance, Calder *et al.* (1997) reported that eucalyptus plantations in southern India used all of the rainfall which infiltrated the soil and also extracted a further 100 mm of water for each 1m depth of soil penetrated by the roots. Therefore, there is need to select trees with desirable root and shoot architecture that will be compatible with food crops under different Agroforestry systems (Bationo, 2008).

Challenges of agroforestry differ from different communities depending of socio cultural and economic factors. Adoption of agroforestry technologies is faster in communities that are educated than among illiterate communities. Therefore, illiteracy is a hindrance to fast adoption of agroforestry technologies (Ramachandran, 1992) In addition; family sizes affect agroforestry technology adoption in two ways. First, a large family size supplies more labour on farm than a small one. Therefore it is easier to adopt labour intensive technologies with a large family. Second, a large family size may cause pressure on the available land, leading to planting of fewer trees to leave more land for crops (Muneer, 2008). Therefore, where land size is a limiting factor, agroforestry may be negatively affected. Household sizes impact on the demand for money in any given situation (Nair, 1992). Agroforestry extension services are another factor hindering adoption of agroforestry technologies. In remote areas, where infrastructure is a challenge, farmers mostly rely on government extension services which are rarely enough. Extension workers play a major role in environmental awareness as well as addressing crosscutting issues in the society that in the long run affect agroforestry (Muneer, 2008).

Lack of equitable share of agroforestry incentives and benefits is a major drawback to adoption of agroforestry technologies in rural communities in Kenya (Kiptot and Franzel, 2011). Although agroforestry is viewed as a solution to climate change mitigation, it cannot achieve this objective without a proper tree and land tenure policy and development of infrastructure that allows value addition and processing of agroforestry products. In most set ups today, tree tenure is customary and products are locally marketed with prices being influenced by middlemen and brokers. Very little international marketing of agroforestry products has been done in Kenya for instance.

International structures for climate change such as the REDD+ (reduction of emission degradation and deforestation) and the CDM (clean development mechanism) view agroforestry as a pathway to mitigating the effects of climate change. These policies however do not offer an incentive at all to the farmers directly involved in sequestering carbon (ASB, 2011).

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Study site description

The study was conducted in two counties in Western Kenya namely Bungoma and Siaya. Two sites from each county (Nzoia and Bumula in Bungoma) and (Ndere and Ulafu in Siaya) were preselected by the Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) Project making a total of four study sites.

Bungoma is located within latitude 0º 25.3’ and 0º 53.2’ North and longitude 34º 21.4’ and 35º 04’ East. The county covers an area of 1,714 km$^2$ and comprises 10 administrative divisions: Kanduyi, Bumula, Chwele, Kimilili, Tongaren, Nalondo, Division, Malakisi, Sirisia and Webuye. The county is located mainly within the upper and lower midland agro ecological zones (UM1-4 and LM1-3 respectively) (GOK 2007). The altitude ranges from 1200 – 1800 meters above sea level (masl), whereas average temperatures range from 16$^o$C to 30$^o$C with an average of 23$^o$C. Most of the soils are well drained (Jaetzold and Schmidt, 1983). There are varying soil types in the area with inherently fertile deep rich Andisols and Nitisols towards the slopes of Mount Elgon. The western part of Bungoma has Acrisols while the central part is predominantly Ferralsols. The area receives bimodal rainfall that ranges from 1500 to 2200 mm per year, with the long rains falling between March and June and the short rains between August and November.

In 2009, the population of Bungoma was 914,075 with a density of 515 persons per km$^2$ and 175,313 households (GOK, 2010). Agriculture is the main economic activity with maize being the main food staple. The other important crops are sugarcane (a major cash crop), beans, sorghum, finger millet, cassava, tobacco, tea, coffee, groundnuts and a variety of horticultural crops.

Ulafu and Ndere are located at latitude 0° 26’ to 0° 18’ North and longitude 33° 58’ East and 34° 33’ West. Ecologically, the sites fall in the lower midland (LM) agro ecological zone. The major agro-ecological zones are Lower midland zone ($LM_1$) , $LM_2$, $LM_3$ and $LM_4$. The $LM_1$ has climatic conditions good for sugarcane production, and it is too wet for cotton and fair for maize production. The $LM_2$ has fair to marginal climatic conditions for sugarcane and fair for maize production. Lastly, $LM_3$ has climatic conditions good to fair for cotton and maize growing. The sites receive bi-modal rainfall: long rains fall between March and June, with a peak in April and May. Short rains occur between August and November. The short rains in the lower zones are less pronounced and not reliable. Rainfall amounts are quite variable. The high altitude areas receive 1800 –2000 mm of rainfall per annum, while the lower regions receive 800 – 1600 mm per annum (Jaetzold, 2007).

In 2009, the population of Siaya was 550, 224 with a density of 325 persons per km$^2$ and 175,313 households (GOK, 2010). Siaya is the poorest county in Nyanza region. Poverty levels have generally been increasing over the years, but the major pockets of poverty are found in the lower parts of Boro, lower Ukwala, Uranga, and Karemo divisions which are characterized by low rainfall and poor soils. The latest constituency poverty mapdaping shows that poverty incidence ranges between 61% and 68% (GOK, 2005).

### 3.2 Sampling procedure

The study was part of the SIMLESA project sites. The study sites were earlier selected to represent diverse agro-ecological zones high versus low potential areas; socio-economic environment and varying importance and production systems of maize–legumes in western Kenya. Other considerations were cultural diversity (Luo and Bukusu) and willingness of communities at each site to collaborate with project. Four farmer groups which consisted of eighteen to twenty five farmers, with a total of 84 farmers formed the total population from which sampling was done. Twelve farms were randomly selected from each group to form a total of 48 farms. A baseline survey was conducted to determine common tree species growing on farms. Using the results obtained from the baseline survey, purposive sampling was used to select farms where crop and soil attributes were measured. The selection of the trees that were used for the study was done by selecting farms that had common trees growing along the farm boundary. The trees species that were found common in the three sites (Bumula in Bungoma county, Ndere and Ulafu in Siaya county) and the tree species that were used for the study were *Grevillea robusta, Leuceana spp, Markhamia lutea* and *Mangifera indica.* Nzoia in Bungoma site was left out since there were no farms which had trees growing within the cropping area. A total of ten farms were selected for the crop and soil survey.

