ECOLOGICAL AND SOCIO-ECONOMIC STUDY ON BAMBOO FARMING IN THE WESTERN MT. KENYA REGION

PREPARED FOR: **ACT! Kenya**

BY

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THE ASSIGNMENT

Mt. Kenya-Burguret Conservation Forum, Thigu Environment Forum and Help Self Help Centre with the support of PACT Kenya are implementing an integrated conservation and development project-*"Integrated Catchment Conservation for Economic Empowerment in Mt. Kenya West (IC2E2- Mt. Kenya)".* The project intends to introduce bamboo on riparian areas currently occupied by Eucalypts. This is one of the proposed interventions to enhance environmental conservation and livelihoods of the local farmers. There are concerns that Eucalypts have negative impacts on the environment yet the local farmers have invested in this species. In order to ensure that the proposed interventions are informed by sound technical knowledge, PACT Kenya engaged the services of KEFRI and NMK to review, document and recommend the viability and suitability of bamboo farming in the Western Mt. Kenya ecosystem and its attendant ecological, social and economic significance.

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EXECUTIVE SUMMARY

Three community groups i.e. The Mt. Kenya-Burguret Conservation Forum, Thigu Environment Forum and the Help Self Help Centre have received a grant from USAID through the Kenyan Civil Society Strengthening Program (KCSSP), implemented by Pact Inc. and Pact Kenya to implement a 2 year project aimed at contributing to the restoration of the Western Mt. Kenya forest ecosystem through rehabilitation of key areas, strengthening community level institutions and promotion of nature based enterprises while increasing the incomes of the local communities from sustainable enterprises. Bamboo farming has been identified as a potential nature - based enterprise that will improve the ecological integrity of Western Mt. Kenya forest ecosystem, reduce poverty among locals by establishing and strengthening three product value chains (Bamboo, Honey & Lorena Jikos). The interventions are targeted to reduce forest dependence by forest-adjacent households and transformation of unsustainable agriculture as key sources of household income. The project intends to introduce bamboo on riparian areas currently occupied by Eucalypts along Burguret, Nairobi, Naromoru and Rongai rivers and on selected farmlands in the catchment area. In order to ensure that the proposed bamboo farming will be viable and socially acceptable intervention, an ecological and socio -economic study was conducted to inform on the bamboo farming with regard to species choices, site suitability mapping, planting, farmers' involvement and suitable models for income generation form bamboo farming. A literature review and field study was undertaken in the project area. The area constitutes the upper catchment area of Ewaso Ngiro River North basin and lies between Nyeri-Nanyuki highway and Mt. Kenya edges to the east with Nairobi River to the south and Nanyuki river on the northern edge.

The **ecological survey** assessed the plant composition and soil characteristics along four rivers i.e. Burguret, Rongai, Naromoru and Nairobi rivers. Pests and diseases associated with bamboo where also identified. Triplicate plots of 10m by 10m were established along the rivers and neighbouring farmlands. Plants present in the plots were recorded and a checklist developed. Composite soil samples were collected within the plots and analysed for pH, electrical conductivity, texture, Carbon, Nitrogen and Phosporus at the NMK Ecology Laboratory. A total of 225 plant species were recorded four of which are endemic to Kenya. The upper catchment zone is characterized by montane forest vegetation type and the lowland area by a savanna zone characterized by alternating grasslands and bushlands. Three categories of riparian zones were identified i.e. degraded zone with or without Eucalypts trees, intact zone with high diversity of plant species and a cattle watering zone. Introduction of bamboo farming should be done on the degraded area and the intact zones should be left intact to preserve and conserve the rich plant diversity.

The soils were moderately acidic to neutral with a pH range of 5.8-7.5 and non-saline with the electrical conductivity ranging from 155-918 µS/cm. Most bamboo species can survive in acidic soils

but cannot tolerate saline soil conditions. The soil pH and salinity levels in the project area are suitable for bamboo cultivation. The Phosphorus values were low and the Total Nitrogen and Carbon were moderate to high. The soils in the project site are moderately fertile and suitable for bamboo cultivation. The soils are texturally clay loam to sandy clay loam.

Various pests and diseases affect bamboo plants because they lack toxic constituents and have large quantities of starch and therefore form a ready source of a variety of organisms. Most bamboo plants are often attacked by fungi and insects. Some of the common fungi include surface molds, stain fungi, decay fungi and rust fungus. Common insect pests include aphids, termites, beetles, chalcid wasps and cockchafer larvae. Bamboo pests and diseases should be monitored regularly and systemic insecticides used to control any pest or disease attacks.

The **socio-economic survey** assessed the socio-economic status of local communities within the project area, status of bamboo cultivation, processing and cultivation in the area and potential human-wildlife conflicts that might arise due to bamboo cultivation. A cost benefit analysis for commercial bamboo farming was also conducted. Three approaches namely key informant interviews, focus group discussions and household surveys within the riparian zones on Rongai, Burguret and Naromoru rivers were used. Twenty three people were interviewed, eight key informants and one focused group discussion held with selected farmers and officials of the CBOs.

The project area is composed of migrant population with average individual land holding of 10 acres. The upper zones of the project receives reasonable amount of rainfall and the lower tends towards woodlands and experiences low rainfall. The land use system include homestead, agricultural land, grazing land/woodlands. Cropping pattern and land use mosaic is dictated by the distribution and magnitude of rainfall and to a large extent the emergence of irrigated agriculture along the riverbanks. There is overreliance on the water resources from the main rivers of Burguret, Naromoru and Nairobi. In the lower zones, agriculture is mainly confined to riparian areas where they draw water from rivers and this source is only plentiful during wet seasons and during dry seasons, the rationing makes it unreliable source for irrigation. The riparian zones were initially marshy/wetlands and the farmers planted Eucalypts as a method of reclaiming them for agricultural use.

The farmers have in the past relied on bamboo materials from the natural forests but with enhanced enforcement by KWS and KFS this source has dwindled and the farmers are enthusiastic about growing of bamboo. Ninety six percent would like to grow bamboo and are willing to set aside average of 0.5 acres for bamboo farming. However, the major constraint cited to bamboo farming is the lack of propagation materials and general lack of awareness on the potentials of bamboo as a commercial and industrial crop. There are scattered introduction and cultivation of bamboo species

in the project area mostly planted out of curiosity and for home use and ornamental purposes. The demand for bamboo culms in the region is high from the horticulture and floriculture industries that use the culms as support for crops and flowers. However, most households do not know about the immense potential of bamboo as an industrial crop. The study also established risks associated with bamboo farming which include poor growth, biological, physical and management risks. Young bamboo shoots are prone to browsing by elephants. Arising from the study findings, the following recommendations are proposed for introduction and development of Bamboo in West Mt. Kenya region

1. Bamboo should only be introduced in the degraded riparian zones. The intact zones should not be cleared for bamboo cultivation since they have a rich diversity of plants and act as refuge for biodiversity. This means that the degraded riparian zones in the four rivers should be properly identified and mapped before the rehabilitation exercise.
2. There is need to create awareness on bamboo farming among different stakeholders through seminars and workshops on Bamboo planting and utilization.
3. Improvement of bamboo production and processing technologies. This can be achieved through training in propagation, management, harvesting, and processing and value addition to ensure sustainability.
4. Increasing availability of planting material to the farmers through strong linkage and technical support from KEFRI
5. The project should proactively engage with potential consumers such as Flower and Horticultural industries to guarantee farmers of market for bamboo produce while other opportunities are explored. The possibility of contract farming should be explored.
6. Creation and strengthening of bamboo farmer groups and associations.
7. In order to inspire local confidence of the local farmers on the potential of bamboo resources -KEFRI/PACT KENYA with support of other partners establish Bamboo demonstration plots in the region.
8. Provision of enterprise development support services to farmer groups and associations. These services include market information, input supplies, and skills development and supply chain arrangements.
9. Establishment of a small scale workshop and a show room for bamboo handicrafts at the project office and possibly open an out let in Nanyuki town. This will increase demand for the bamboo products
10. There is need to integrate other high value indigenous trees in the rehabilitation of the riparian areas to avoid bamboo monoculture

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1.0 INTRODUCTION

1.1 BACKGROUND AND INTRODUCTION

Mt. Kenya is an important water catchment area, and forms one of the five main “water towers” of Kenya. Mt. Kenya East forms the catchment for Tana River (the largest river in Kenya) while the western region forms a catchment for the Ewaso Nyiro River. Tana River provides the country's major source of hydropower and also supplies water for irrigation schemes including Mwea rice scheme, Bura and Tana Delta irrigation scheme. In addition, Mount Kenya ecosystem constitutes an important reservoir for biodiversity and is a renowned biodiversity hotspot in the country. However, like other ecosystems in the country, Mt. Kenya ecosystem is facing pressure from the adjacent communities who depend on it for their livelihoods. Human induced illegal activities such as extensive logging of indigenous tree species, charcoal production, grazing and encroachment are increasingly degrading Mt. Kenya leading to loss of biodiversity, extreme events of climate variability and low water levels. As a consequence, the livelihoods of the adjacent communities that depend on this ecosystem have been adversely affected and have resorted to unsustainable practices such as cultivation of riparian areas, charcoal burning, indiscriminate tree poaching for timber, poles and firewood for sale. There is therefore need to promote alternative livelihoods to reduce pressure on Mt. Kenya. Bamboo farming had been proposed as a viable and sustainable income generating activity that could contribute to livelihood improvement in Mt. Kenya.

Three community groups have received grants from USAID through the Kenya Civil Society Strengthening Programme (KCSSP), implemented by Pact Inc. and Pact Kenya to promote cultivation of bamboo as an alternative livelihood as well as enhance environmental conservation in the western region of Mt. Kenya. The groups include the Mt. Kenya- Burguret Conservation Forum, the Thiga Environment Forum and the Help Self Help Centre. Mt. Kenya-Burguret Conservation Forum is a consortium made up of two community based organizations, the Burguret River Water User’s Association (BRWUA) and Mt. Kenya Biodiversity Conservation Group (Mt. KBCG). The Thiga Environment Forum is a community based organization based within the western side of Mt. Kenya specifically Kabaru Forest and its environs and covers a radius of 5km from the forest border. The Help Self Help Centre supports individuals and community groups to participate in nature based enterprises and conservation and protection of Mt. Kenya West forest landscape.

The bamboo farming project targets the Mt. Kenya West ecosystem. It is the source of the River Burguret, Naromoru, Rongai, Nairobi, Thego and Nanyuki River. All these rivers traverse the Western Mt. Kenya area and are important source of water for domestic use and small, medium to commercial scale horticulture and pastoralist. The project intends to introduce bamboo on riparian

areas currently occupied by Eucalypts. This is one of the proposed interventions to enhance environmental conservation and livelihoods of the local farmers. There are concerns that Eucalypts have negative impacts on the environment yet the local farmers have invested in this species. To meet the twin goals of environmental conservation and livelihoods improvement in western Mt. Kenya region, Pact Kenya and other stakeholders in the project have proposed bamboo as one of the potential species targeted to replace Eucalypts. In order to ensure that the proposed interventions are viable and socially acceptable- an ecological and socioeconomic study on bamboo farming was proposed to inform the project interventions with regard to species choices, site suitability mapping, planting, farmer's involvement and suitable models for income generation from bamboo farming. In this regard, Kenya Forestry Research Institute (KEFRI) and National Museums of Kenya (NMK) were tasked to undertake the study. This report documents results based review of literature on bamboo and a field study undertaken in the project area by a team of Kenya Forestry Research Institute and National Museums of Kenya scientists for a period of one week (20th-25th June 2011).

1.2 OBJECTIVES

The overall objective of the study was to review, document and recommend the viability and suitability of bamboo farming in the Western Mt. Kenya ecosystem and its attendant ecological, social and economic significance.

1.2.1 SPECIFIC OBJECTIVES

I Ecological component

1. Assess the plant composition and soil characteristics in the project area
2. Assess the ecological requirements of the various bamboo species against the ecological conditions of the study sites
3. Identify pests and diseases associated with bamboo
4. Propose a rationalized Eucalyptus replacement strategy using bamboo as an alternative along the riverine/riparian systems in the study area

II Silvicultural component

5. Identify bamboo species that can be planted on the riparian lands
6. Assess the potential of introducing exotic bamboo species in the project area
7. Identify fast growing bamboo species that can be grown commercially in Mt. Kenya region
8. Recommend propagation protocols for the identified bamboo species
9. Assess capacity of local/project area farmers in propagation ad management/growing of bamboo

10. Asses training needs for bamboo propagation, management, processing and general utilization for the local farmers/communities

III Socio-economic component

11. Assess socio-economic status of local communities within the project area using existing baseline studies
12. Assess status of bamboo cultivation, processing and utilization in the area
13. Carry out a cost benefit analysis for commercial bamboo farming
14. Assess human /wildlife conflicts that might arise due to bamboo introduction

The outputs of this study will be used to develop a site- specific management plan for Eucalyptus replacement initiative using bamboo in the project area.

2.0 BACKGROUND INFORMATION AND LITERATURE REVIEW

2.1 GENERAL INFORMATION

Bamboos are plants of global interest because of their distinctive life form, their ecological importance and the wide range of uses and values they have for humans. They are the fastest growing woody plants on the planet, with some species growing up to 1 meter per day. Their extensive rhizome system found primarily in the top layers of soil plays a major role in stabilizing soils on slopes and river banks, preventing erosion and landslides. This also makes them important in securing the hydrological function of catchments and rivers. Many forest bamboos are characteristic of high-altitude ecosystems on steep slopes and so their role in soil stabilization is critical. This also makes them important in securing the hydrological function of catchments and rivers. In addition to their ecological benefits, bamboos are multipurpose crops, with over 1 500 documented uses (Scurlock,et al., 2000,RELMA, 2003; Madhab, 2003,).

Their most important traditional uses include housing, food and material for handicrafts. Worldwide, over 2.5 billion people trade in or use bamboo (INBAR 1999). Globally, domestic trade and subsistence use of bamboo are estimated to be worth US$4.5 billion per year, and export of bamboo generates another US$2.7 billion (INBAR 1999). The many uses and the economic importance of bamboo mean that it plays a considerable role in improving the livelihoods of rural poor people.

Bamboo therefore is an important non-timber forest resource and can play an important role in the reduction of timber production, environmental and forest protection, poverty alleviation and sustainable development of rural economy. It is high yielding, renewable natural resource and a

viable replacement for wood in many construction scenarios. The diversified use of bamboo is limited in Africa, largely due to lack of awareness. Bamboo in Kenya plays a very important role in fencing, house construction and water harvesting. It is also used in cottage industries, in the manufacturing of matchstick, baskets, tooth-picks, and various other handicrafts. It is also used in agricultural farming especially for supporting horticultural crops. Kenya has so far recorded up to 48 local bamboo uses (Ongugo et al, 2000).

Kenya has only one native bamboo species i.e. *Yushania alpina* found in the highlands of Mau, Mt. Kenya, Aberdares, Mt. Elgon and Cherengani. It covers about 150,000 ha. In 1986, a ban on harvesting of bamboo from natural stands was passed. However, illegal harvesting of bamboo has continued unsustainably threatening the survival of the remaining natural stands. Due to bamboo's contribution and great potential to social, economic, environmental and rural development, there is an increasing interest to develop and promote bamboo production in Kenya. Recent studies indicate that only 0.06% of bamboo is from farms and out this, the farmers get about Kshs. 6.7 million (Ongugo et al, 2000) but the imposition of the ban has impacted on its development.

The bamboo resources in Kenya also consist of exotic species such as *Oxytenanthera abyssinica,* and *Bambusa vulgaris*. The latter is widely distributed on farmlands and urban centers as ornamentals. Due to its lightweight, high elasticity and great resistance to rapture, bamboo is ideal for numerous construction uses. It can also be used in the production of pulp and paper, handicrafts, household goods, rehabilitation and stabilization of gullies and riverbeds and recycling and filtration of domestic and industrial wastewater (ICRAF 2009). Bamboo shoots are a good source of human food, while the leaves are widely used for animal fodder. With a growth rate that is three times faster than eucalyptus, bamboo matures in about 3-5 years (depending on different environmental field conditions), after which harvests are possible for up to 80-120 years (Kibwage et al 2007).

2.2 PRODUCTIVITY OF BAMBOO SPECIES

As regards biomass production by bamboos, there is a wide variation depending on species and region of cultivation. Even within the same region, production potential varies due to clump densities, mode of plantation and silvicultural management adopted. Total above ground biomass in both monopodial and sympodial bamboo types generally varies between 7 to 165 t/ha as recorded from 26 bamboo species worldwide (Kleinhenz & Midmore 2001). Bamboo has high productivity and has been found to attain annual yield of 20-40 tons per hectare on a managed plantation (Kibwage et al 2007). It can produce harvestable culms within 4–7 years of planting, which subsequently can be harvested annually. For this reason, it is expected that, in the future, the major demand for bamboo will be for timber substitution.

In contrast to trees that can accumulate biomass over long periods through radial and vertical extension of stems (trunks), bamboo culms lay down most of their biomass within their first year of growth, largely from current assimilation but also from redistribution from older culms and rhizomes (Magel et al. 2006), and die off after a maximum of 8–10 years, resulting in a decline in biomass of individual culms over long periods. On an annual basis, above-ground culm growth rates (fresh weight) of 10–30 t/ha/year have been reported (Kleinhenz and Midmore 2001), which is in line with those of woody species (Hunter and Wu 2002). Productivity of bamboo on an annual basis is generally equals to that of woody species and therefore fixes almost the same amount of carbon as other woody species. However, one advantage of bamboo over trees is that culms can be harvested much sooner than trunks of woody species and another is that they can be harvested annually without the environmental consequences of clear-fell. Below the ground, bamboo sequesters carbon in the form of rhizomes, and below-ground biomass is greater proportionately for monopodial (running) species at c. 43% of total biomass compared to c. 31% for sympodial (clumping) species (Kleinhenz and Midmore 2001).

The productivity of locally introduced bamboo species ranges from 4.9tons/ha for *D.membranaceus* in Muguga and 36.8 tones/ha in coastal lowlands of Jilore, *D.brandisii* from 17.8tones/ha in Gede and 37.9 tones in Kakamega, *D.hamiltonii* from 11.3tones/ha in Gede and highest of 29.0 in Muguga.

2.3 BAMBOO PESTS AND DISEASES

Bamboos lack toxic constituents and therefore form a ready food source for a variety of organisms. Normally bamboo will be attacked by fungi and insects (beetles and termites). The presence of considerable quantities of starch in green or dry bamboo makes it more attractive to such organisms, especially stain fungi and borer beetles.

2.3.1 BAMBOO DISEASES AND FUNGI

Various diseases affecting the bamboo culms can dwindle the stand productivity. In natural stands and plantations, bamboo leaves and culms are affected with various diseases at different growth phases which result in partial to complete failure in culm production. The foliage diseases cause comparatively less damage to bamboo stands than culm diseases. Diseases affecting the emerging and growing culms are much more serious as they cause extensive damage to bamboo stands. Some of the diseases affecting bamboo include rot, culm blight, leaf spot, and leaf rust, sooty moulds, tar spot, and shoot rot. Culm blight, manifests as brown to black blighted spots in the culm. Leaf spot infection starts as whitish to yellowish lesion on the leaves. The spots turn brownish to dark brown causing the severely infected leaves to defoliate. Leaf rust starts as tiny yellow lesions

on leaf's upper portion, which turns yellow to brown. These lesions coalesce to develop into necrotic areas.

The forming of bamboo mold and white spores on the surface of bamboo canes is common, especially when harvested bamboo is not 100% dry. Surface mold on bamboo products will only occur once, maybe twice until the moisture content inside the bamboo canes is completely evaporated. Some common fungi affecting bamboo include:

- **Surface Molds**: These bamboo molds grow on the surface and at the cross-ends of bamboo culms. Although they look spectacular, they have no influence on the strength of the bamboo and can be wiped off easily.
- **Stain Fungi**: These bamboo fungi can penetrate round bamboos from cross cut ends as well as from cuts at the nodes after removal of the branches. Attack is indicated by shades of blue/grayish-black discoloration on the surface in the form of spots and streaks. It reduces the aesthetic appearance but does not affect the strength properties of bamboo (except in severe cases of attack).
- **Decay Fungi**: These bamboo fungi include *Fusarium moniliforme* var. i*ntermedium* and *F. equiseti* and cause the most serious kind of damage. They grow within the lumen of the cells. The enzymes either decompose only the cellulose and hemicellulose leaving behind the lignin leading to brown rot, or they decompose lignin leading to white rot (white rot is more common in bamboo than brown rot). Early decay is difficult to detect. Even before slight color change or weight loss becomes apparent; the strength properties are much reduced, in particular the impact and bending strength. Early damage can be characterized by dampness in bamboo. At later stages of deterioration the culm is soft to the touch and may be only a fibrous or powdery mass.
- **Rust Fungus:** The rust fungus, *Dasturella divina*, has been reported to affect bamboo plantations. It destroys tissues of bamboo leaves changing the distribution of elements in leaf tissues and therefore decreasing the rate of photosynthesis.

2.3.2 BAMBOO INSECT PESTS

Insects affecting bamboo are either defoliators, sap- sucking or culm and shoot borers. Leaf-biting and sap-sucking insects may be a problem in shoot plantations especially when bamboos are young. Adult plants do not seem overly affected by such pests. Most defoliating insects remain low in population and hence, are generally considered pests of minor importance. But some of them show periodic fluctuations in population and epidemics can cause severe or even total defoliation of bamboo stands. Damage caused by leaf feeders reduces the surface area available for photosynthesis, affecting vigour, growth and survival of plants.

Sap-sucking insects have highly modified piercing-sucking mouthparts and feed on the sap of leaves, lay eggs on the leaves, inject toxic compounds into the plant and transmit diseases. This results to defoliation, wilting of young shoots and branches, and even death of the culm.

Compared to defoliators and sap suckers, culm and shoot borers have less effect on the plant physiology. But these can greatly reduce culm and shoot yields and are considered to be of major economic importance. A single larva of a culm borer can destroy a culm. The attack of the borer ***Cyrtotrachelus* spp.** is positively correlated with the density of the culms.

Some bamboo insect pests include:

a) **Aphids:** These are sap-suckers and are the most prevalent insect pests that ravage bamboo (Plate 1). The seasonal infestation is usually concentrated in certain parts of a bamboo plantation and also within it to only certain parts of the plant. Aphids build small colonies that suck the sap from the young leaves and shoots and thereby weaken the plant. These insects usually produce sufficient amount of honeydew that drips into the base of the culm or flowering stem that turns into favourable environment for black sooty moulds to grow. The aphid ***Oregama bambusae*** sucks the sap of growing shoots of bamboos. Heavy infestation results in the withering of young shoots, which ultimately die.

   Control measures against aphids are only necessary in very young plantations. This can be achieved by spot treatment of the colonies with Malathion 50%.

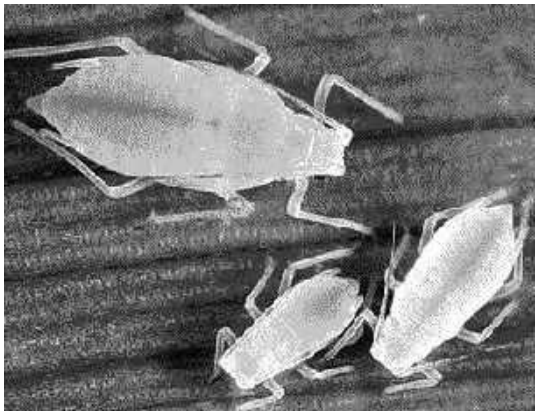


Plate 1: Aphid attack on young bamboo leaves

b) Termites (Isoptera: Rhinotermitidae and Termitidae): These insects live in well-organized colonies having a population of several thousands to a few millions of individuals. They are among the few insects capable of using cellulose as a source of food. Some varieties of termites (subterranean) need high humidity and access to water for survival. Other types (drywood type) survive without ground contact, obtaining moisture from the culm (Plate 2).

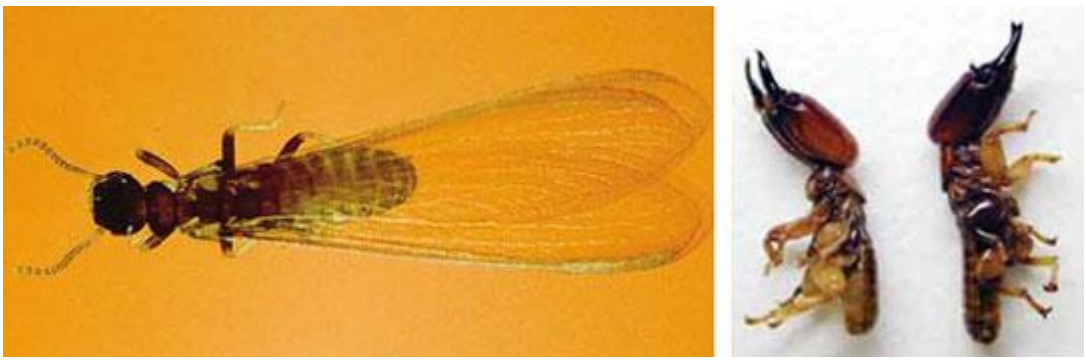


Plate 2: Subterranean termite (left) and Drywood termites (right)

Subterranean termites attack bamboo on ground contact by extending above the ground in tube-like runways made of soil. The gnawing takes place inside the bamboo culm. **Drywood termites** build their nests inside the bamboo culm parts that they are eating. Often attack becomes visible only at a late stage of deterioration.

Usually termites feed only on dying and dead culms, however, the termites feeding around bamboo culms cause new culms to originate higher up, ultimately resulting in congested culm growth. The incidence and extent of damage caused by termites to standing bamboo culms is generally negligible.

c) **Beetles:** These are culm and shoot borers and include **Powder-post beetles** which may consume the whole bamboo culm leaving only a thin outer shell on exiting. Larvae of beetles nourish on the starch and sugars in the parenchyma cells in the culm and the intensity of attack will depend on the amount of starch available. Thus culms with higher starch content, for example, those harvested during shooting or the rainy season, are more prone to attack. Once the larvae grow, they can consume other cell wall components as well. Powdery dust falling out of holes indicates ongoing bamboo insect infestation. The beetle larvae can tunnel through the entire inner tissue leaving behind only a thin surface of the hard cortex which may give a false impression when evaluating the significance of damage for repair work. The powder-post beetle is the most important pest of bamboo under storage, either as culms or as finished products.

d) **Chalcid wasp species:** This induces galls to form on bamboo twigs. Galls cause abnormal growth and shedding of leaves on the affected twigs and thus, affecting photosynthesis. The impact of galls on the productivity of bamboo stands, however, remains to be evaluated.

e) **Cockchafer larvae:** This is a common pest that attacks and destroys new roots of bamboo (Plate 3). The nursery bed soil should be prepared from soil that has been cultivated for many years and is free from cockchafer larvae.

Plate 3: Cockchafer larvae

Other insect pests known to attack bamboo plants are plant hopper (*Purcheta purcovenosa*), leaf roller (*Pelopideas mathias*), tussock moth (*Lymantria lunata*), grasshopper (*Locusta migratoria*), mealybug (*Planococus lilacinus*), mites (*Aponychus corpuze*), and rodents (Rattus sp.).

Bamboo Pests and diseases should be monitored regularly. Systemic insecticides and predatory species can be used to control bamboo pests and diseases.

3.0 STUDY METHODOLOGY

3.1. DESCRIPTION OF THE PROJECT AREA

3.1.1 GEOGRAPHIC LOCATION

The project area is situated on the northern part of Kieni East District of Nyeri County. The area lies between Nyeri-Nanyuki highway and Mt. Kenya edges to the east with Nairobi River to the south and Nanyuki river on the northern edge (Figure 1). The area constitutes the upper catchment area of Ewaso Ngiro River North basin. The area spans from moist forested area to drier savanna region. The project area is drained by several perennial rivers including Burgurtet, Naromoru, Nairobi and Rongai rivers. The river flow of these rivers is controlled by the Mt. Kenya forest and water abstractions. The waters of the Mt. Kenya tributaries of Ewaso Ng'iro North River have been tapped extensively to supply water to rural and urban settlements, small scale irrigation by small holder

settlers and lately, to support commercial horticulture for the local and export market. Since 1963 the basin has experienced dramatic changes in both land ownership and land use due to a rapid population growth of 7–8% per annum. The reduction of available land in the rangelands has led to serious land degradation illustrated by soil erosion gullies and deforestation due to charcoal burning. The water needs of small- and large-scale farmers and the rapid expansion of urban centers in the region cause problems of inadequate water from the many perennial rivers affecting both upstream and downstream users.

3.1.2 CLIMATE

The project area is relatively dry due to the rain shadow effect of Mt. Kenya. The area has a mean annual temperature of 15˚C. Annual rainfall is typically between 450mm and 750 mm. Rainfall is affected by the inter-tropical converge zone (ITCZ) and is of convective origin. Rainfall is bimodal, the long rains occurs from March to June and the short rain season occurs from October through December while the dry conditions prevail between rain seasons. Both onset and duration of rain seasons is unreliable. In the drier areas, rainfall is episodic and interspersed by lengthy periods of drought. Potential evapotranspiration on the other and ranges from less than 1000mm at higher altitudes to over 2500mm at the lower altitudes. The upper slopes (altitude above 1900m) are characterized by heavy rains and less evapotranspiration hence experience significant surface runoff which feed into rivers and springs. The lower slopes are drier and do not receive a lot of rainfall and experience higher evapotranspiration. The basin thus represents a water-surplus highland area adjacent to water-deficit lowland. The arid conditions in the lower belt mean that the ecosystem is fragile while socio-economic potential is extremely limited. The only viable option is pastoralism, in response to the ecosystem. In recent past there has been a prolonged drought and weather pattern has tended to be unpredictable and has impacted negatively on local livelihoods and tended to increase the pressure on natural resources and conflicts.

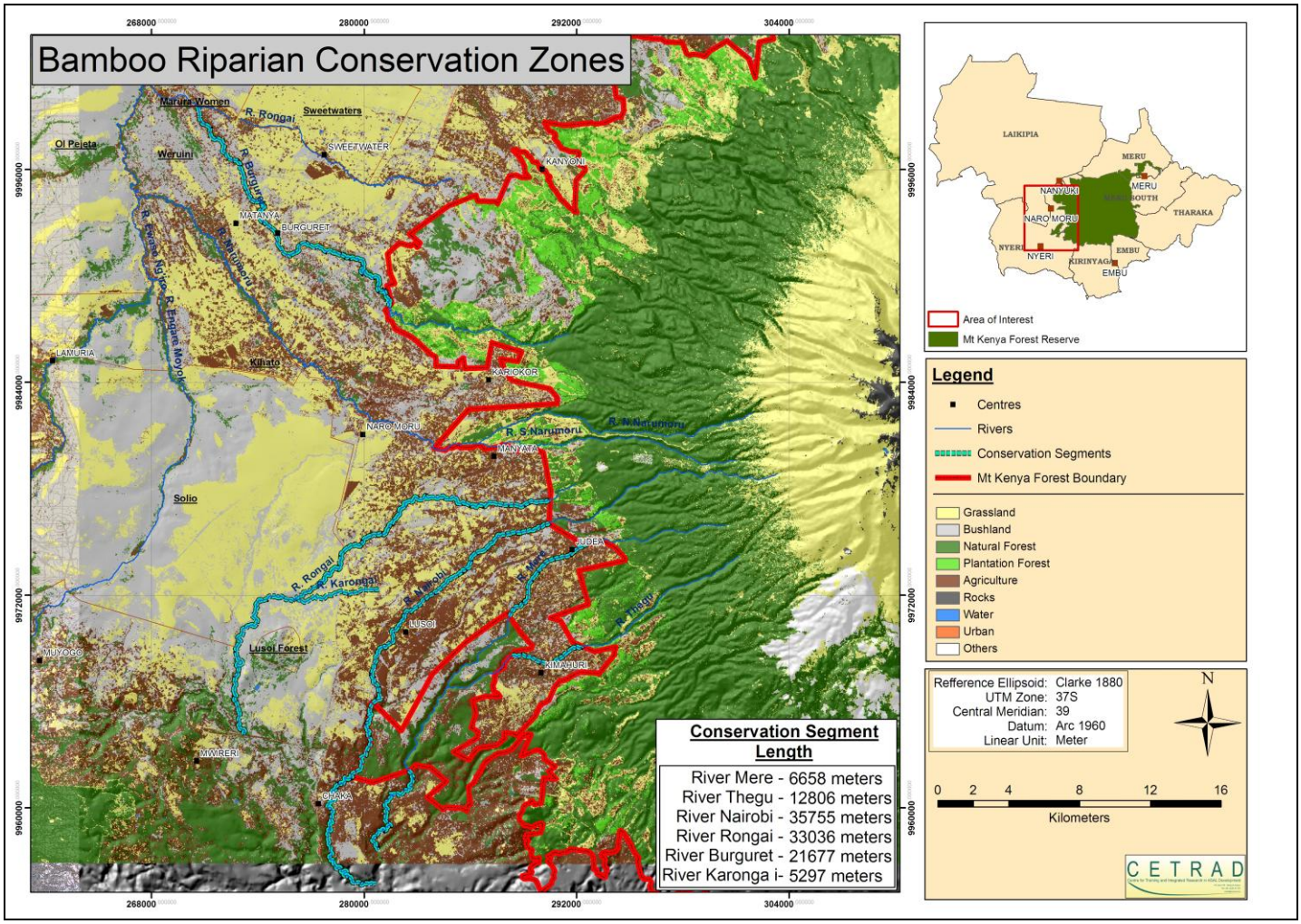


Figure 1: Detailed map of the project area showing riparian zones and adjoining areas

3.1.3 WIND

The area is on the leeward side of Mt. Kenya, and experiences high wind speed from the month of May to September when the wind speed can be as high as 40km/hr. During the rainy seasons the wind speed are quite low and not harmful to the crops.