*Grevillea robusta* and *Leuceana spp* were investigated in Bumula and Ulafu while *Markhamia lutea* and *Mangifera indica* were investigated in Ndere and Ulafu. Only

Ulafu site had the three tree species that were selected for investigation. The selection of the trees depended on the location of the trees in the farm; only the trees growing along the farm boundaries were selected. The selection was also according to the size of the trees that was estimated by the DBH and how far the trees were from other trees so that the influence of other trees could be avoided.

### 3.3 Study design

The study was a complete randomized design (CRD) with a 4 tree species x3 distance intervals x5 replicates (4x3x5) factorial. . There were 12 factor combinations (4x3) and a total of 60 experimental units (12x5=60) which were used for the soil analysis. For the maize growth parameters a 4 x 3 x 3 factorial in a complete randomized design was used. The three factors investigated were 4 tree species, 3 distance intervals and 3 stages of plant growth; at levels 6, 9 and 12 Weeks After Crop Emergence (WACE) in each site.

### 3.4 Farm management practices

The selected farms were planted and managed by the farmers with consultation from the researcher to ensure that some of the research attributes were not interfered with maize variety Duma 33 was planted at a spacing of 0.7m by 0.45m which is the standard spacing in the region, giving a plant population of approximately 27,000 plants per hectare. Management practices such as fertilizer application, and weeding were done by the farmers.

### 3.5 Determination of prevalent tree species

Survey of tree species was carried out in the forty eight farms to determine the main tree species grown in these areas, where the trees are grown in the farms and why farmers grow those particular trees species. The position of each farm was marked using a hand held Global Positioning System (GPS). For every tree species identified in each farm, the number of individual trees was counted and their location on the farm noted down. The data on trees was subjected to descriptive statistics to determine the frequency of the tree species. Pivot tables were used to determine the total number of each tree species and its location on the farm. Thenumber of individual tree species was expressed as a percentage of all the trees counted. The percentage frequencies were then divided according to sites and the results presented in tables and frequency charts. These results were then used in sampling whereby three farms with at least three most common species were selected in every site. The selected farms in Nzoia, Bumula, Ulafu and Ndere were used for the study. A chi square test was done to test whether there was a significant difference in the tree species composition within the sites.

### 3.6 Determination of effect of trees on the chemical properties of soil

Investigation of the soil parameters was done in three sites. This is after leaving out Nzoia site of Bungoma county because there were no trees that were found growing along the farm boundaries. Soil sampling was done before planting at the beginning of the long rainy season 2012. Soil samples were randomly taken at a 1m radius using a soil auger for three distance intervals, that is, 2, 7 and 12m distance away from each of the selected tree and mixed thoroughly to come up with a composite sample for each treatment. This was repeated for two other trees of the same species in the same farm. Sampling was done at two levels, that is, a sample of the top soil 0-15cm (top soil) and a sub-soil sample between 15-30cm (sub soil) was obtained. Each soil sample was packed in a labeled container for laboratory analysis. The soils were analyzed for soil pH, total organic carbon (TOC) and Cation Exchange Capacity (CEC). The three soil properties were selected because their significance in influencing the quality of soil for agricultural production. The data were subjected to a two way factorial Analysis of Variance (ANOVA) with the two factors being the tree species and the distance from the trees to determine treatment effects.

### 3.7 Determination of effect of trees on growth and yield of maize

Six maize plants were selected randomly at each distance intervals, 2, 7 and 12m away from the trees. The maize plants were marked with a ribbon for repeated measurements. The measured parameters included the basal diameter and the height of the plant to the top of canopy which were measured using a string and a tape measure and the results recorded. The measurements were done at 6, 9 and 12 Weeks After Crop Emergency (WACE). The yield of maize in each farm was assessed at the end of the cropping season. The yield measurements included fresh cob weight and dry grain weight. The cobs were separated from the stover and weighed separately during harvesting. The maize cobs were placed in labeled bags and oven-dried at (105 $^{o}$C) for four days. The dry weight of the maize grain was then determined after shelling the cobs.

The data were subjected to a two way factorial Analysis of Variance (ANOVA) with the two factors being the tree species and the distance from the trees to determine the treatment effects. From this analysis the effect of each factor on yield of maize was determined. The averages of yields under each tree species were obtained and presented in tables and bar charts showing the trends of maize yield under the selected trees at the different distances from the trees.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

### 4.1 Tree diversity and utility in western Kenya

A variety of tree species were encountered with varying levels of frequency of the species during the survey. *Eucalyptus species*, *Markhamia lutea* and *Grevillea robusta* dominated the landscape, representing 30.5%, 15.2% and 14.5%, respectively of all the trees encountered in western Kenya (Figure 1).