3.1.4 SOILS

The soils in the project area are characterized by deep Vertisols, typically luvic phaeozems, and Luvisols. Luvic Phaozems are dark gray, clay, imperfectly to moderately drained and occur on the lower semi-arid area. The Luvisols are well drained, very deep, dark reddish brown, firm clay and

occur on the high altitude area. The soils are clayey that shrink and develop cracks when dry (Plate 4) and swell and close up when they are moist.

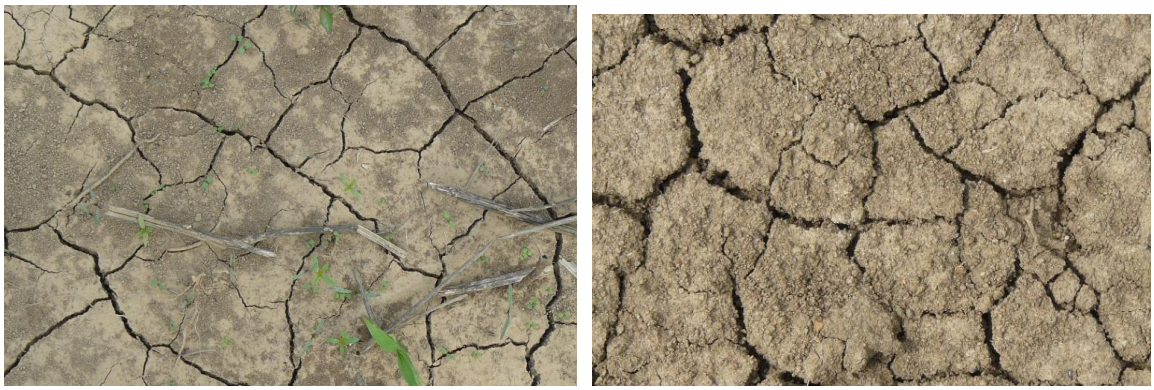


Plate 4: Soils of the study area showing cracks caused by contraction due loss of moisture during the dry season

3.2 ECOLOGICAL STUDIES

3.2.1 SAMPLING DESIGN

The ecological survey was conducted along four rivers i.e. Burguret, Rongai, Naromoru and Nairobi rivers that drain west of Mt. Kenya. The area sampled had an altitudinal range of 1752m to 2194 m above sea level. Along each river, a minimum of three sampling points were selected. Additional three sampling plots were sampled on the neighboring farmlands (Figure 2). In each sampling point, three plots of 10 x 10 meters were randomly demarcated and all the plants present in the plots recorded. Plant specimens were collected for plant species that could not be identified in the field and identified at the National Museum of Kenya (NMK) Herbarium. In each plot, a composite soil sample was obtained by sampling three random spots (Plate 5). The soils were sampled at two depths i.e. 0-20cm and 20-50cm. Soil pH, Electrical conductivity, and texture, Carbon, Nitrogen and Phosphorus. The analyses were conducted at the NMK Ecology Laboratory. GPS co-ordinates were recorded for each sampling point for future monitoring.

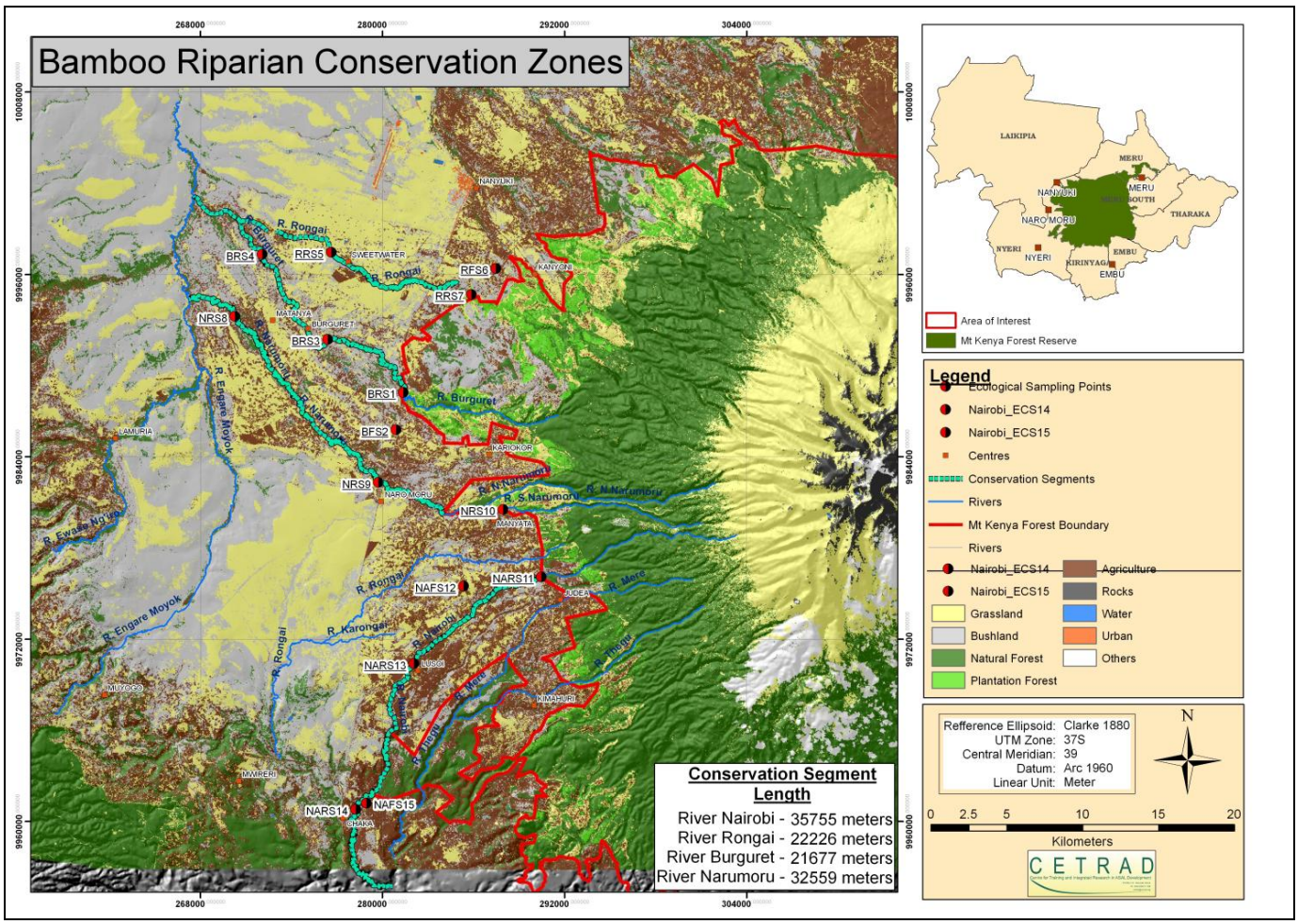


Figure 2: Map of Western Mt Kenya showing the points sampled along the four rivers

Plate 5: Soil sampling during the survey

3.3 SOCIOECONOMIC AND SILVICULTURAL

The socioeconomic study was undertaken using three approaches namely Key informant interviews, focus group discussions and household surveys within the three riparian zones of Rongai, Burguret and Naro moru rivers (Figure 3). The targeted households were sampled based on an earlier list prepared by the project team of the farmers who had shown interest in bamboo growing. Twenty three people were interviewed, eight key informants and one focused group discussion with selected farmers and officials of the CBOs **(Appendix 1 & 2).** Visits were made to farmers who had bamboo clumps for identification of species, assessment of growth performance, management, harvesting and use of bamboo. The farmers were also advised on bamboo management and potential uses during the course of interactions. Nurseries involved in propagation of bamboo seedlings were visited to assess the level of competence on bamboo propagation techniques (selection of propagation materials, nursery practices etc).

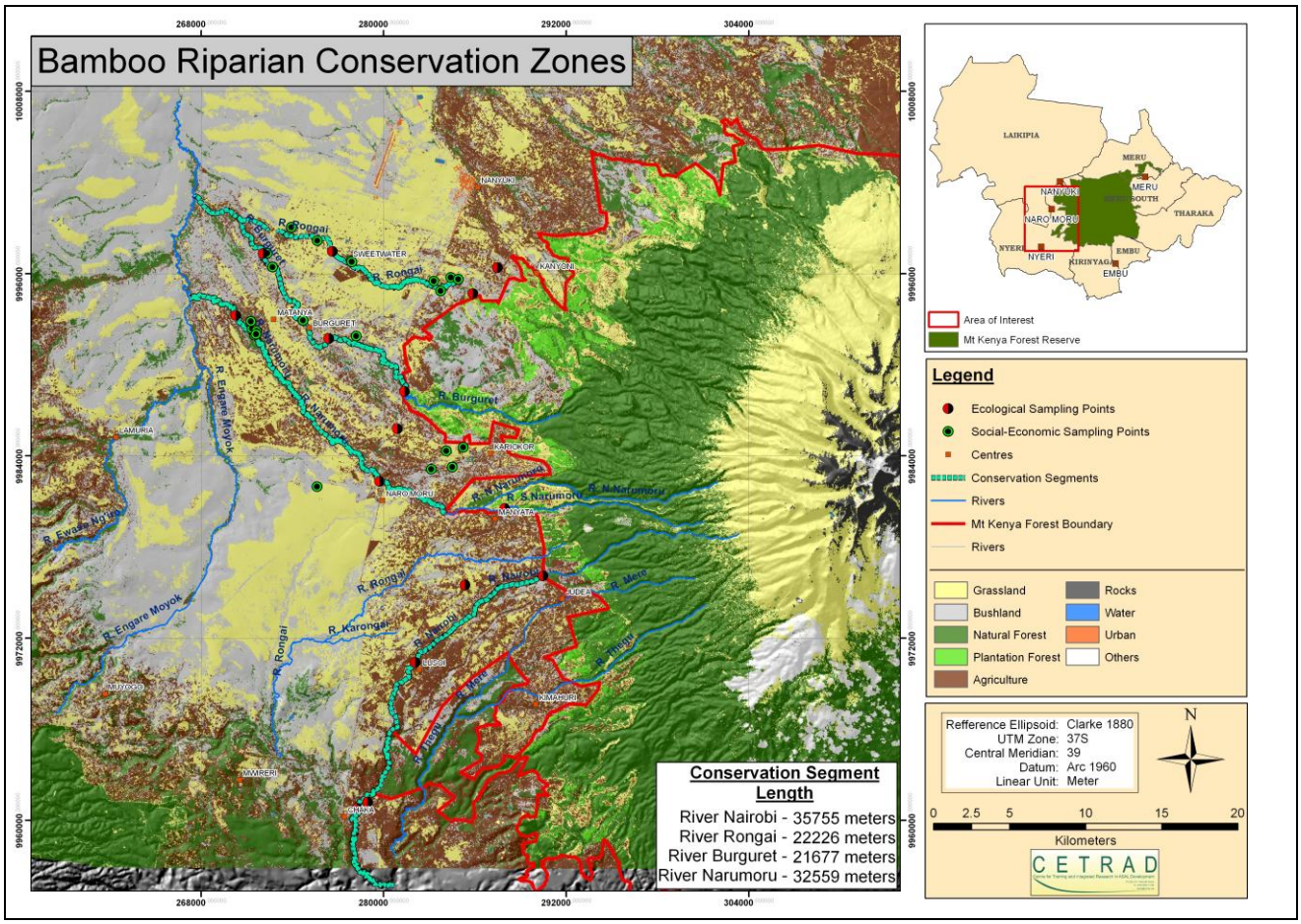


Figure 3: Map of Western Mt Kenya showing the locality of the households visited during the survey

4.0 RESULTS

4.1 FLORISTIC COMPOSITION AND SOILS

4.1.1 FLORISTIC COMPOSITION

A total of 225 plant species from 74 families and 172 genera were recorded **(Appendix 3).** Four species are endemic to Kenya and three of them occur in Nairobi river. The most abundant species in descending order included; *Achyranthes aspera, Rhus natalensis, Grewia similis, Conyza bonariensis, Euclea divinorum, Thunbergia alata, Maytenus senegalensis, Commelina africana, Aspilia mossambicensis and Trichocladus ellipticus.* The most represented families in descending order included; Compositae, Leguminosae, Labiatae, Gramineae, Solanaceae, Euphorbiaceae, Malvaceae, Rubiaceae, Amaranthaceae, Capparaceae and Polygonaceae (Figure 4)

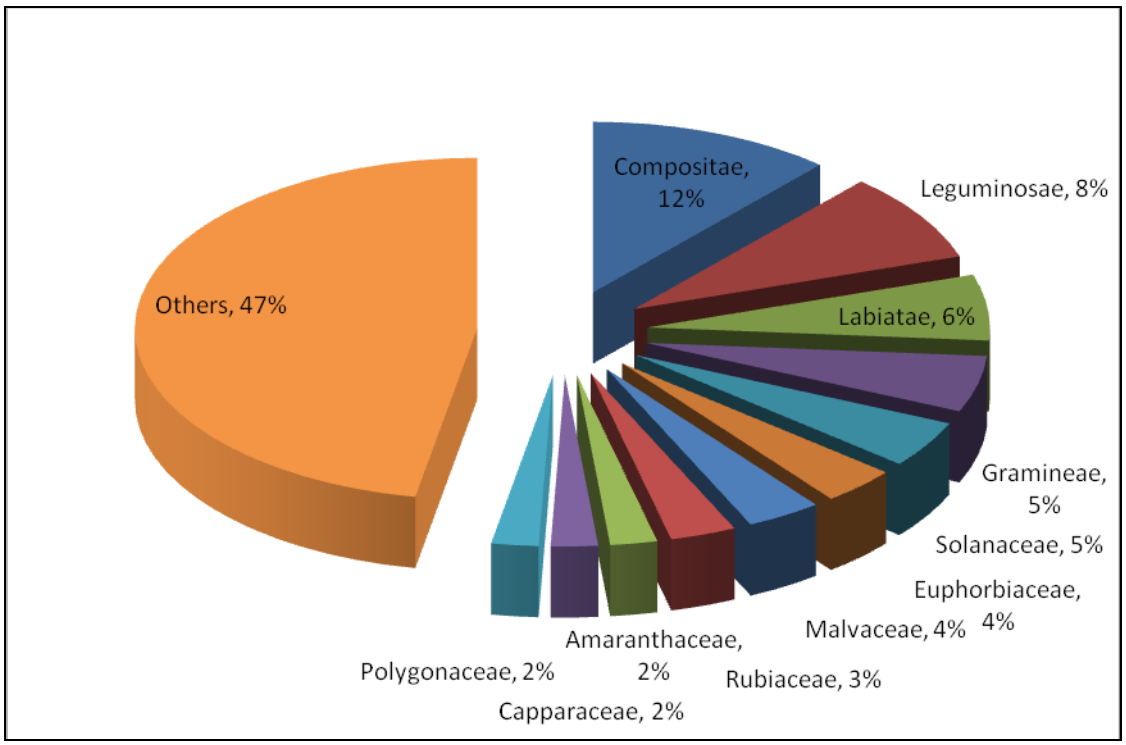


Figure 4: Percentage composition of plant families

4.1.2 LIFE FORMS

Herbs were the most dominant life form, followed by trees. Climbers were least represented (Figure 5).

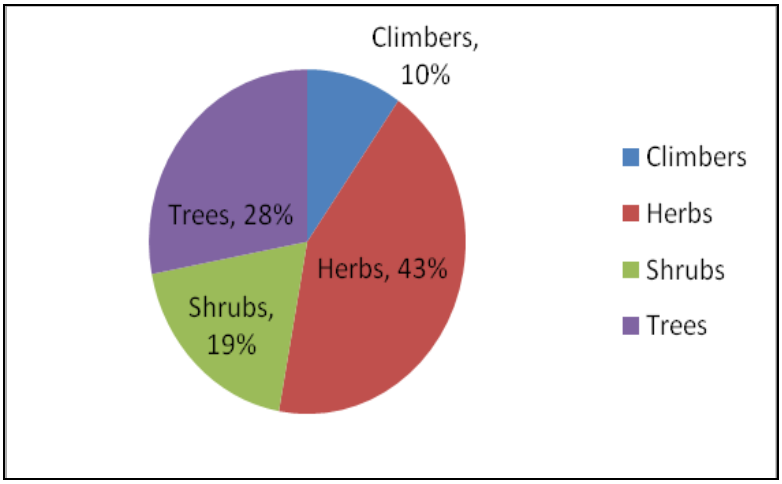


Figure 5: Percentage distribution of life forms

4.1.3 PLANT SPECIES DIVERSITY

River Nairobi was the most diverse and Naromoru river was the least diverse.

	Overall	Burguret	Rongai	Naromoru	Nairobi
Species richness (S)	225	111	95	97	134
Diversity (H')	5.13	4.62	4.51	4.50	4.79
Eveness (J)	0.95	0.98	0.99	0.98	0.98

4.1.4 VEGETATION ZONES

The upper catchment zone is characterized by montane forest vegetation type and the lowland area is typically a savannah zone which is characterized by alternating grasslands and open bushlands. Much of the dense vegetation which naturally lines river courses has been subjected to disturbances by the small scale farmers' use of land adjacent to these river courses. Three categories of the riparian zone were identified namely: degraded zone with or without a few *Eucalyptus* trees, intact zone with high diversity of plant species and watering zone used by cattle for watering (Plate 6).

Intact riparian zone

Degraded riparian zone

Cattle watering point

Plate 6. The three kinds of riparian zones observed

Species composition was compared between the sampled rivers and three vegetation group or zones were differentiated namely farmland, the mid-altitude vegetation zone with an altitudinal range between 1750-1980 and the high-altitude vegetation zone occurring in an altitude of over 2000 m a.s.l. (Figure 6 & Plate 7). The dominant species on the farmland zone were mostly weeds and comprised of *Tagetes minuta*, *Bidens pilosa*, *Commelina africana* and *Galinsoga parviflora*. The mid-altitude vegetation zone occurred on the semi-arid area and was comprised on *Euclea divinorum*, *Grewia similis*, *Psiadia punctuata* and *Boscia angustifolia*. The dominant species in the

moist high altitude vegetation zone were *Podocarpus falcatus*, *Trichilia emetica*, *Syzygium guineese* and *Teclea simplicifolia*.

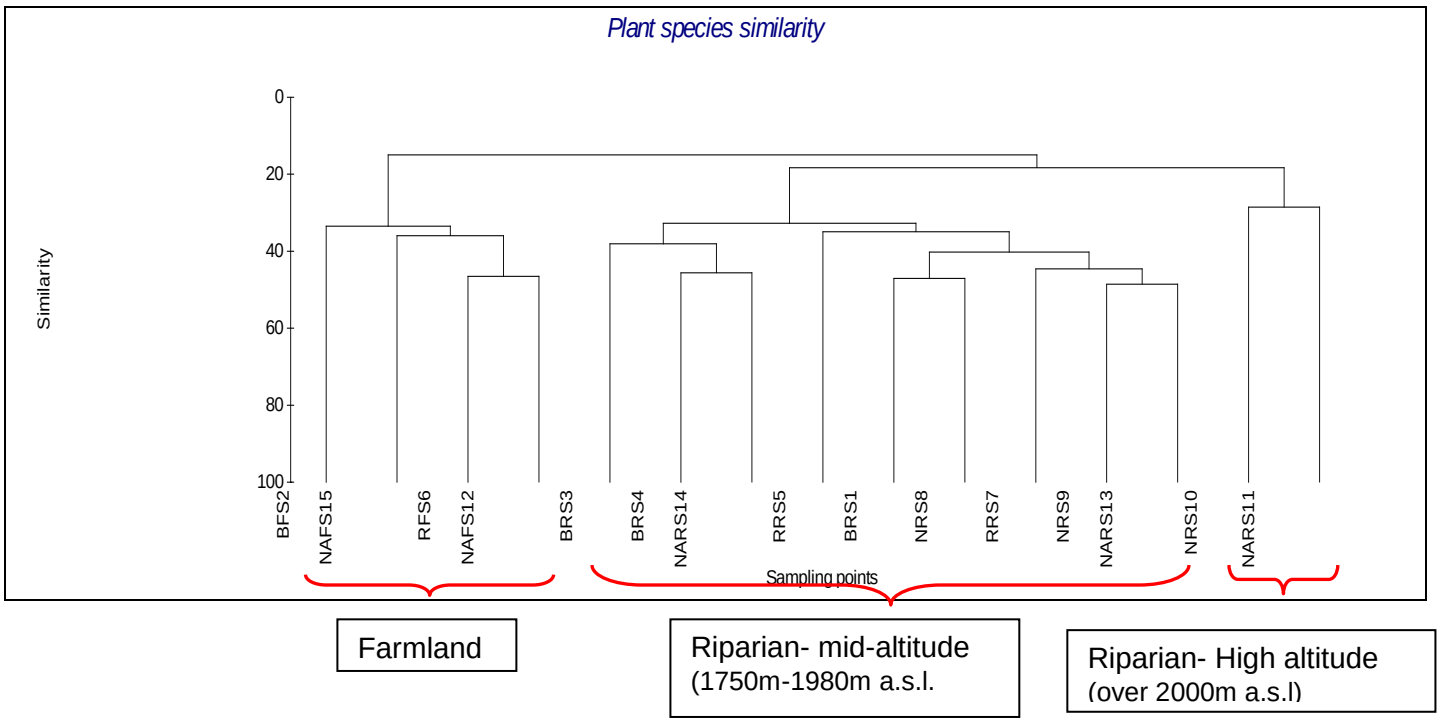


Figure 6. A dendrogram showing the three vegetation zones in the study area

Plate 7. Representative vegetation in each zone

4.2 SOIL PHYSICO-CHEMICAL PROPERTIES

Soil physico-chemical characteristics of the topsoil within the fifteen sampling points is given in Table 1 below. The soil pH ranges from 5.8 to 7.5 and is moderately acidic to neutral. Most plants grow best if the pH is between 6.0 and 7.5. Soil pH impacts nutrient availability Soil pH is an important chemical property because it affects the availability of nutrients to plants and the activity of microorganisms in the soil. Most plants will grow over a soil pH range of 1-2 units.

The electrical conductivity ranged from 155-918 µS/cm indicating the soils were non-saline. Measurement of Electrical conductivity (EC) is an indicator of the amount of ions or salts in the soil solution. The electrical conductivity increases as the soluble salts in the soil solution are increased. A high content of ions or salts leads to salinity. Salinity affects root development, water stress and nutrient imbalances and some plants become stunted. The relative sensitivity levels for different EC values and their effect on plant growth are given below. Rating is based on based on FAO (USDA) classification. (FAO, 1988).

Salinity rating	**EC(µS/cm)**	**Effect on plant growth**
Non saline	0-2000	none
Slightly saline	2001-4000	sensitive plants are inhibited
Moderately saline	4001-8000	many plants are inhibited
Strongly saline	8001-16000	most cultivated plants are inhibited
Very strongly saline	> 16000	few plants are tolerant

Plant available Phosphorus measured using the modified Olsen method ranged from 3 - 131.5 mg/Kg. The P values were generally low in most of the sampling points. Total N values were moderate to high and ranged from 0.16- 0.57%. The Total C levels were moderate and ranged from 1.08 – 2.91%. The soils are texturally clay loam to sandy clay loam (Table 2). As expected the subsoil had lower values for all the soil parameters measured (Table 3).

Table 1: Chemical characteristics of the Topsoil (0-20cm) in the 15 sampling points

River	Burguret				Rongai			Naromoru			Nairobi				
Sampling point	BRS1	BFS2	BRS3	BRS4	RRS5	RFS6	RRS7	NRS8	NRS9	NRS10	NAR11	NAF12	NAR13	NAR14	NAF15
Altitude	1924	2005	1876	1816	1858	2059	1978	1834	1974	2166	2194	2119	1967	1752	1774
pH	**7.54**	6.10	6.07	6.63	6.94	5.47	6.33	6.65	6.37	6.18	**5.86**	6.22	6.38	6.88	6.77
Electrical conductivity (µS/cm)	**918**	282	272	171	566	**155**	211	267	184	273	**155**	313	176	209	506
Phosphorus (mg/kg)	13.44	44.40	9.86	13.85	6.25	49.42	7.97	7.52	37.50	4.42	2.67	**131.49**	5.88	**3.02**	10.92
Nitrogen (%)	0.20	0.18	0.24	**0.16**	0.18	0.18	0.23	0.18	0.20	**0.57**	0.52	0.20	0.22	0.17	0.23
Organic Carbon (%)	2.05	1.59	1.73	1.18	1.69	**1.08**	2.25	2.24	2.31	**2.91**	2.58	1.37	2.00	1.53	1.28

Table 2: Texture characteristics of the Topsoil (0-20cm) in the 15 sampling points

River	Burguret				Rongai			Naromoru			Nairobi				
Sampling point	**BRS1**	**BFS2**	**BRS3**	**BRS4**	**RRS5**	**RFS6**	**RRS7**	**NRS8**	**NRS9**	**NRS10**	**NAR11**	**NAF12**	**NAR13**	**NAR14**	**NAF15**
Altitude	1924	2005	1876	1816	1858	2059	1978	1834	1974	2166	2194	2119	1967	1752	1774
% Clay	35	**53**	29	32	33	39	33	19	32	27	23	28	30	28	35
% Sand	41	26	49	46	43	31	45	**57**	39	41	54	34	39	52	44
% Silt	25	21	23	22	25	30	22	24	29	32	23	38	31	20	21
Texture class	Clay loam	Clay	Sandy clay loam	Clay	Clay loam	Clay loam	Clay loam	Sandy loam	Clay loam	Clay loam	Sandy clay loam	Clay loam	Clay loam	Sandy clay loam	Clay loam

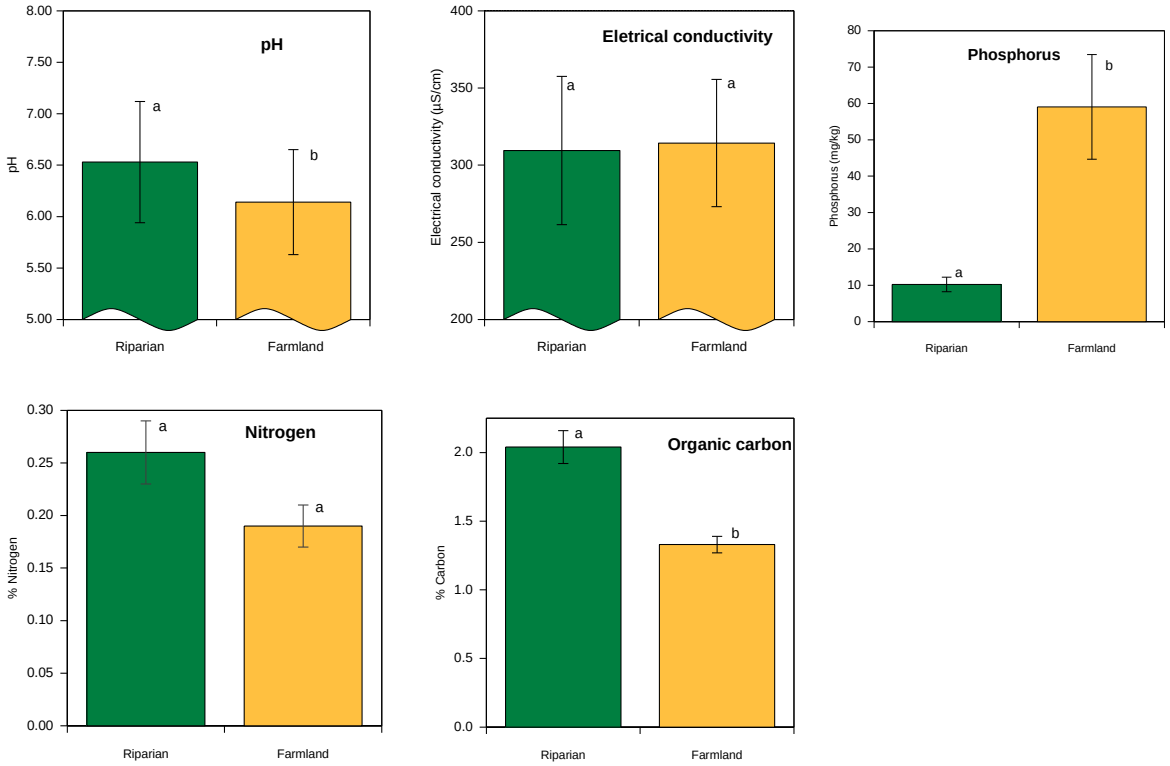
Table 3: Chemical characteristics of the subsoil (20-50cm) in the 15 sampling points

River	Burguret				Rongai			Naromoru			Nairobi				
Sampling point	BRS1	BFS2	BRS3	BRS4	RRS5	RFS6	RRS7	NRS8	NRS9	NRS10	NAR11	NAR12	NAR13	NAR14	NAR15
Altitude	1924	2005	1876	1816	1858	2059	1978	1834	1974	2166	2194	2119	1967	1752	1774
pH	**7.44**	6.37	**5.66**	6.30	6.67	5.75	6.53	6.10	7.37	5.97	6.00	6.36	6.47	6.78	6.88
Electrical conductivity (µS/cm)	**1124.00**	249.00	220.33	171.00	285.00	166.67	141.67	146.00	225.00	113.33	**94.33**	215.00	118.33	163.33	457.00
Phosphorus (mg/kg)	6.38	17.67	10.92	8.16	8.48	7.48	5.17	5.12	24.98	3.23	2.53	**91.47**	2.36	**1.00**	3.71
Nitrogen (%)	0.10	0.06	0.06	0.06	**0.02**	0.04	0.05	0.07	0.09	**0.12**	0.12	0.04	0.03	0.03	0.06
Organic Carbon (%)	1.77	0.84	1.29	1.08	**0.60**	0.67	0.87	1.20	1.28	1.49	**1.91**	1.00	0.84	0.90	0.90

4.2.1 LAND USE EFFECT ON SOIL CHEMICAL CHARACTERISTICS

A comparison was done of soil chemical parameters between the two land uses sampled i.e. riparian and farmland. Topsoil soils on the farmland were significantly different in pH, Phosphorus and Organic carbon (Figure 7). The farmland topsoils were more acidic, had less organic carbon and more phosphorus compared to the soils on the riparian areas. The same trend was observed in the subsoils.

Topsoil (0-20cm)



Subsoil (20-50 cm)

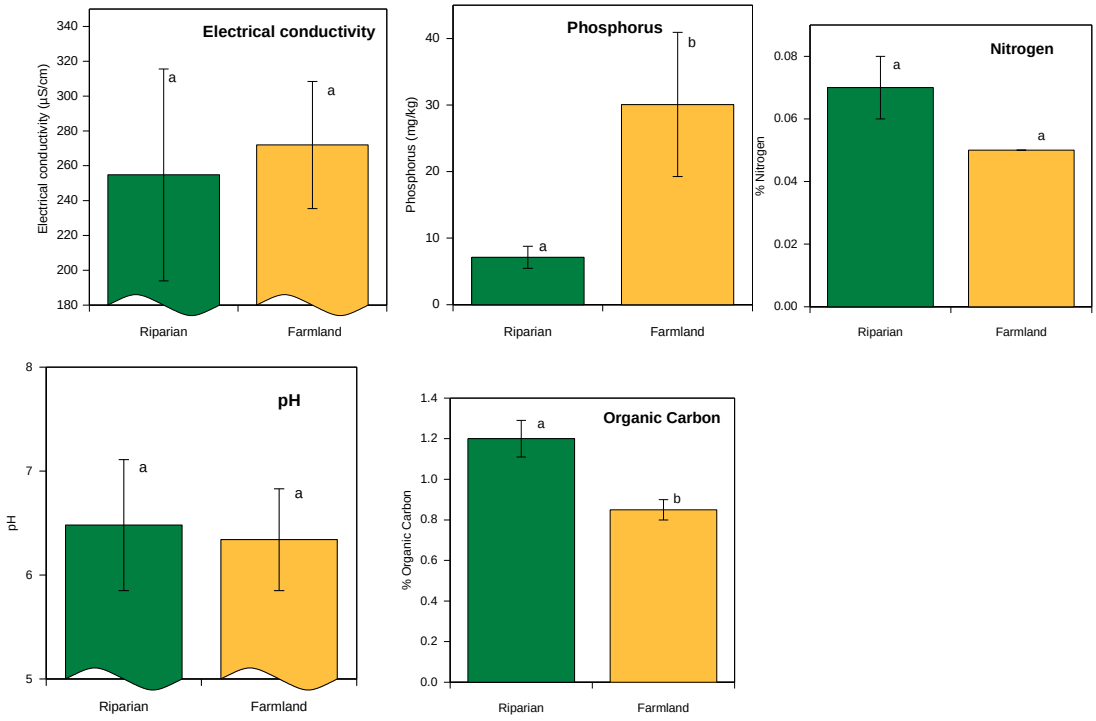


Figure 7: Comparison of chemical properties between the farmland and riparian soils

4.3 SOCIO ECONOMIC ENVIRONMENT OF THE STUDY AREA

4.3.1 LAND USE

The study area is composed of migrant population that migrated from high potential areas to settle in the former white highlands. Availability of land, which the majority bought through land buying companies, is the main factor for migration. The migration to these areas peaked in late 1970's and early 1980's and later decelerated in the 1990's (Nareda 2003).

According to field surveys, the average individual land holding is 10 acres out of which about 2.5 acres is under agricultural crops while 4.4 acres is devoted to grazing(natural and planted pastures). Cropping pattern and land use mosaic is dictated by the distribution and magnitude of the rainfall and to a large extent the emergence of irrigated agriculture within the main rivers. There are two distinct farming systems in the project area of intensive commercial farming, and subsistence farming and these practices are delineated by agro-ecological zones (Zone III and IV). The commercial farming is mainly restricted to upper zones while in the lower zone there is predominance of subsistence farming. Table 4 below show some characteristics of the respondents and the land use.