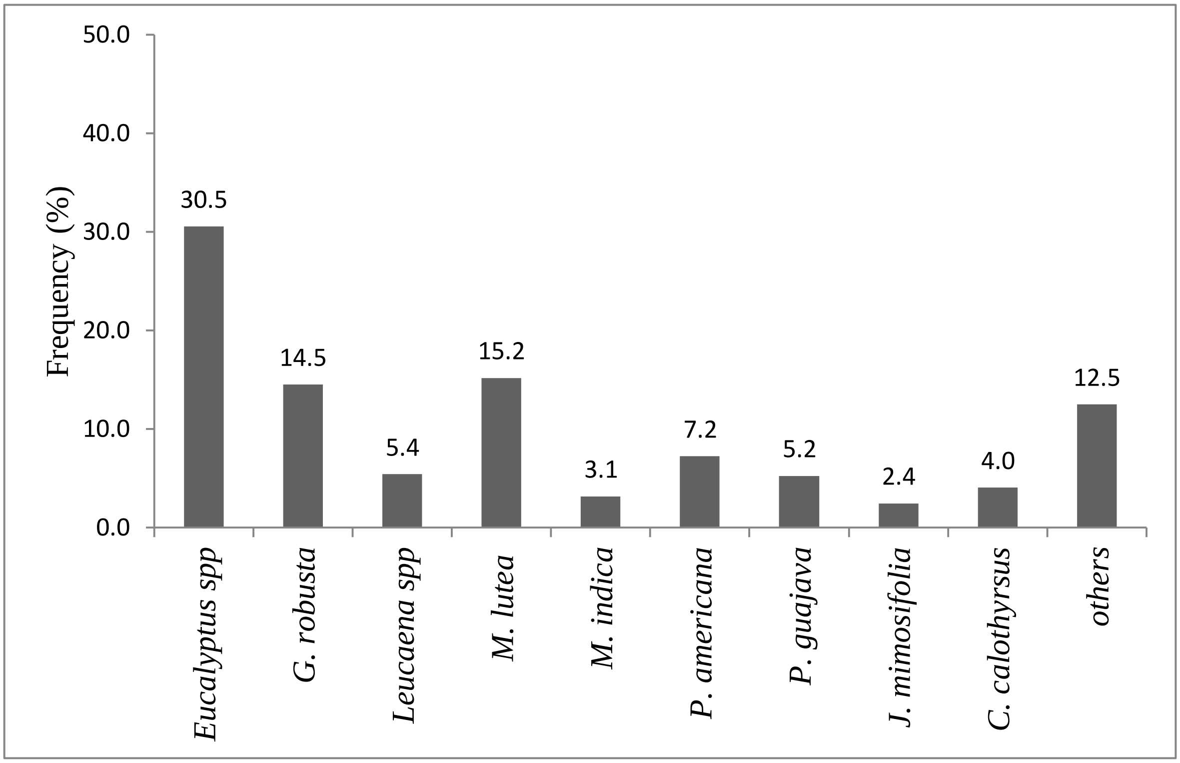

**Figure 1:The relative abundance (frequency) of tree species encountered on farms in western Kenya**

The dominant tree species are mainly planted for timber and fuel wood, although utility of individual species may vary with family needs. Previous studies have shown that highly competitive tree species, such as eucalyptus are planted separate from crops e.g., in woodlots or along (farm) bounderies (Kuyah et al. 2008). While eucalyptus has been reported to have adverse effects on soil nutrients (Michelson *et al.*, 1993), water and growth of other neighboring trees (Lisanework and Michelsen, 1993), judicious integration of the species in the landscape has been reported to protect biodiversity and help raise the income of resource poor farmers (Kidanu *et al.*, 2005). Multi-purpose trees such as *G robusta* can be used for mulching, moisture conservation, soil aeration and off farm uses including production of timber for building materials. Farmers can also derive cash income from such tree species.

Other commonly occuring tree species included *Percea americana* (7.2%), *Leucaena* species (5.4%) and *Mangifera indica* (5.2%) (Figure 1) which were mainly planted for fruits and fodder. Minor uses of these trees included shadding, medicinal and aesthetic value. Majority of these trees were planted within the homesteads (65.9%), while the rest were planted along farm boundaries 23.3% or intergrated within cropland (10.8%). Other tree species were also found scattered across the landscape and include, *Vitex doniania, Combretum molle, Albizia coriaria,Terminalia mentalis,Cupresus lusitanica and Sesbania sesban* although in small numbers.

The distribution and composition of tree species among the four sites varied substantially, (Table 1). A chi square test of goodnes of fit, $X^2 = 37.16$ revealed that trees within the sites were not equitably distributed. Therefore the trees are not evenly distributed among the four sites. *Eucalyptus* spp was most frequent in Nzoia and Bumula while *P.*

*americana, G. robusta, P. guajava* and *M. lutea* were sparsely distributed in Nzoia (Table 1).

**Table 1: The percentage distribution and composition of tree species in Nzoia, Bumula, Ndere and Ulafu sites in western Kenya**

| | Sites | | | |
|---|---|---|---|---|
| Species | Ulafu | Ndere | Nzoia | Bumula |
| *Eucalyptus spp* | 17.9 | 10.9 | 47 | 41.9 |
| *Grevillea robusta* | 16.9 | 6 | 9.4 | 19 |
| *Leuceana spp* | 11.4 | 4.3 | 0.2 | 4.7 |
| *Markhamia lutea* | 21.8 | 38 | 6.3 | 7.6 |
| *Mangifera indica* | 6.7 | 3.4 | 2.1 | 2 |
| *Persea americana* | 9.3 | 6.3 | 14.5 | 2.5 |
| *Psidium guajava* | 3.3 | 7.4 | 6.7 | 4.9 |
| *Jacaranda mimosifolia* | 4.1 | 6.9 | 0.1 | 0.1 |
| *Calliandra calothyrsus* | 5.3 | 4.6 | 0.1 | 0.1 |
| Others | 3.3 | 12.3 | 13.9 | 17.6 |

Similarly in Bumula, the frequency of *G. robusta*, *M. lutea P. guajava* and *Leucaena* spp was low. Ndere and Ulafu sites were dominated by *M. lutea* (Table 1). The prevalence of indigenous tree species such as *M. lutea* may be due to their ecological adaptability and economic importance (Nair, *et al.*, 1984; Sebukyu and Mosango, 2012 ). The Ndere site had low frequency of *Eucalyptus spp*, *G. robusta*, and *P. americana* compared to Ulafu (Table 1). *Psidium guajava* and *Jacaranda mimosifolia* were restricted to Ndere while *Leucaena* spp, *Mangifera indica* and *Calliandra calothyrsus* were only encountered in Ulafu. There was varying frequency of trees in terms of where they are planted within the farm. Most farmers had their trees planted within their home compounds. However, some trees were found incorporated within the cropland and along the farm boundaries (Figure 2).