Table 4: Some characteristics of respondents in the project area

Characteristic	Mean	Standard Deviation	Minimum	Maximum
Household members	6.3	2.7	2.0	12.0
Resident years of household	25.7	14.9	4.00	50.0
Education years of Head Household	11.0	5.4	0.0	29.0
Total land area	10.0	10.8	1.0	48.0
Land under maize	1.6	1.4	0.08	5.0
Land under potatoes	0.9	0.7	0.1	2.3
Land under natural pastures	2.5	2.6	0.13	11.0
Land under planted pastures	1.7	2.1	0.3	7.0

Source: Field surveys

The key components of the land use system include homestead, agricultural land, grazing land/woodlands. Currently farmers use the upper part of their land parcel for homestead and grazing land while the lower part of the land is reserved for crop production followed by riparian forests predominantly of Eucalypts in the wetlands. Before the 1980s, the upland fields were mainly secondary forests or fallows. During 1980s -1990s, the forest land was converted to food crops. Since 2000, farmers have planted exotic trees of Cypress and Silky Oak (*Grevillea robusta*) on the uplands while Eucalypts are planted mainly on the lowlands along the river banks. This trend shows the impacts of growing scarcity of wood products and the occupation of lands due to in migration from the densely populated parts of Nyeri and Meru Counties. As the population pressure increased, there is reported clearing of indigenous vegetation and growing demand on water from the three rivers.

4.3.2 LIVELIHOODS OF THE PEOPLE

The main income sources are agriculture/livestock, sale of forest products, business and small scale enterprises (Figure 8) and most residents derive most of their livelihoods from crops and livestock and this is reflected in farming as the leading occupation for most heads of household(Figure 9).

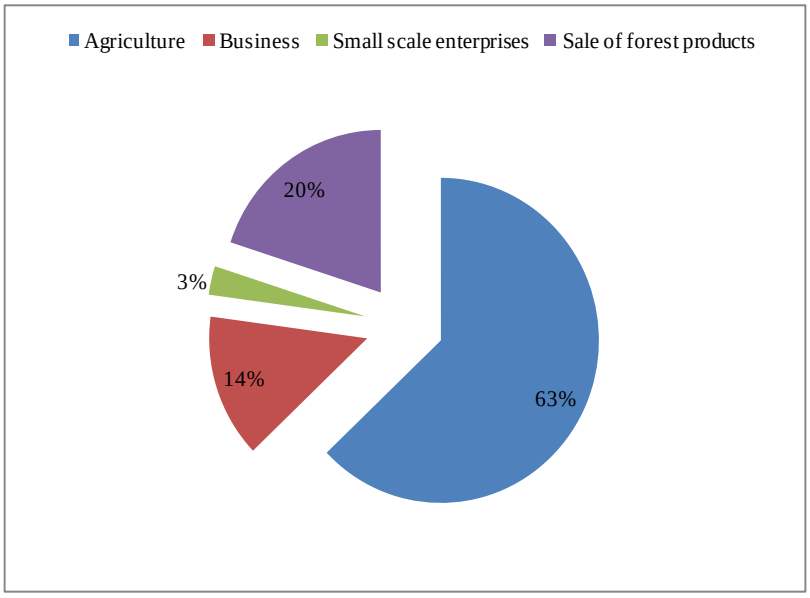


Figure 8: Sources of income of households

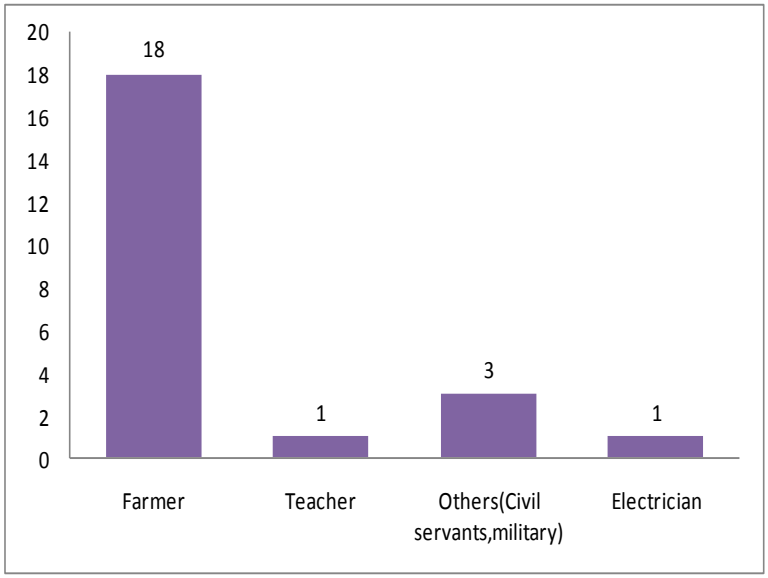


Figure 9: Main occupation of the head of household

According to the survey households in the area are considered to be medium category in terms of their wealth status (63%) while 21% and 16% are in the poor and wealthy category. Most households are mainly involved in subsistence agriculture with average land holding of about 10 acres. Upper zones of the project are receives reasonable amount of rainfall and the lower tends towards woodlands and therefore experiences low rainfall. There is overreliance on the water resources from the main rivers of Burguret, Naro Moru and Nairobi. In the lower zones, agriculture is mainly confined to riparian areas where they draw water from rivers and this source is only plentiful during wet seasons and during dry seasons, the rationing makes it unreliable source for irrigation. The riparian zones were initially marshy/wetlands and the farmers planted Eucalypts as a method of draining them for agricultural use.

Eighty seven percent of residents interviewed are married and living their spouses and less than 10% are widowed (9%) (Figure 10) and most heads of households were born in the villages (Figure 11).

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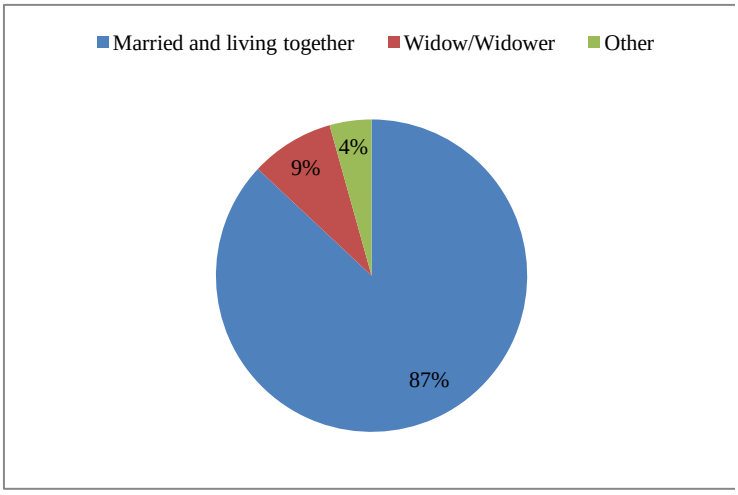

Figure 10: Marital status of the head of household

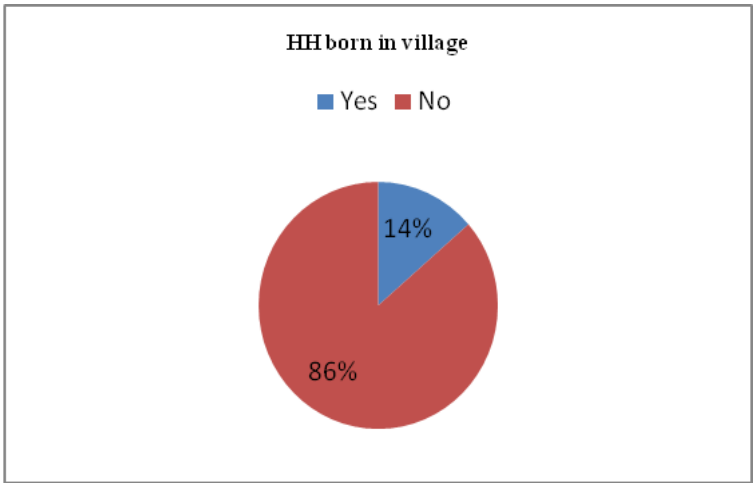

Figure 11: Proportion of households where HH was born in the village of residence

As can be drawn from the figure below, only 4% of the households interviewed are illiterate, 22 %, 30% and 44% respectively have primary, secondary and post secondary education (Fig.12).

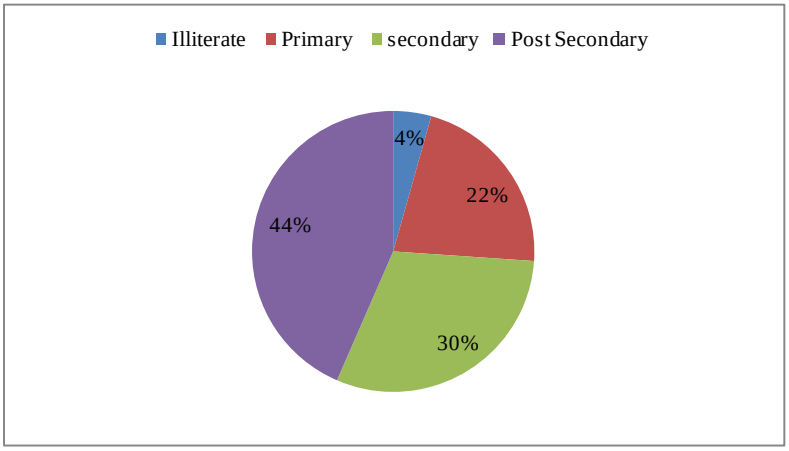

Figure.12: Level of education for head of household

Most households in the project area purchased food for own use. Only 46% can afford to sustain their food requirements from their farms and these were mainly found in upper zones. The rest of the households can survive on their food for less than six months (Figure 13).

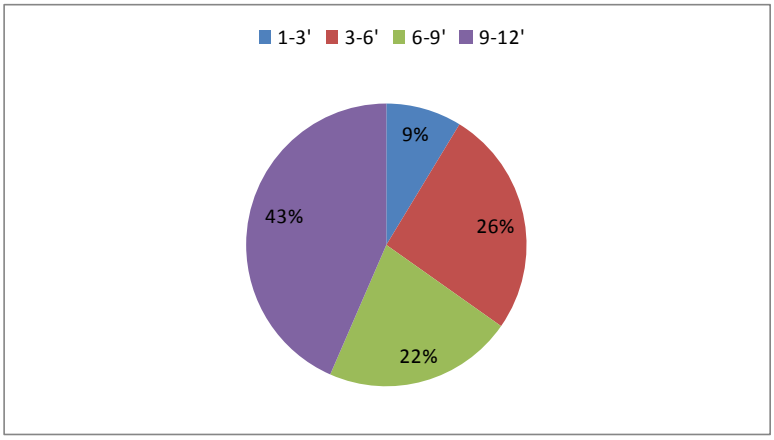

Figure 13: Food sufficiency levels in months for households

4.3.4 LOCAL PERCEPTION OF BAMBOO AND EUCALYPTS

The farmers have in the past relied on bamboo materials from the natural forests but with enhanced enforcement by KWS and KFS this source has dwindled and the farmers are enthusiastic about growing of bamboo. Ninety six percent would like to grow bamboo and are willing to set aside average of 0.5 acres for bamboo. The bamboo crop is new to the local area and only 26% of the respondents have isolated plantings of bamboo on their farms However, they have shown enthusiasm for bamboo, 96% have indicated that they wish to plant bamboo on their farms (Figure 14 & 15). The farmers have indicated that they wish to plant the bamboo in wetlands/rocky portions of their land due to availability of water (Figure 16 &17) the niches currently occupied by Eucalypts in most farms.

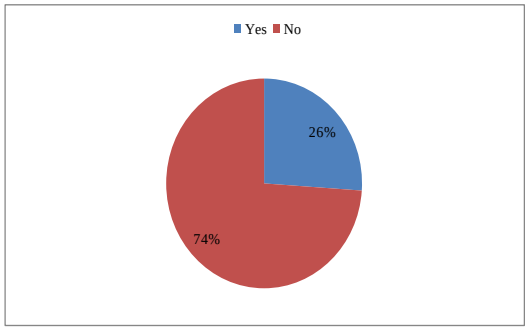

Figure 14: Do you have bamboo in your farm

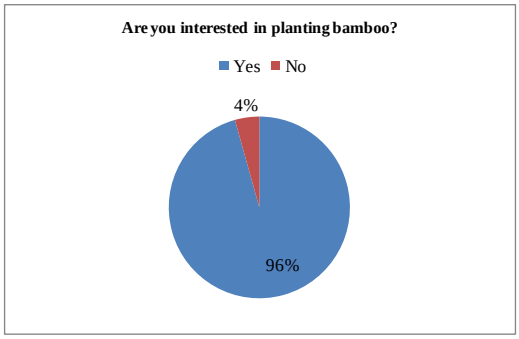

Figure 15: Are you interested in planting bamboo

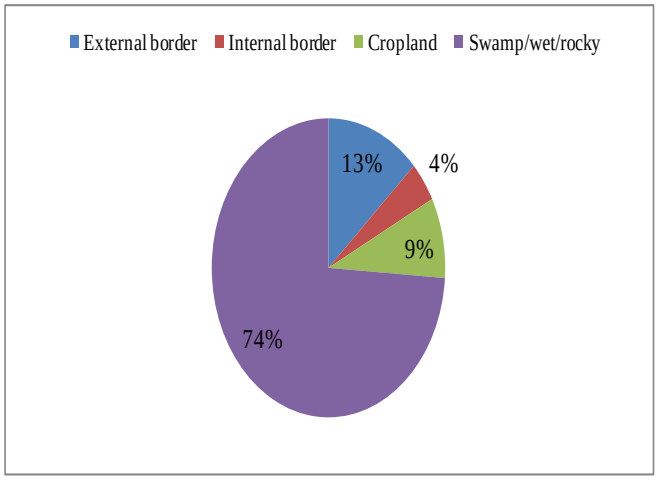

Figure 16: Proposed bamboo niches by farmers

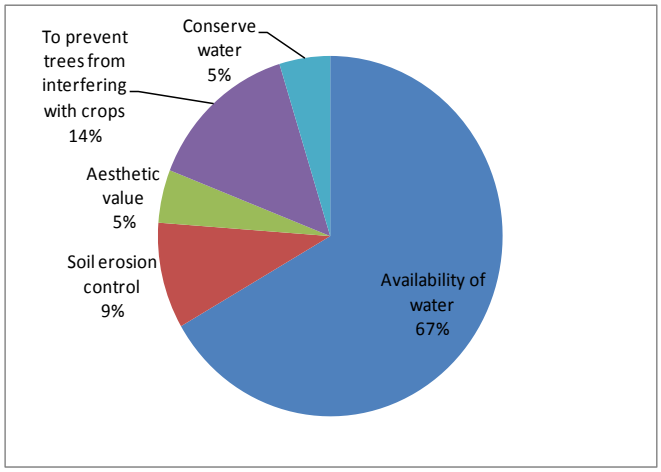

Figure 17: Reasons for selecting the planting niche

3.8.1 LOCAL OPINIONS ON THE EUCALYPTUS DEBATE

Though the farmers recognize the potential harm Eucalypts have on the environment, they still value it as important component of the farming landscape because it grow fasts and give good returns to the farmers (Figure 18-22).

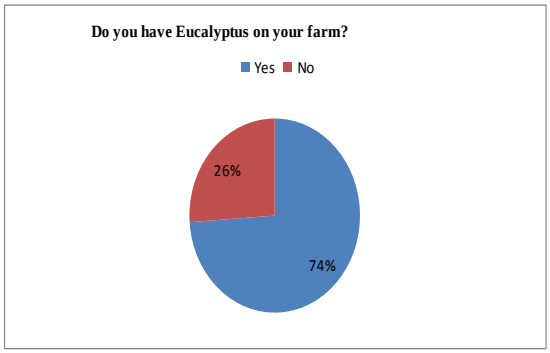

Figure 18. Presence of bamboo in individual farms

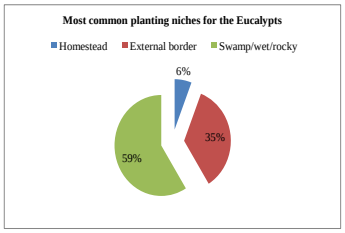

Figure 19: Eucalyptus planting niches

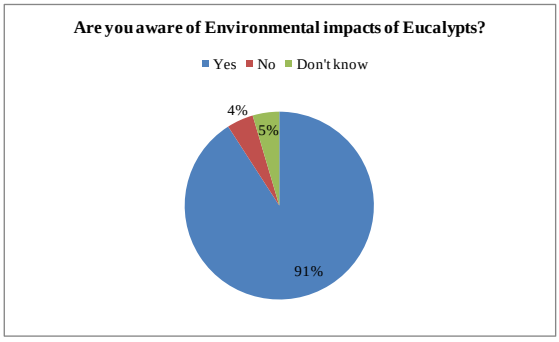

Figure 20: Awareness on environmental impacts of blue gums

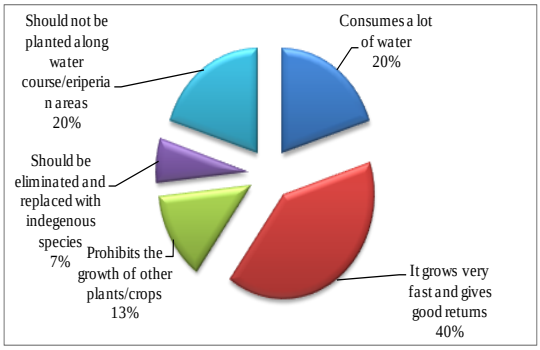

Figure 21: Reasons for planting niches

The farmers feel that bamboo can replace Eucalypts but need to be convinced on the viability of the bamboo growing (Markets and potential uses). When farmers were asked about the potential tree species to replace Eucalypts, they mentioned Cypress as the most preferred tree species, Croton, Olea spp. (Olives) and bamboo (Figure 23). The choice of species is in most cases was dictated by the likely benefits the farmer the farmers would get from the species and the best options to deploy available resources.