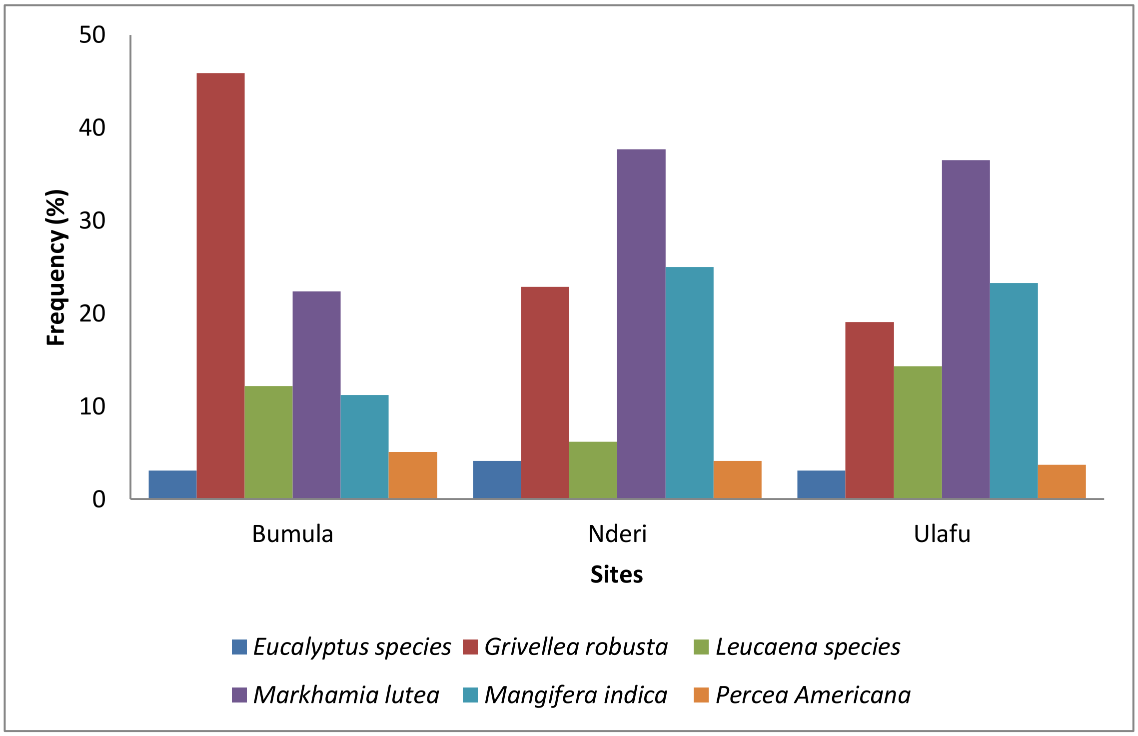

**Figure 2: The frequency of tree species encountered within the cropping area and along the farm boundaries in western Kenya**

*M.lutea* (34.7%) and *G .robusta* (32.3%) were the most common tree species that were grown within the cropping land and along the farm boundary. Other tree that were found growing within the cropping area included *Leuceana* spp (11.6%), *M. indica* (10.9%), *P.americana* (7.1%) and *Eucalyptus* spp (3.5%). The high frequency of *G. robusta* and *M. lutea* is due to the ability of the trees to provide timber, fuel and complement crop since the litter from these trees are used as mulch and provide organic matter that amends soil.

## 4.2 Influence of tree species and distance on soil pH, CEC and TOC.

### 4.2.1. Influence of tree species on soil pH of top and sub soils in Ulafu, Ndere and Bumula

Table 2 shows the influence of selected tree species on soil pH in the three sites of Western Kenya. The soil pH varied with the tree species and in the different sites. Soils sampled under *G. robusta* canopies had an average pH with a mean (and standard error, SE) of 6.10±0.12 which was similar to that recorded under *M. indica*. *Leuceana* spp had a mean (±SE) of 6.00±0.12 while *M. lutea* recorded a mean (±SE) of 5.80±0.07, (Table 3).

**Table 2: Influence of tree species on soil pH of top and sub soils in Ulafu, Ndere and Bumula**

| | **pH Top soil** | | | |
|---|---|---|---|---|
| **Species/Site** | Ulafu | Ndere | Bumula | Mean factor |
| ***G robusta*** | 6.36 | - | 5.94 | 6.15a |
| ***Leuceana* spp** | 5.95 | - | 6.07 | 6.01a |
| ***M lutea*** | 5.84 | 5.83 | - | 5.81b |
| ***M indica*** | 5.87 | 6.57 | - | 6.2a |
| | **pH Sub soil** | | | |
| ***G robusta*** | 5.93 | - | 5.61 | 5.76x |
| ***Leuceana spp*** | 5.88 | - | 5.47 | 5.66x |
| ***M lutea*** | 5.74 | 5.63 | - | 5.67x |
| ***M indica*** | 5.75 | 6.34 | - | 6.05x |

Means with the same letter (a), (b) represent significant difference for top soil while (x),(y) for sub soil at 5% level of significance.

The results from ANOVA revealed significant difference (P = 0.01) in the soil pH of top soils sampled under *M lutea* at 0.05 level of significance. Soils sampled under *G. robusta*, *M. indica*, *Leuceana* spp did not show a significant difference (P>0.05) (Table 3). Soils sampled under the canopies of *M.lutea* showed a significant difference (P< 0.01) when compared with soils sampled under the other tree species. The differences in the soil pH could be due to the fact that the litter from the various trees is of different composition therefore the difference in the soil pH. The pH of sub soil sampled under the four tree species was not significantly different. This could be attributed to the leaching of organic acids produced by the decomposing litter which has shown to be due to the presence of high lignin and tannin contents in litter (Millen, 1995; White, 1991) cited by Nsambimana et al., (2008).

The soil pH of soils sampled at the various distances 2, 7 and 12m was analyzed and their means compared for differences. Soils sampled 2m away from the trees recorded an average pH with a mean (and standard error, SE) of 6.10±0.12 when compared to those sampled at 7 m which had an average pH with a mean (±SE) of 5.9±0.11 and 12m which recorded a mean (±SE) of 6.00±0.03, (Table 3).

**Table 3: Influence of distance on soil pH of top and sub soils in Ulafu, Ndere and Bumula**

| | **pH Top soil** | | | |
|---|---|---|---|---|
| **Distance(m)/ Site** | Ulafu | Ndere | Bumula | Mean Factor |
| **2** | 5.9 | 6.4 | 6.23 | 6.12a |
| **7** | 5.99 | 6.1 | 5.55 | 5.87a |
| **12** | 5.97 | 5.9 | 6.03 | 5.94a |
| | **pH Sub soil** | | | |
| **2** | 5.72 | 5.83 | 5.7 | 5.75x |
| **7** | 5.78 | 5.38 | 5.63 | 5.58x |
| **12** | 5.81 | 5.6 | 5.48 | 5.63x |

Means with the same letter (a), (b) represent significant difference for top soil while (x),(y) for sub soil at 5% level of significance.

Many variations were shown in the different distances from the trees, there was no significant difference (P>0.05) in the pH of soils sampled at the three points.

### 4.2.2. Influence of tree species on soil CEC of top and sub soils in Ulafu, Ndere and Bumula

Differences in the distribution and abundance of the exchangeable cations in surface layers of soil also occurred between the different tree species. The soil CEC for soils sampled under *G. robusta* had an average mean (±SE) of 35.61±2.6 while those sampled under the canopies of *Leuceana SPP* had a mean (±SE) of 36.01±2.45, (Table 4). The effect of tree species on CEC were significantly different (p<0.001). Further analysis however showed that there were significant differences (P<0.001) in the CEC of soils sampled under *G. robusta and Leuceana* spp with those that were sampled under *M. indica and M. lutea*, (Table 4).

**Table 4: Influence of tree species on soil CEC of top and sub soils in Ulafu, Ndere and Bumula**

| Species/Site | Ulafu | Ndere | Bumula | Mean factor |
|---|---|---|---|---|
| ***G robusta*** | 34.45 | - | 36.98 | 35.25a |
| ***Leuceana spp*** | 33.49 | - | 39.79 | 35.78a |
| ***M indica*** | 64.8 | 42.7 | - | 54.75b |
| ***M lutea*** | 69.07 | 35.49 | - | 52.28b |
| | **Sub soil** | | | |
| ***G robusta*** | 28.55 | - | 37.12 | 32.82x |
| ***Leuceana spp*** | 28.16 | - | 36.14 | 32.15x |
| ***M indica*** | 63.4 | 38.9 | - | 51.51y |
| ***M lutea*** | 64.01 | 33.57 | - | 48.79y |

Means with the same letter (a), (b) represent significant difference for top soil while (x),(y) for sub soil at 5% level of significance.

There were no significant differences between *M. lutea* and *M. indica*. However, the contribution of the individual tree species shows that *M. indica* had an increased level of exchange capacity than the other tree species (Table 4). *G. robusta* had a much lower CEC than the other three and all this can be attributed to the amount of organic matter in the soil. Research (Jaiyeoba, 2003; Ciotta et al., 2003) has shown that increase in CEC in the surface soils is due to increased soil organic carbon.

On the other hand, no significant difference (P >0.05) was seen in the soil CEC at the three distances, (Table 5). However, the CEC at 12m was lower compared to the CEC of soils sampled at 2m and 7m.

**Table 5: Influence of distance on soil CEC (Cmol/kg) of top and sub soils in Ulafu, Ndere and Bumula**

| | | **CEC (Cmol/kg) Top soil** | | |
|---|---|---|---|---|
| **Distance(m)/ Site** | Ulafu | Ndere | Bumula | Mean Factor |
| **2** | 5.9 | 6.4 | 6.23 | 6.12a |
| **7** | 5.99 | 6.1 | 5.55 | 5.87a |
| **12** | 5.97 | 5.9 | 6.03 | 5.94a |
| | | **CEC (Cmol/kg) Sub soil** | | |
| **2** | 5.72 | 5.83 | 5.7 | 5.75x |
| **7** | 5.78 | 5.38 | 5.63 | 5.58x |
| **12** | 5.81 | 5.6 | 5.48 | 5.63x |

Means with the same letter (a), (b) represent significant difference for top soil while (x),(y) for sub soil at 5% level of significance.

The higher values (> 25Cmol/kg) of CEC in the three sites could be due to tight soil structure which has a poor internal drainage and requires more organic matter.

### 4.2.2. Influence of tree species on soil (%) TOCof top and sub soils in Ulafu, Ndere and Bumula

Tree species that are well managed can influence soil chemical properties that can impact the short term and long-term sustainability of production systems. Organic carbon plays an important role in determining the fertility of the soil. The amount of organic carbon varied over the different tree species (Table 6). Soils sampled under the canopies of *M. lutea* had an increased percentage of soil TOC compared to the soil TOC of the other tree species. The amounts of total organic carbon measured was not significant (P>0.05) for the four tree species (Table 6).