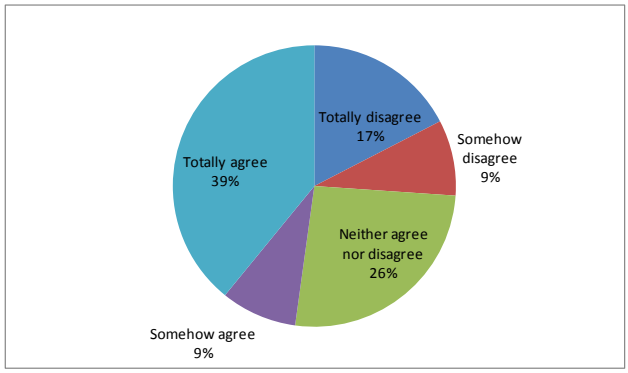

Figure 22: Level of agreement with the statement that Eucalyptus be cut and replaced with other tree species

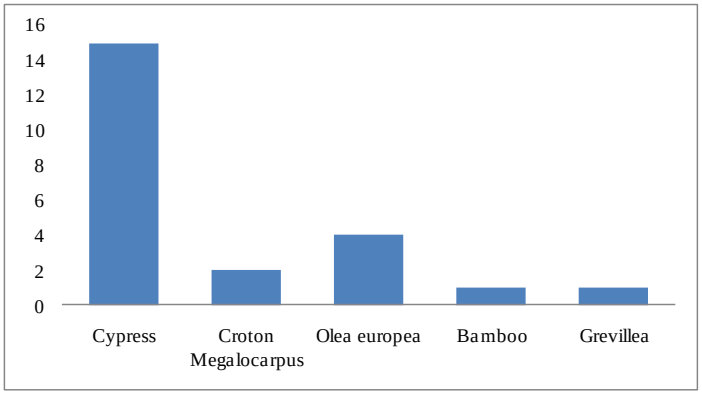

Figure 23: If eucalyptus is to be replaced, what tree species would you like to plant in your farm?

There are opportunities for intensification of production from existing stands as well as expansion of area under plantation. However, the major constraint cited is the lack of propagation materials and general lack of awareness on the potentials of bamboo as a commercial and industrial crop. There is however inadequacies in the current extension systems that do not have the resources or capacity to deliver effective support to bamboo farmers wanting to grow bamboo as a crop. The extent of bamboo planting is low due to lack of awareness on the immense potential of bamboo as industrial and commercial crop, prohibitive cost of seedlings and the lack of suitable propagation materials.

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4.4 STATUS OF BAMBOO CULTIVATION, PROCESSING AND UTILIZATION

In the project area there are scattered introduction and cultivation of bamboo species. These isolated plantings were mainly introduced out of curiosity by farmers as ornamental species and for home uses. The bamboo species encountered during the study were: *Bambusa vulgaris*, *Bambusa blumenana*, *Oxynanathera abbysinica*, *Dendrocalamus giganteus* and *Phyllostachys nigra* (Table 5).

4.4.1 BAMBOO MANAGEMENT

In the nurseries visited, there is lack of information on bamboo propagation (wrong selection of propagation materials-immature propagation materials, poor splitting technique, pest and disease attack and poor watering regime. **See Appendix 5** for best or recommended management and harvesting practices for bamboo plantation.

4.4.2 KNOWLEDGE ABOUT POTENTIALS OF BAMBOO

Most households do not know about the immense potential of bamboo as an industrial crop and this was reflected in local uses where bamboo was only used for fencing, house construction and as fodder for domestic animals during dry seasons. The methods of harvesting are wasteful and in most cases, farmers harvest young culms and destroying regeneration of new bamboo shoots. There is no value processing except for rudimentary splitting.

Table 5: Status of isolated bamboo plantings in the project area

Riparian area	Bamboo species	Year planted	Max height(M)	Clump diameter(M)	Remarks
Burguret (upper zone)	*Bambusa vulgaris*	2008	6m	3.0	Healthy clump, Planted away from riparian zone
Burguret(Middle zone)	*Bambusa blumeana*	2003	3 m	0.5	Stunted growth- Planted away from riparian zone
Burguret (Lower zone)	*Dendrocalamus giganteus*	2009	14m	2.0	Healthy clump- Planted along the river
Burguret (lower zone	*Oxytenanthera abyssinica*	1985	10m	5.0	Status- Health clump, Planted in riparian zone
Bulguret (Lower zone)	*Dendrocalamus giganteus*	May 2010	3m	0.5	Healthy plantation ,85% survival Planted in riparian zone
Burguret (lower zone)	*Bambusa vulgaris*	May 2010	1m	0.25	Status- Stunted growth, destroyed by rodents (80 seedlings planted, 15 Survived) Planted away from riparian zone
Burguret (Lower zone)	*Phyllostachys nigra*	1989	10m	4.0	Very healthy clump 3 Clumps planted on a swamp, farm outside project area but can be a good source of planting material
Kiganjo	*Bambusa vulgaris*	1980	12m	7m	Very healthy clumps- this could be a good source of planting material

There are opportunities for intensification of production from existing stands as well as expansion of area under plantation. However, the major constraint cited is the lack of propagation materials and general lack of awareness on the potentials of bamboo as a commercial and industrial crop.

The extent of bamboo planting is low due to lack of awareness on the immense potential of bamboo as industrial and commercial crop, prohibitive cost of seedlings and the lack of suitable propagation materials.

4.5 FINANCIAL ANALYSIS OF BAMBOO GROWING

Bamboo harvesting takes place after 3-4 years. This study made the assumption that a bamboo culm of 3 years is ready for harvesting. This study estimated the mean rate of harvesting as 11.477 culms per clump per year. For a farm with 200 clumps, the expected harvest per year is 2295 culms per annum. The price per culm in the study area is ranges from KShs 80 to 100. Using the most conservative price of Kshs 80 per culm, ceteris paribus, the annual revenue per acre will be KShs 183,600. This gives a net income of Kshs134480 **(Appendix 4).** But the farmers can only start harvesting bamboo three years after planting. The farmers will therefore need to get an alternative in the two years before harvesting. This study therefore proposes that another crop can be planted in the two years while bamboo grows. This is because bamboo can be intercropped with other crops. Bamboo is most attractive when judged in terms of the net income per day labour, due to its comparatively low labour input.

5.0 SYNTHESIS/DISCUSSION

5.1 CONSIDERATIONS FOR THE INTRODUCTION OF BAMBOO IN THE LANDSCAPE

There are key considerations to ensure successful introduction of bamboo in landscape and these include: identification of suitable bamboo species, suitability of soils, climatic conditions, and compatibility with current uses, acceptance by the local people, financial viability, market opportunities, legal and policy environment and the likely environmental impacts of bamboo introduction.

5.1.1 IDENTIFICATION OF SUITABLE BAMBOO SPECIES

In selecting species of bamboo for introduction, primary consideration should be given to the relative performance of the species and the products or purpose for which these are to be grown. In order to achieve the expected objectives i.e. fast growth, high quality and high yield, certain species should be selected that have adaptability and bring economic benefits and are suitable for particular environmental conditions, soil and topography. In the selection of potential species for introduction, the team analyzed the performance of isolated introduction of bamboo species in the area and those introduced and planted by KEFRI in areas with similar climatic conditions. Of the six sites where KEFRI has established bamboo trials, Muguga's altitude and climatic conditions are comparable to those of project area. Species performance in Muguga can therefore be used as a basis for selection of species for the project sites in West Mt.Kenya. In Muguga, D*. hamiltonii* showed good performance in terms of the number of culms per clump as well as in potential yield **(Appendix 6).** This is a candidate species for the upper zone of the project area which lie at a higher altitude but has excellent growing conditions and high rainfall. It should be regarded as a priority species for the production of large culms. *B. vulgaris* produces a high number of culms per clump. It showed a very good relative performance in terms of average culm weight and a high estimated potential yield per hectare. The potential yield of *D. brandisii* was the highest of the species planted in Muguga, but its relative performance in terms of height was low. It was observed that *B. vulgaris and Dendrocalamus giganteus* grows well in Upper and lower Burguret and therefore this species should be one of the main species in plantations recommended to be introduced in the area. If the purpose of the plantation is to obtain the highest culm yield in terms of tons per ha, then the selection of species to be recommended are D. brandisii followed by *D. hamiltonii*. However, these are merely provisionally recommended species. Culm yield, weight, and height are not the only criteria for selecting species for a bamboo plantation. It is essential to have a market/ product focus for selection of suitable bamboo species. Though some species may produce lower yield per hectare but have desirable characteristics such as ease of splitting and

therefore suited for such uses as, weaving and basketry, toothpicks and handicraft production which may have a ready market. Bamboo species such as; *B.tulda* , *B. vulgaris* , *Dendrocalamus giganteus* have a high potential in this regard. In conclusion, *B. vulgaris* , *Dendrocalamus giganteus*, *D.hamilitonii*, *D.brandisii*, *and B.tulda* are provisionally recommended species introduction in the project area. A more refined list of species for the area can be updated after establishment of demonstration trials.

5.1.2 IDENTIFICATION OF SUITABLE SITES FOR BAMBOO INTRODUCTION

Some riparian areas had a high diversity of indigenous plants with some species being Kenyan endemics. The moist environment and the rich alluvial soils on the riaparian areas contributed to the high plant diversity. The riparian areas thus serve as refugia for plant biodiversity and should not be cleared but should be protected and conserved. However, some areas on the riparian areas are highly degraded either because the indigenous vegetation has been cleared to pave way for farmland or they are used as watering points for cattle. Such areas need to be rehabilitated by introducing bamboo cultivation. Identification and mapping of the actual sites for bamboo cultivation should done.

5.1.3 SOIL TYPES AND SUITABILITY FOR BAMBOO GROWING

Most bamboo species have dense, shallow root systems which play an important role of absorption of water and nutrients from the soil. The root system of bamboo forms a thick root mat with many fine roots and root hairs within the uppermost soil layer with a few roots extending below 40 cm depth. The fine roots and root hairs of the bamboo root system play a significant role in supporting high productivity. Soil should be heaped around the developing clump to allow and ease shoot production, which take place mainly on the periphery of the clump.

Soil physical properties

Bamboo is known to grow in “poor’’ soil and is therefore used for rehabilitation of degraded areas. Bamboo productivity is influenced by soil physical factors which include slope, texture, bulk density, moisture holding capacity and temperature. Most bamboo species grow optimally in silty soils as compared to sandy or clay soils. Heavy clay soils are less suitable for bamboo production since they have high bulk density which restricts rhizome (and root) growth. Sandy soils on the other hand have less water holding capacity and therefore are not suitable for bamboo growth since bamboo require a high amount of water for growth. Soil physical properties can however be improved through tillage and

mulching. Application of mulches in bamboo stands protects rhizomes, roots and new shoots from excessive warm or cold temperatures and from solar radiation. Most of the sampled areas in the study area had clay loam soils indicating **that they need to be improved either through tillage or mulching for bamboo cultivation.**

Soil Chemical properties

Soil pH, salinity and nutrient availability are important soil chemical properties governing bamboo growth and yield. Bamboos thrive best under moderately acidic to neutral soils. However they can also survive in acid or low pH making them suitable for cultivation in degraded area. Most bamboo species are sensitive to salinity and do not tolerate saline soil conditions. The soil pH and salinity levels recorded in western Mt. Kenya are suitable for bamboo cultivation. The primary source of nutrients is soil organic matter. The Carbon and Nitrogen levels in the study area were moderate to high indicating the soils are moderately fertile and the soils may not require fertilizer addition for bamboo cultivation. Soils in the farmland had extremely high levels of Phosphorus possibly due to addition on fertilizer during cultivation. It is not clear whether the high Phosphorus levels might have a detrimental effect on bamboo growth. Soil in the farmland are less fertile as shown by the low carbon content, fertilizer addition and mulching might be required on the farmland before bamboo cultivation.

5.1.4 WATER

Bamboo growth requires high water availability especially during the shoot and culm growth phase. Precipitation therefore affects distribution and limits growth of bamboo more than any other component of climate, except temperature (Biswas, 1988). The project area in western Mt. Kenya lies within the leeward side of Mt. Kenya and therefore experience less rainfall. In recent past there has been a prolonged drought and weather pattern has tended to be unpredictable. This is likely to affect bamboo cultivation negatively. Drought during the shoot phase is likely to have detrimental effects on bamboo growth**. Irrigation might be necessary for intensively managed shoot stands after 10 days without rainfall during the shoot season.** It has been found that water logging negatively affects the survival and growth of bamboo cuttings, particularly the giant species (Kibwage et al., 2008) and therefore bamboo is not recommended in waterlogged / marshy areas.

5.2 LOCAL ACCEPTANCE OF BAMBOO

The farmers feel that bamboo can replace Eucalypts but need to be convinced on the viability of the bamboo growing. Ninety six percent are willing plant bamboo on their farms. There is therefore convincing reasons for the introduction of bamboo with interested farmers.

5.3 FINANCIAL VIABILITY

Based on the financial analysis, bamboo growing can be a profitable enterprise. Perhaps the greatest barrier to the expansion of bamboo cultivation is the transition from short cycle annual crops (e.g. maize, Kales and potatoes) to a perennial crop that does not provide income for the first 3-5 years and uncertainty about future demand and prices for bamboo. **Inter-cropping** with annual crops such as Kales, Maize and beans in earlier years reduce some of the costs of transition and encourage uptake of bamboo growing.

5.4 MARKET OUTLOOK FOR BAMBOO PRODUCTS

There are number horticultural industries within Mt. Kenya region. The floriculture industry uses a lot woody material as support for flowers and snow peas. The demand for bamboo culms in region is high and is expected to grow as more companies venture into horticulture. For example, the James Findlay flower farm in Timau consumes between 160 and 200 tonnes per year. At the moment most bamboo products used in the sector are sourced from distant places and are from unsustainable sources mainly through illegal extraction from public forests in Mt.Kenya and Aberdares.

In addition, the growing of bamboo will stimulate the growth of the other small scale cottage industries involved in secondary processing like the making of tooth picks, furniture; handicraft can provide additional markets for bamboo. Most of the toothpicks used in the country are mainly imported are mainly sourced from China, (72%), India (26%) and Thailand (2%)(Kibwage et al 2008) and therefore the introduction of bamboo and promotion of processing will increase domestic supply of high quality bamboo products

5.5 POLICY AND LEGISLATIVE ENVIRONMENT

While there is a growing interest in bamboo at a national level on the potential role bamboo can play in economic and rural development. There is therefore an opportunity for the project to build on these positives changes to develop a local strategy for bamboo growing and processing at the county level.

The government through favorable policies is giving emphasis to farm forestry (the Economic Recovery strategy for wealth and employment creation paper (2003), new forest policy encourages farm forestry and Forest Act 2005) and market based pricing –the proposed forest policy intends to entrench forest products trade liberalization and promotes value addition in forest products. The introduction of bamboo is opportune because it is also coming at the time when the Agriculture subsidiary legislation which requires farmers to at least have 10% tree cover on their farms is emphasized. The continued ban on harvesting of indigenous bamboo provides a big potential market for bamboo planted on private lands. Moreover, the recent concern by NEMA, WRMA and other stakeholders of the potential negative impacts of Eucalypts on wetlands provides a window of opportunity for bamboo growing in riparian areas for rehabilitation of degraded areas in addition to being a good source of income to the farmers.

Other opportunities are in increasing to use bamboo for energy, microenterprise development. There are efforts currently being undertaken by government and partners to promote growing and value addition of bamboo resources. In addition, Cabinet paper has been developed to guide the development of bamboo sub-sector in the country.

5.6 BAMBOO AND THE ENVIRONMENT-IMPACTS ON THE SOIL, WATER AND BIODIVERSITY

There are two main environmental considerations when it comes to introduction and intensive growing of bamboo in plantations:

1. *Does the cultivation and harvesting of bamboo have discernable positive or negative on the environmental impacts?*
2. *What are the main environmental impacts of the different processing industries?*

The most important concern at the project inception is on the potential impacts of bamboo introduction and harvesting on the environment. The other aspects on processing will be of relevance in later in the project cycle.

Bamboo is widely regarded as an attractive crop from an environmental perspective. The main environmental benefits of bamboo include:

Bamboo is a sustainable cropping system for sloping lands, reducing soil erosion, and delivering sustainable yields over the longer term. Therefore increased land allocated for bamboo production rather than annual crops will therefore have important environmental benefits in the local area.

Bamboo is a suitable crop as part of the recovery of degraded lands and is the fastest growing canopy in such situations;

1. Through a combination of root structure, canopy and dense litter, bamboo reduces rain run-off and retains much water in the watershed. As well as reducing erosion, the reduction in peak run-off rates and extended period over which run-off occurs reduces the risk of flash floods in downstream areas.
2. Bamboo's rapid growth rate and selective harvesting means that it can sequester up to 12 tonnes of Carbon dioxide per hectare depending on species, density and harvesting patterns. There is therefore an opportunity for farmers to enter into carbon markets in future (Hunter and Wu 2002)

When compared to natural forests, the main environmental risk from bamboo is through the development of mono-cultures if large areas of land are converted to single species bamboo plantations. This can reduce biodiversity in the local area compared to mixed forest cover. The introduction of small scale planting in the area may not be a source of major concern because the plantings will be scattered within individual farms and will be integrated in the wider farming landscape.

5.6.1 WIDER ENVIRONMENTAL IMPACT

The wider environmental impact is primarily driven by the extent to which bamboo products are used as a substitute for hardwood and slow growing timber. Greater use of bamboo as an alternative to hardwoods would contribute easing pressure on the natural forests and hence slowing in the depletion of natural forests, with corresponding benefits to biodiversity, conservation and carbon sequestration.

5.7 RISK ANALYSIS

There are risks associated with forest investments and the most important risks for bamboo plantations are poor growth, biological, physical and management risks.

5.7.1 POOR GROWTH

Poor climatic conditions could affect the bamboo growth and delay harvesting. This could be due to poor fertility in some areas/ poor establishment methods (spacing or poor site-species matching) or poor protection and care. It is therefore important to use the best practices available from KEFRI to ensure this level of risks is minimized.

5.7.2 BIOLOGICAL RISKS

Risks to the forest plantation exist from pest and diseases. Since introduction, Bamboo has not suffered major cases of pest and diseases outbreaks. However, there are risks of pests and diseases, which the farmers and other development promoters should take cognizance so as to adequately prepare for any eventuality. Though, the attacks on bamboo have not been reported in the Kenya, it is important to be aware of this potential threat and its likely impacts on productivity of Bamboo. This is more so for new introductions in new areas where the species have not develop coping mechanisms.

5.7.3 PHYSICAL DAMAGE

The physical risks include fire, droughts. Fire is anticipated to be major risks especially during the dry period from December to February and the following precautionary steps are recommended:

1. Do not burn agricultural wastes or debris near the bamboo and clear as much as possible the ground vegetation to reduce fuels.
2. Maintain close links with neighbors to jointly reduce fire risks.

5.7.4 ENVIRONMENTAL DAMAGE

Bamboo growing may not represent a major risk to the environment but may do when it comes to processing. The main environmental risk from bamboo is through the development of mono-cultures if large areas of land are converted to single species bamboo plantations. This can reduce biodiversity in the local area compared to mixed forest cover. Bamboo introductions in the area will not pose a major risk because, the species will be introduced to existing landscape and massive creation of huge plantations are not anticipated except small plantings on individual farms.

5.7.5: HUMAN WILD LIFE CONFLICTS

Young bamboo leaves and twigs are a favorite meal for elephants and therefore in areas bordering the forest without electric fences are likely to face persistent incursion by the elephants. Though farmers are optimistic that elephant menace is currently under control, there is high possibility of increased human/wildlife conflicts when there is acute shortage of forage in natural forests of Mt.Kenya.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

There is acceptance among the community that Bamboo is the best alternative to Eucalyptus because of its faster maturity and potential diversified uses. Bamboo is the most suitable replacement of Eucalypts along riparian areas. This assertion is supported by the fact that during the EIA processes bamboo was supported as an alternative to Eucalypts in the riparian areas. There is also a feeling that some high value trees suitable for the area should be incorporated into farming systems and in rehabilitation of degraded riparian areas. The soils and climatic and other conditions favour the growing of bamboo in the project area and therefore recommended for introduction.

There is opportunity to increase tree cover and introduce bamboo species because of the new Agriculture Policy of 10 % tree cover on farms to rehabilitate degraded riparian and conserve catchment areas. Trees such as Cypress, indigenous trees have been proposed by farmers in addition to bamboo. The Eucalypts are currently playing critical role in the livelihoods in terms of provision of wood products for domestic needs and for cash income. This reality should be taken into consideration in designing a viable exit strategy for Eucalypts from the farms. Replacement of *Eucalyptus* stands with bamboo on-farm should be done gradually since farmers need first to be convinced about the economic value of bamboo cultivation and the likely disruptive events of massive clearance on forest products supply, local livelihoods and short term local ecological consequences.

The introduction of bamboo is likely to have positive impacts on the livelihoods through the value addition and positive influence on the agricultural production.

The utilization of bamboo in the area is replete with wasteful harvesting and utilization because the uses are mainly for constructions and fencing and there is hardly any value addition. There is limited knowledge on the diversified uses of bamboo and this has limited perception of bamboo as an important crop.

Based on the field observations, key informant discussions and appraisal of performance of the exotic bamboo species in Kenya-two potential species are recommended for exploration. These are *Bambusa vulgaris* and *Dendrocalamus giganteus (Giant bamboo).*The other potential species *are : D.hamilitonii, D.brandisii*, *and B.Tulda*

6.2 RECOMMENDATIONS

Arising from the study findings, the following recommendations are proposed in order to develop the bamboo farming in West Mt. Kenya region: Development of on-farm bamboo farming can be achieved through introducing bamboo growing by farmers who have shown enthusiasm and recruiting other people interested in growing bamboo. When more farmers start growing bamboo on their own land, supply of raw materials will increase and additionally, there will be reduction on encroachment on the protected areas thus reducing environmental threats and increasing environmental rehabilitation.

1. Bamboo should only be introduced in the degraded riparian zones. The intact zones should not be cleared for bamboo cultivation since they harbour a rich diversity of plants and act as refuge for biodiversity. This means that the degraded riparian zones in the four rivers should be properly identified and mapped before the rehabilitation exercise. The project should adapt the principle of conserving the existing biodiversity while planting along the riparian zones'.

2. There is need to create awareness on bamboo farming among different stakeholders through seminars and workshops on bamboo growing. There is need to train project staff on bamboo propagation, management, processing and value addition. This approach will inspire confidence in the farmers in the region to promote bamboo as alternative crop and these campaign and promotions should be based on sound technical knowledge. KEFRI is willing to provide the leadership in provision of technical materials and resource persons for such a sensitization and promotion (awareness and campaign); There is more need to sensitise the officials of CBOs involved in the project areas

3. Increasing availability of planting material to the farmers through strong linkage and technical support from KEFRI

4. Improvement of bamboo production and processing technologies. This can be achieved through training in propagation, management, harvesting, and processing and value addition to ensure sustainability. There is need to develop capacity of the local community/farmers to undertake secondary processing and that acquisition of skills should be targeted in consonance with uptake of bamboo materials.

5. In the initial phase of bamboo introduction, we recommend that proactive engagement with potential consumers such as Flower and Horticultural industries be initiated to guarantee farmers of market for bamboo produce while other opportunities are explored. The possibility of contract farming should be explored.

6. Creation and strengthening of bamboo farmer groups and associations. This could be achieved by organizing exposure visits for bamboo producers/ actors to bamboo processing industries locally and may be organize study tours to countries such as China to open their horizons in new innovations and business ideas and product development.

7. In order to inspire local confidence of the local farmers on the potential of bamboo resources we are proposing that KEFRI/PACT KENYA with support of other partners establish Bamboo demonstration plots in the region.

8. Provision of enterprise development support services to farmer groups and associations. These services include market information, input supplies, and skills development and supply chain arrangements.

9. Establishment of a small scale workshop and a show room for bamboo handicrafts at the project office and possibly open an out let in Nanyuki town. This will increase demand for the bamboo products

10. There is need to in cooperate other high value indigenous trees in the rehabilitation of the riparian areas to avoid bamboo monoculture

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APPENDICES

APPENDIX 1: KEY INFORMANTS INTERVIEWED

1. Mr. Edwin Mwango -District Agricultural Officer
   Kieni East District
2. Mr. George -Everest Enterprise Limited Manager
3. Mr. Paul Maina -Help Self Help Center Field Co-Ordinator
4. Mrs. Jenipher Maina-Forest Extension Officer Kieni East
5. Mrs. Easter Riberia -Ewaso Ngiro North Development Authority Regional Co-Ordinator
6. Mrs. Anastacia Wanjiru Njukia-Thirigitu Mt. Kenya Conservation Network Chairperson
7. Mr. Mugambi Muthinja -Water Resource Management Authority ; Water Rights Officer And Assistant Sub-Regional Officer
8. Mr. Paul Salim-Production Manager –Siraji Farm-James Findlay
9. Mr. John Karimi- Assistant Production Manager- Siraji Farm-James Findlay

APPENDIX 2: ORGANISATIONS INVOLVED IN THE FOCUS GROUP DISCUSSION

- ✓ Nature Kenya
- ✓ MT. KENYA BURGURET CONSERVATION FORUM
- ✓ KFS
- ✓ MKBCF
- ✓ KEFRI
- ✓ WRMA
- ✓ CFA
- ✓ DLPO (Ministry of Livestock)
- ✓ BRWUAT

APPENDIX 3: PLANT CHECKLIST OF SPECIES ENCOUNTERED ALONG THE FOUR RIVERS

		Sampled River				
Family	***Species name***	**Burguret**	**Rongai**	**Naromoru**	**Nairobi**	**Endemism**
Acanthaceae	*Crabbea velutina S.Moore*				1	
Acanthaceae	*Hypoestes aristata (Vahl) Roem. & Schult.*			1		
Acanthaceae	*Hypoestes forskahlii (Vahl) R.Br.*	1				
Acanthaceae	*Thunbergia alata Bojer ex Sims*	1	1	1	1	
Aloaceae	*Aloe kedongensis Reynolds*			1		1
Amaranthaceae	*Achyranthes aspera L.*	1	1	1	1	
Amaranthaceae	*Aerva lanata (L.) Juss*		1		1	
Amaranthaceae	*Amaranthus graecizans L.*	1	1		1	
Amaranthaceae	*Amaranthus hybridus L.*	1				
Amaranthaceae	*Cyathula cylindrica Moq.*				1	
Amaryllidaceae	*Scadoxus multiflorus (Martyn) Raf.*			1		
Anacardiaceae	*Rhus natalensis Krauss*	1	1	1	1	
Apocynaceae	*Acokanthera schimperi (A.DC.) Schweinf.*	1	1		1	
Apocynaceae	*Carissa edulis (Forssk.) Vahl*		1	1	1	
Apocynaceae	*Landolphia buchananii (Hallier f.) Stapf*			1		
Apocynaceae	*Saba comorensis (Bojer) Pichon*				1	
Araliaceae	*Cussonia holstii Engl.*			1	1	
Asclepiadaceae	*Periploca linearifolia Quart.-Dill. & A.Rich.*		1	1	1	
Asclepiadaceae	*Secamone parvifolia (Oliv.) Bullock*			1	1	
Asparagaceae	*Asparagus africanus Lam.*		1	1	1	
Asparagaceae	*Asparagus racemosus Walld.*		1			
Asparagaceae	*Asparagus setaceus (Kunth) Jessop*	1	1	1	1	
Basellaceae	*Basella alba L.*	1				
Bignoniaceae	*Jacaranda mimosifolia D.Don*	1		1		
Bignoniaceae	*Markhamia lutea (Benth.)K.Schum.*	1				
Boraginaceae	*Cordia africana Lam.*	1		1		
Cactaceae	*Opuntia sp.*		1		1	
Canellaceae	*Warburgia ugandensis Sprague*		1			
Capparaceae	*Boscia angustifolia A.Rich.*		1			
Capparaceae	*Capparis fascicularis DC.*		1			
Capparaceae	*Capparis tomentosa Lam.*		1	1		
Capparaceae	*Maerua calantha Gilg*	1	1	1	1	
Capparaceae	*Maerua triphylla A.Rich.*			1		
Casuarinaceae	*Casuarina sp.*	1				
Celastraceae	*Elaeodendron buchananii (Loes.) Loes.*		1	1		
Celastraceae	*Loeseneriella africana*	1				
Celastraceae	*Maytenus senegalensis (Lam.) Exell*	1	1	1	1	
Celastraceae	*Mystroxylon aethiopicum (Thunb.)*			1		

	Loes.					
Chenopodiaceae	*Atriplex semibaccata R.Br.*	1				
Chenopodiaceae	*Chenopodium murale L.*	1	1		1	
Commelinaceae	*Commelina africana L.*	1	1	1	1	
Compositae	*Ageratum conyzoides L.*				1	
Compositae	*Aspilia mossambicensis (Oliv.) Wild*	1	1	1	1	
Compositae	*Bidens pilosa L.*	1	1		1	
Compositae	*Carduus chamaecephalus (Vatke) Oliv. & Hiern*		1			
Compositae	*Conyza aegyptiaca (L.) Ait*	1				
Compositae	*Conyza bonariensis (L.) Cronquist*	1	1	1	1	
Compositae	*Conyza subscaposa O.Hoffm.*		1			
Compositae	*Conyza sumatrensis (Retz.) E.H.Walker*	1		1		
Compositae	*Dichrocephala integrifolia (L.f.) Kuntze*			1	1	
Compositae	*Ethulia vernonioides (Schweinf.) M.G.Gilbert*			1		
Compositae	*Galinsoga parviflora Cav.*	1	1		1	
Compositae	*Helichrysum forskahlii (J.F.Gmel.) Hilliard &Burtt*				1	
Compositae	*Melanthera scandens (Schumach. & Thonn.) Brenan*	1			1	
Compositae	*Notonia petraea R.E Fries*		1			
Compositae	*Osteospermum vaillantii (Decne.) Norl.*	1				
Compositae	*Psiadia punctulata (DC.) Vatke*	1	1	1	1	
Compositae	*Schkuhria pinnata (Lam.) Kuntze*	1	1		1	
Compositae	*Senecio hadiensis Forsk.*	1				
Compositae	*Senecio mesogrammoides O.Hoffm.*		1			
Compositae	*Solanecio mannii (Hook.f.) C.Jeffrey*		1		1	
Compositae	*Sonchus oleraceus L.*	1			1	
Compositae	*Sphaeranthus suaveolens (Forsk.) DC.*		1		1	
Compositae	*Tagetes minuta L.*	1	1	1	1	
Compositae	*Tithonia diversifolia (Hemsl.) A.Gray*			1	1	
Compositae	*Vernonia galamensis (Cass.) Less.*		1	1	1	1
Compositae	*Vernonia lasiopus O.Hoffm.*	1		1	1	
Convolvulaceae	*Dichondra repens J.R.Forst. & G.Forst.*	1		1	1	
Convolvulaceae	*Ipomoea batatas (L.) Lam.*	1				
Convolvulaceae	*Ipomoea cairica (L.) Sweet*	1				
Convolvulaceae	*Ipomoea wightii (Wall.) Choisy*				1	
Crassulaceae	*Kalanchoe densiflora Rolfe*	1	1	1	1	
Cruciferae	*Erucastrum arabicum Fisch. & C.A.Mey.*	1				
Cruciferae	*Erucastrum arabicum Fisch. & C.A.Mey.*	1				
Cucurbitaceae	*Cucumis sp.*				1	
Cucurbitaceae	*Lagenaria abyssinica (Hook.f.) C.Jeffrey*	1	1		1	