**Table 6: Influence of tree species on soil TOC of top and sub soils in Ulafu, Ndere and Bumula**

| | | **TOC (%) Top soil** | | |
|---|---|---|---|---|
| **Species/Site** | Ulafu | Ndere | Bumula | Mean factor |
| ***G robusta*** | 2.14 | - | 1.12 | 1.62a |
| ***Leuceana spp*** | 1.77 | - | 1.13 | 1.45a |
| ***M indica*** | 1.52 | 1.39 | - | 1.47a |
| ***M lutea*** | 1.53 | 1.76 | - | 1.64a |
| | | **TOC (%) Sub soil** | | |
| ***G robusta*** | 1.38 | - | 1.11 | 1.24x |
| ***Leuceana spp*** | 1.42 | - | 0.98 | 1.21x |
| ***M indica*** | 1.53 | 1.36 | - | 1.39x |
| ***M lutea*** | 1.35 | 1.66 | - | 1.38x |

Means with the same letter (a), (b) represent significant difference for top soil while (x),(y) for sub soil at 5% level of significance.

The amount of TOC in the various sites varied with tree species (Table 7). However there were no significant differences in the amount of TOC within the sites. Soils that were sampled at 2m had an increased TOC compared to soils at 7 and 12m, (Table 8). The TOC of soils at 2m were significantly different (P=0.01) from soils at 7 and 12m. This is due to the decomposition of tree litter that led to the higher content of carbon in soils closer to the tree canopies.

**Table 7: Influence of distance on soil TOC of top and sub soils in Ulafu, Ndere and Bumula**

| | **TOC (%) Top soil** | | | |
|---|---|---|---|---|
| **Distance(m)/ Site** | Ulafu | Ndere | Bumula | Mean Factor |
| **2** | 1.56 | 1.82 | 1.32 | 1.56a |
| **7** | 1.25 | 1.75 | 1.25 | 1.31b |
| **12** | 0.84 | 1.48 | 0.84 | 1.12b |
| | **TOC (%) Sub soil** | | | |
| **2** | 1.4 | 1.5 | 1 | 1.30x |
| **7** | 1.25 | 1.65 | 1.02 | 1.31x |
| **12** | 1.42 | 1.42 | 0.91 | 1.25x |

Means with the same letter (a), (b) represent significant difference for top soil while (x),(y) for sub soil at 5% level of significance.

Similar results on the influence of different tree species on the soil TOC were recorded by Nsabimana et al., (2008), that soil carbon content is modified by plant uptake, wood harvest and increased by litter fall and root exudates, thus soil carbon content may differ from one tree species to the other. The high TOC near the trees is attributed to accumulation of organic matter and humus from decomposing tree matter and this humus as organic colloid play a major role in enhancing the TOC of the soil (Mishra 2002).

## 4.3 Influence of tree species and distance on growth parameters and yield

### 4.3.1 Influence of tree species and distance on height of maize

The average of plant height measurements were obtained from measurements taken at 6, 9 and 12 weeks after crop emergence (WACE) on maize growing at the different points under different tree species.

At 6 WACE the maize that was sampled at the different points showed differences in the plant height under the different tree species. Generally, the plant height increased away from the tree under all the selected tree species apart from *M Lutea* where the plant height showed a decreasing away from the tree, (Table 8), although no significant difference (P>0.05) was recorded in the height of maize at the various distances. The effect of the tree species on the plant height varied substantially. There was a significant difference (P=0.001) in the effect of trees on the height of maize. Further analysis showed that the height of maize that was sampled under *M lutea* was significantly different from the height of maize sampled under the other tree species, (Table 8).

At 9 and 12 WACE there was no significant difference recorded in the plant height at 2, 7 and 12m despite the individual differences at the different points. During this time, the maize plants that were sampled 2m away from *M. indica* showed a reduced height compared to the other trees. This became significant at 12 WACE where the height of maize under *M. indica* and *M lutea* were significantly different (P=0.02) from the height of maize under the other trees (Table 8).

**Table 8: Influence of tree species on height of maize in Ulafu, Ndere and Bumula**

| Species / site | Ulafu | Ndere | Bumula | Mean factor |
|---|---|---|---|---|
| | | **Height (cm) at 6 WACE** | | |
| *G. robusta* | 112.10 | - | 102.44 | $105.33^{a}$ |
| *Leuceana spp* | 112.71 | - | 98.32 | $105.53^{a}$ |
| *M. indica* | 108.15 | 104.00 | - | $102.42^{a}$ |
| *M.lutea* | 121.92 | 109.6 | - | $112.30^{b}$ |
| LSD | | | | 5.15 |
| | | **Height (cm) at 9 WACE** | | |
| *G. robusta* | 183.5 | - | 170.2 | $175.48^{b}$ |
| *Leuceana spp* | 187.6 | - | 192.17 | $177.32^{b}$ |
| *M. indica* | 169.33 | 185.10 | - | $174.67^{b}$ |
| *M.lutea* | 195.68 | 222.51 | - | $207.26^{a}$ |
| LSD | | | | 4.22 |
| | | **Height (cm) at 12 WACE** | | |
| *G. robusta* | 231.82 | - | 252.98 | $245.43^{ab}$ |
| *Leuceana spp* | 233.60 | - | 261.8 | $248.31^{ab}$ |
| *M. indica* | 188.34 | 235.1 | - | $217.12^{b}$ |
| *M.lutea* | 250.71 | 292.3 | - | $265.84^{a}$ |
| LSD | | | | 4.81 |

Means with the same letter (a) (b) represent significant difference at 5% level of significance.

The general low maize height that was recorded for *G. robusta*, *Leuceana* spp and *M. indica* could be due to competition for light water and nutrients factor between the trees and the maize crop. The different trend shown could be attributed to the growing patterns in terms of the rooting systems of the trees and the crown. Most trees that were grown simultaneously with crops were regularly pruned for timber thus caused less shading effect.

### 4.3.2 Influence of tree species on maize basal diameter in Ulafu Ndere and Bumula

The basal diameter of maize in was influenced by the various trees differently. Generally, there were individual variations in the maize basal diameter though no significant difference (P> 0.05) was recorded for the influence of the trees on the basal diameter (Table 9).

**Table 9: Influence of tree species on basal diameter (cm) of maize in Ulafu, Ndere and Bumula**

| Species/ site | Ulafu | Ndere | Bumula | Mean Factor |
|---|---|---|---|---|
| | | Basal diameter (cm) at 6 WACE | | |
| **G robusta** | 6.3 | - | 6.4 | $6.4^a$ |
| **Leuceana** | 6.7 | - | 6.7 | $6.7^a$ |
| **M indica** | 6.2 | 7 | - | $6.6^a$ |
| **M lutea** | 6.5 | 6.9 | - | $6.7^a$ |
| | | Basal diameter(cm) at 9 WACE | | |
| **G robusta** | 6.8 | - | 7 | $7.2^a$ |
| **Leuceana** | 7.1 | - | 7.3 | $7.3^a$ |
| **M indica** | 6.7 | 7.1 | - | $6.8^b$ |
| **M lutea** | 6.9 | 7.4 | - | $7.3^a$ |
| | | Basal diameter(cm) at 12WACE | | |
| **G robusta** | 7.2 | - | 7.4 | $7.6^a$ |
| **Leuceana** | 7.5 | - | 7.7 | $7.7^a$ |
| **M indica** | 7.1 | 7.3 | - | $7.2^b$ |
| **M lutea** | 7.4 | 7.8 | - | $7.6^a$ |

Means with the same letter (a), (b) represent significant difference at 5% level of significance.

In all the three sites (Table 9) the crops near the tree canopy, that is at two meters away from the tree had a smaller basal diameter compared to that of maize plants that were away from the trees at seven and twelve meters away. This trend was seen in crops under all the selected tree species apart from *M. lutea* where the basal diameter showed a decrease away from the tree. Despite the variation in basal diameter at different points from trees, no significant difference ($P \geq 0.05$ was realized at the various distances from the tree species in all the sites. This could be explained by the suppression of the maize crop by the trees due to competition.

### 4.3.3 Influence of tree species and distance on yield of maize in Ulafu Ndere and Bumula

Different selected tree species influenced growth and yield of maize differently. Although the effects of shading on reduced maize yield under *G.robusta* have been reported in a similar study in Machakos by Ong, et al., (2000), maize that was sampled under the canopies of *G. robusta* had the highest average yield of 3.2 t ha$^{-1}$ compared to the yields under other selected trees. *M. indica* had the lowest average yield of 2.6 t ha$^{-1}$. The pH levels of soils sampled under *G.robusta* and *M. indica* was equal (6.4) and very close to the optimum requirements for the growth of maize 6.5 to 7, (Nielsen, 2005), there was a very wide difference in the yields of maize under the two tree species with one (*G.robusta*) having the highest yield of all the selected trees and the other (*M. indica*) having the lowest yield (Figure 3). This difference could ne as a result of other factors than the soil pH such as the ability for the tree to show complementarity or competition when planted with crops. On the contrary soils sampled under the canopy of *G.robusta* had the highest percentage TOC of 2.25 with the lowest CEC compared to all the selected tree species while *M. indica* had the highest average CEC of 54.9 and the lowest TOC.

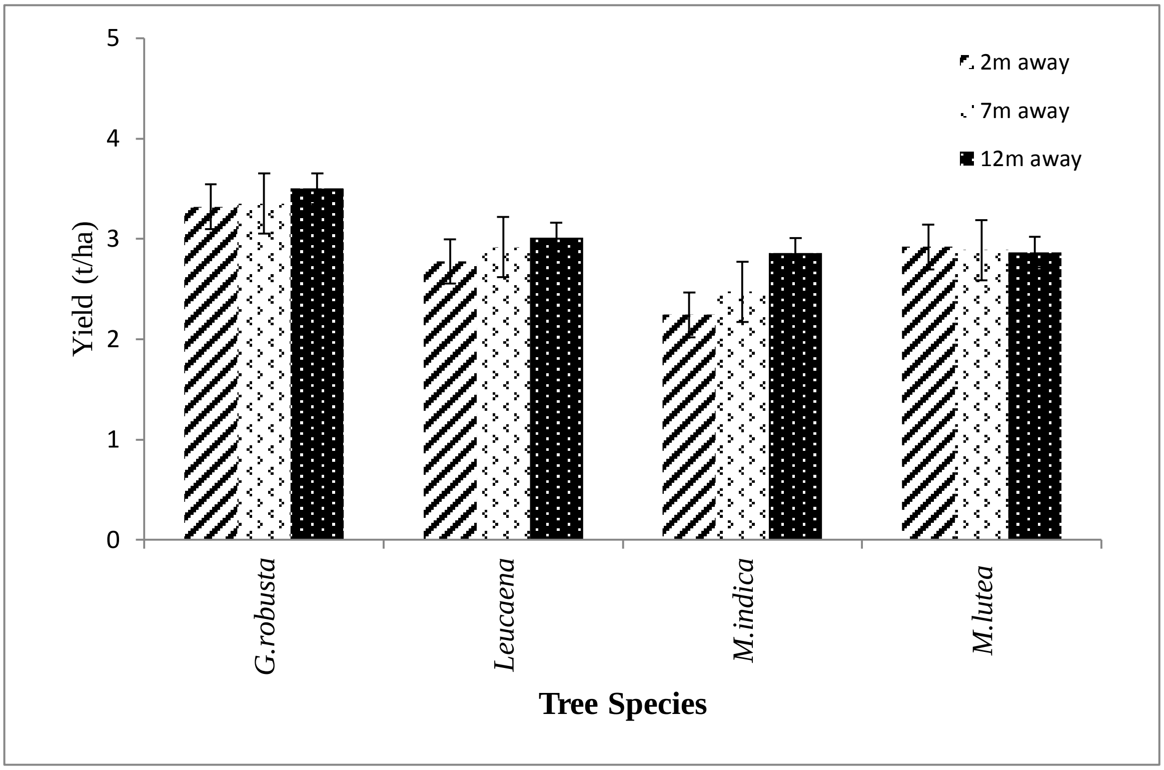

**Figure 3: The influence of different tree species and distance on maize yield in western Kenya**

The high TOC for soils under *G.robusta* canopy could account for the higher maize yields since TOC has long been identified as a factor that is important to soil fertility in both managed and natural ecosystems (Kucharik et al., 2001). All the tree species had a particular trend in the average yield of maize at the different sampled points; 2m, 7m and 12 m away from the tree. Whereas G. *robusta*, *Leuceana* spp *and M. indica* had a similar trend of increasing yield away from the tree, (Figure 5), *M. lutea* had a different trend of reducing yield away from the tree that is the maize yield that was sampled two meters away from *M. lutea* trees had a higher yield compared to yield of maize sampled 12 m away from the same tree. This contradicts a similar study where coppicing trees such as *Gliricidia* and *Leucaena* spp. caused increases in residual soil fertility beyond 2–3 years because of the additional organic inputs that are derived each year from coppice re-growth that is cut and applied to the soil (Akinnifesi et al., 2008) that led to increased maize yields. Maize yield that was obtained two meters away from *M. indica* was significantly different ($P < 0.05$) from yield obtained at 12m away from the same tree. This reflects in the growth parameters of basal diameter and height of maize under the *M.indica* species which was consistently lower with suppressed plant growth. However, the other selected trees had variations in the yield of maize sampled under their canopies but they did not show a significant difference at the different points; 2m, 7m and 12m away from the tree. G. *robusta* was significantly different ($P < 0.05$) from *M. indica* but was not significantly different ($P >0.05$) from, *Leuceana* spp and *M. lutea.*

# CHAPTER FIVE

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

In Western Kenya, tree planting is mainly farm-based with a mix of exotic and indigenous trees dominating the landscape. These farmers plant the different trees in various parts of their homes for different uses. Most farmers in the region have their trees planted within their homesteads while very few are incorporated within the agricultural landscapes. The major challenge has been the selection of trees to be incorporated in the agricultural landscapes. This is because the choice of tree depends on land size, utility of the tree and the family needs.

The trees that were prevalent in the landscape were *Eucalyptus* spp, which was the most dominant and was majorly planted within the homesteads or in woodlots. The tree is mostly preferred for its ability to grow very fast to provide timber that help raise the income of resource poor farmers by generating additional income and fuel wood. *Grevillea robusta* was also a common tree species and was prefered because it is a multifurpose tree species. Althogh it was planted within the compounds by some farmers most farmers prefer to plant it along farm boundaries. *Markhamia lutea* was also prefered by most farmers especially within the agricultural landscapes and along the farm boundaries for its timber and farmers believe that it compliments the growth of crops. Other tree species that were found though in less proportions but run across the landscapes included *Leuceana* spp, *Psidium guajava, Mangifera indica, Jacaranda mimosifolia* and *Persea americana.*

The selected tree species were found to influence soil chemical properties, growth and maize yields differenly. *Grevillea robusta* had a greater influence on soil TOC compared the other selected tree species while *M.indica* had the least influence on the soil TOC. The TOC of soils sampled near the trees, 2m away was generally higher than the TOC of soils sampled away from trees at 7m and 12m though not significant. For both the top and sub soil under the selected tree species in the three sites, the pH showed a general decreasing trend away from the tree; the pH of soils sampled near trees, 2m away, was higher compared to the pH of soil samples further from the trees 7 and 12m away. The CEC of soils samples near all the selected tree species 2m away was lower than that of soils sampled away from trees at 7m and 12m away.

On the growth and yield of maize, all the selected trees showed a particular trend in the height basal diameter and yield of maize. All the measured parameters were found to be increasing away from the selected tree species part from *M. lutea* which showed a decreasing trend in the height, basal diameter and yield of maize. Of all the selected tree species *Markhamia lutea* was found to be the best agroforestry tree in the region and *M. indica* was the worst tree to be used in agroforestry. This is because maize that were sampled at two meters away fem *M. indica* had a more suppressed growth and their yield was significantly different from that of maize sampled away at 7m and 12 m where the influence of the tree is believed to be less.

## 5.2 Recommendations

Trees show complementarity and completion when planted simultaneously with crops. Therefore studies should be done in order to come up with standard methods of selecting what tree species can be incorporated in crop land to complement plant growth. This is because trees play an important role in conservation of soil and have a high economic value due to their off farm uses.

High cost of inorganic fertilizers, low purchasing by most small holder farmers limit their use for artificial fertilizers. This has made the farmers to experience recurrent low yield since they cannot afford the fertilizers yet most farmers in western Kenya do not include fertilizer trees in their agricultural landscapes which have shown to improve crop production, a scenario that will see the farmers enjoy increased yields at low reduced costs. Ways of making farmers aware of including appropriate trees in their landscape should be sought.

More studies on *M. lutea* should be carried out to establish its full potential as an agroforestry tree in terms of its ability to improve the physical and chemical properties and general improvement on growth and yield of crops.

Other tree species that have been shown to improve growth and yield of crops yet they are not prevalent should be introduced and studies carried out to assess their potential as good agroforestry tree species in the region so as to increase the diversity. The study was done for only one season in four sites therefore more studies on the same should be done for several seasons and in different in different sites of the same counties so that tangible conclusions can be made.

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