Cucurbitaceae	*Zehneria scabra (L.f.) Sond.*	1	1	1		
Dracaenaceae	*Dracaena laxissima Engl.*				1	
Ebenaceae	*Euclea divinorum Hiern*	1	1	1	1	
Euphorbiaceae	*Acalypha fruticosa Forssk.*		1		1	
Euphorbiaceae	*Clutia abyssinica Jaub. & Spach*		1	1		
Euphorbiaceae	*Croton megalocarpus Hutch.*	1	1	1	1	
Euphorbiaceae	*Erythrococca bongensis Pax*	1	1	1	1	
Euphorbiaceae	*Euphorbia candelabrum Kotschy*			1	1	
Euphorbiaceae	*Euphorbia tirucalli L.*	1	1			
Euphorbiaceae	*Ricinus communis L.*	1		1	1	
Euphorbiaceae	*Tragia brevipes Pax*	1	1			
Flacourtiaceae	*Dovyalis abyssinica (A.Rich.) Warb.*	1		1	1	
Flacourtiaceae	*Dovyalis caffra Warb.*	1	1	1	1	
Flacourtiaceae	*Trimeria grandifolia (Hochst.) Warb*		1	1	1	
Gesneriaceae	*Streptocarpus caulescens Vatke*			1		
Gramineae	*Aristida kenyensis Henr.*			1		
Gramineae	*Bothriochloa insculpta (A.Rich.) A.Camus*				1	
Gramineae	*Chloris gayana Kunth*		1		1	
Gramineae	*Cynodon sp.*	1			1	
Gramineae	*Eragrostis sp*		1			
Gramineae	*Eragrostis superba Peyr.*	1				
Gramineae	*Harpachne schimperi A.Rich.*		1			
Gramineae	*Pennisetum clandestinum Chiov.*		1		1	
Gramineae	*Setaria incrassata (Hochst.) Hack.*	1				
Gramineae	*Setaria plicatilis (Hochst.) Engl.*	1	1	1		
Gramineae	*Setaria sp.*	1			1	
Gramineae	*Themeda triandra Forssk.*				1	
Guttiferae	*Hypericum revolutum Vahl*				1	
Hamamelidaceae	*Trichocladus ellipticus Eckl. & Zeyh.*	1	1	1	1	
Labiatae	*Ajuga remota Benth.*	1	1		1	
Labiatae	*Fuerstia africana T.C.E. Fries*		1	1	1	
Labiatae	*Leonotis mollissima G• rke*	1				
Labiatae	*Leonotis nepetifolia (L.) R.Br.*	1	1	1	1	
Labiatae	*Leucas glabrata (Vahl) R.Br.*				1	
Labiatae	*Leucas grandis Vatke*				1	
Labiatae	*Leucas tomentosa Gürke*			1		
Labiatae	*Nepeta azurea Benth.*		1			
Labiatae	*Ocimum basilicum L.*				1	
Labiatae	*Ocimum gratissimum Forssk.*				1	
Labiatae	*Ocimum kilimandscharicum Gürke*			1		
Labiatae	*Plectranthus barbatus Sims*				1	
Labiatae	*Plectranthus pseudomarrubioides R.H.Willemse*				1	
Labiatae	*Pycnostachys meyeri Gürke*				1	
Lauraceae	*Persea americana Mill.*	1				
Leguminosae	*Acacia mearnsii De Wild.*	1	1		1	
Leguminosae	*Acacia nilotica (L.) Willd. ex Delile*			1		
Leguminosae	*Acacia xanthophloea Benth.*	1	1	1	1	
Leguminosae	*Albizia gummifera (J.F.Gmel.) C.A.Sm.*	1		1	1	

Leguminosae	*Amphicarpa africana (Hook.f.) Harms*				1	
Leguminosae	*Cassia didymobotrya Fresen.*	1			1	
Leguminosae	*Crotalaria incana L.*				1	
Leguminosae	*Crotalaria lebrunii Baker f.*				1	
Leguminosae	*Dalbergia lactea Vatke*		1			
Leguminosae	*Erythrina abyssinica DC.*	1		1		
Leguminosae	*Indigofera swaziensis Bolus*		1	1		
Leguminosae	*Kotschya africana Endl.*				1	
Leguminosae	*Newtonia buchananii (Baker) G.C.C.Gilbert & Boutique*				1	
Leguminosae	*Pterolobium stellatum (Forssk.) Brenan*		1	1	1	
Leguminosae	*Rhynchosia minima (L.) DC.*	1				
Leguminosae	*Rhynchosia sp.*	1				
Leguminosae	*Sesbania keniensis Gillett*	1			1	
Leguminosae	*Sesbania sesban (L.) Merr.*	1				
Leguminosae	*Trifolium usambarense Taub.*		1	1	1	
Loranthaceae	*Erianthemum dregei (Eckl. & Zeyh.) Tiegh.*			1		
Malvaceae	*Abutilon mauritianum (Jacq.) Sweet*				1	
Malvaceae	*Hibiscus diversifolius Jacq.*		1	1		
Malvaceae	*Hibiscus fuscus Garcke*				1	1
Malvaceae	*Malva parviflora L.*	1	1		1	
Malvaceae	*Pavonia patens (Andr.) Chiov.*	1	1	1	1	
Malvaceae	*Sida acuta Burm.f.*	1				
Malvaceae	*Sida massaica Vollesen*	1	1	1	1	
Malvaceae	*Sida rhombifolia L.*	1				
Meliaceae	*Trichilia emetica Vahl*			1	1	
Melianthaceae	*Bersama abyssinica Fresen.*			1		
Menispermaceae	*Cissampelos mucronata A. Rich.*	1				
Menispermaceae	*Cissampelos pareira L.*	1				
Moraceae	*Ficus thonningii Blume*	1		1	1	
Myrsinaceae	*Maesa lanceolata Forssk.*	1	1	1	1	
Myrsinaceae	*Rapanea melanophloeos (L.) Mez*			1	1	
Myrtaceae	*Eucalyptus saligna Sm.*	1	1			
Myrtaceae	*Syzygium cordatum Hochst.*		1	1		
Myrtaceae	*Syzygium guineense (Willd.) DC.*	1	1	1	1	
Ochnaceae	*Ochna holstii Engl.*			1		
Ochnaceae	*Ochna kirkii Oliv.*			1		
Ochnaceae	*Ochna thomasiana Engl. & Gilg ex Engl.*	1				
Oleaceae	*Olea europaea*	1		1	1	
Oliniaceae	*Olinia rochetiana A.Juss.*				1	
Orobanchaceae	*Orobanche minor Sm.*				1	
Oxalidaceae	*Oxalis corniculata L.*	1	1		1	
Oxalidaceae	*Oxalis latifolia Kunth*	1	1		1	
Piperaceae	*Peperomia abyssinica Miq.*			1		
Pittosporaceae	*Pittosporum viridiflorum Sims*				1	
Plantaginaceae	*Plantago palmata Hook.f.*				1	
Podocarpaceae	*Podocarpus falcatus Mirb.*	1	1	1	1	

Podocarpaceae	*Podocarpus latifolius (Thunb.) Mirb.*			1		
Polygalaceae	*Polygala stenopetala Klotzsch*		1			
Polygonaceae	*Oxygonum sinuatum (Meisn.) Dammer*	1				
Polygonaceae	*Polygonum pulchrum Blume.*	1	1	1	1	
Polygonaceae	*Polygonum salicifolium Willd.*	1				
Polygonaceae	*Polygonum senegalense Meisn.*	1				
Polygonaceae	*Polygonum setosulum A. Rich*	1			1	
Proteaceae	*Grevillea robusta R.Br.*	1	1	1		
Ranunculaceae	*Clematis brachiata Thunb.*				1	
Ranunculaceae	*Clematis simensis Fresen.*		1			
Resedaceae	*Caylusea abyssinica (Fresen.) Fisch. & C.A.Mey.*		1			
Rhamnaceae	*Helinus mystacinus (Aiton) Steud.*	1				
Rhamnaceae	*Rhamnus prinoides L'H,r.*			1	1	
Rhamnaceae	*Scutia myrtina (Burm.f.) Kurz*	1	1	1		
Rosaceae	*Prunus africana (Hook.f.) Kalkman*				1	
Rosaceae	*Rubus keniensis Standl.*				1	1
Rosaceae	*Rubus steudneri Schweinf.*		1		1	
Rubiaceae	*Galium scioanum Chiov.*				1	
Rubiaceae	*Oldenlandia scopulorum Bullock*		1			
Rubiaceae	*Pentas lanceolata (Forssk.) Deflers*	1		1	1	
Rubiaceae	*Rubia cordifolia L.*				1	
Rubiaceae	*Tarenna graveolens (S.Moore) Bremek.*		1	1		
Rubiaceae	*Vangueria infausta Burch.*			1	1	
Rubiaceae	*Vangueria madagascariensis J.F.Gmel.*				1	
Rutaceae	*Calodendrum capense (L.f.) Thunb.*	1	1			
Rutaceae	*Clausena anisata (Willd.) Benth.*	1	1	1	1	
Rutaceae	*Teclea simplicifolia (Engl.) Verd.*	1		1	1	
Rutaceae	*Toddalia asiatica (L.) Lam.*			1	1	
Salicaceae	*Salix subserrata Willd.*	1				
Santalaceae	*Thesium sp.*			1		
Sapindaceae	*Cardiospermum halicacabum L.*	1				
Sapindaceae	*Dodonaea angustifolia L.f.*		1			
Scrophulariaceae	*Craterostigma pumilum Hochst.*			1		
Smilacaceae	*Smilax aspera L.*				1	
Solanaceae	*Datura stramonium L.*	1			1	
Solanaceae	*Nicandra physaloides Gaertn.*				1	
Solanaceae	*Solanum aculeastrum Dunal*				1	
Solanaceae	*Solanum incanum L.*	1	1	1	1	
Solanaceae	*Solanum mauense Bitter*	1	1	1	1	
Solanaceae	*Solanum mauritianum Scop.*				1	
Solanaceae	*Solanum nigrum L.*	1				
Solanaceae	*Solanum pseudocapsicum L.*	1				
Solanaceae	*Solanum terminale Forssk.*	1			1	
Solanaceae	*Solanum tuberosum L.*	1	1		1	

Sterculiaceae	*Dombeya kirkii Mast.*	1	1	1	1	
Tiliaceae	*Grewia similis K.Schum.*	1	1	1	1	
Tiliaceae	*Triumfetta rhomboidea Jacq.*			1	1	
Umbelliferae	*Steganotaenia araliacea Hochst.*			1		
Urticaceae	*Urtica massaica Mildbr.*				1	
Verbenaceae	*Lantana camara L.*	1			1	
Verbenaceae	*Lantana trifolia L.*		1	1	1	
Verbenaceae	*Lippia javanica (Burm.f.) Spreng.*	1	1	1	1	
Verbenaceae	*Verbena officinalis L.*	1	1		1	
Vitaceae	*Cyphostemma kilimandscharicum (Gilg) Wild & R.B.Drumm.*	1	1	1	1	
Zygophyllaceae	*Tribulus terrestris L.*				1	

APPENDIX 4: COST OF GROWING BAMBOO PER ACRE (KSHS)

ACTIVITY	UNIT OF MEASURE	UNITS REQUIRED	COST/UNIT	TOTAL COST
1.Seedlings	Pieces	200	150	30000
2.Land preparation	Acre	1	2500	2500
3.Pitting	Number	200	20	4000
4.Planting	Number	200	10	2000
5.Weeding	Acre	1	1000	1000
6.Fertilizer	Kg	8	60	480
7.Fertilizer application	Labour-days	1	200	200
8.Agrochemicals	Variable			1000
9.Application of agro-chemicals	Variable			1000
10.Removal of suckers	Labour-days	1	200	200
11.Prunning	Labour-day	1	200	200
11.Harvesting	Piece rate	2200	3	6600
Total cost				49180

APPENDIX 5: BEST AGRONOMIC PRACTICES FOR BAMBOO PLANTATION MANAGEMENT AND HARVESTING

Proper maintenance and protection of the plantation is highly important. This involves replanting, plant protection, weeding, general tending and sustainable harvesting of bamboo culms (bamboo stems). Below are recommendations on best management and harvesting practices for bamboo plantations.

Mulching

All transplanted bamboo should be mulched. Mulching should be 15 to 20cm depth around the seedling. Mulching protect the ground from drying, control the soil temperature and checks growth of weeds. Depending on its composition mulch furnishes various nutrients and improves soil conditions**.**

Weeding

Spot weeding should be done at a radius of 60cm around the seedling after out planting. Weeding should be done using a hoe to scrape the ground surface except during in the time just before emergence of fresh shoots. Weeds compete for nutrients meant for bamboo and they also lower soil temperature and may retard shoot emergence. Weeding is therefore necessary after out planting. Weeding can also be controlled through intercropping but this should be discontinued after 3 years.

Replanting

Not all transplanted seedlings survive in the new environment, it is therefore important to visit the plantation regularly to check and monitor the survival rate of the transplanted seedlings. The dead seedlings should be replaced simultaneously with the first weeding schedule.Replanting should be done in subsequent rainy season when there is enough moisture until the second year.

Plant protection

Bamboo are palatable to many animals especially in during the dry season when cattle, goats and wild animals graze freely on any green foliage. It is necessary to protect the bamboo plantations against grazers by using simple sticks. The sticks are stuck to the ground around the seedling and made to converge above the seedling forming a conical shape. Where large animals are involved, fencing may be necessary to allow the establishment of the bamboo seedlings. Patrolling the area regularly may also protect the plantation from foraging animals.

Fire is also a major hazard to a bamboo plantation especially during dry season and in drier areas. A 10 meter wide fire line/break should be established safeguard the plantation. Fire breaks stop fire from spreading into the plantation. The ground litter layer should always be kept thin to reduce the risk of fire outbreak.

Early treatment of plants

- Plants showing poor growth and slow development should be removed.
- Leguminous crops are suitable for intercropping with bamboos since they are nitrogen fixing.
- For the first 2 to 3 years, most new shoots should be allowed to grow into culms. A bamboo seedling thrives better under shade condition up to the age of 2 years.
- Sometimes bamboo rhizomes produce slender stems that grow from old rhizomes. These stems should also be pruned to reduce competition for water and nutrients.
- After five years the number of culms per clump should be reduced to avoid crowding.
- Depending on the soil fertility and climate factors the number of bamboo seedlings planted per hectare should be between 1500 and 2000. This density should be maintained for the entire lifespan of the plantation.

Fertilizer Addition

Bamboo is a heavy feeder so even rich soil becomes depleted off minerals after a few years if no fertilizer is added. Fertilizer may be applied after shoot or culm harvesting or just before the onset of rains. Nitrogen and potassium which are found in compost, stable manure is recommended. Lime is often used both as fertilizer and as a neutralizer for acid soils.

Culm harvesting

Most of the bamboo species cultivated in Kenya are the clumping type. The clumping habit enables the plant to regenerate naturally after harvesting. Culms usually attain maximum growth after 7 years. Harvesting of bamboo involves selection of mature culms for cutting rather than clear felling. The uncertainty of culm age can be avoided by marking the year in which the culms emerge. The first harvest after planting is done after 6-8 years. Thereafter cutting of mature culms is done at intervals of 4 years. Over harvesting of bamboo from one clump can cause serious degeneration of the stand and should be avoided. Cutting cycle and method of extraction of bamboo from the clumps is a very important management system of the entire bamboo plantation.

Cutting cycles and method of cuttings

Clumping bamboo tend to become congested, resulting in deterioration both in quality and quantity. In a clump, new culms are normally produced outwards, towards the periphery of the clump while older culms are left in the centre. Harvesting of bamboo therefore should be from the centre and not from the sides of the clump.

This makes it necessary to maintain the clump in the shape of a horse-shoe.The open end of the horse-shoe facilitate entry inside the clump for cutting of mature culms. Alternatively, the clump can be managed by creating a cross tunnel which divides the clump into 4 sections and allow full access for harvesting mature culms. It is advisable to leave a few older culms in the clump so that they support the new and soft culms.

Bamboo cutting rules

- All dead and dry culms should be cut and removed.
- All heavily congested clumps may not be salvaged to productive stake and should be clear felled.
- All the culms that are twining around other culms or are infested by diseases and insects should be cut.
- The numbers of older culms retained should not be less than the number of current years culms.
- In order to avoid future congestion, it is advisable to create and maintain the horse-shoe shape in the early stages of the clump development.
- Culms should be cut between 15 and 45cm from the ground but not below the first prominent node above the ground.
- Cutting should be made with a sharp panga or saw to avoid splitting the stump.
- All cut debris should be collected land removed on way from the clump.
- Culm cutting should be done only during the dry season but not during rainy season.
- In case of sporadic or gregarious flowering, all flowered clumps which have shed their seeds should be clear felled.
- The areas under bamboo should be protected from fire.

Shoot harvesting and handling

Bamboo shoots are young culms that are harvested for food before they are 2 weeks old or one foot tall. Bamboo shoots are crisps and tender and are comparable to asparagus with flavor similar to corn. Commercially canned bamboo shoots are common but fresh locally grown bamboos have a far better flavor and texture. Although plantations in Kenya are not intended for edible bamboo shoot production it is important to note the following points:

- The emergence of new shots begins during the rainy season of the year after planting.
- These new shoots shoul be allowed to grow to full height in order to promote healthy establishment of the clump.
- A small amount of edible shoots may be harvested in the third year of the plantation i.e. two rainy seasons after planting.
- Shooting for some species may start earlier then for others.
- Harvesting of shoots should only be done on well established clump.

Rules for harvesting of bamboo shoots

- Swellings or bumps around the clumps start to appear at the start of the first rains and are signs of the imminent emergence of new shoots. These areas should be protected during harvesting.
- Some species may shoot as early as April, while others may shoot several months later. It is important for a farmer to become familiar with shooting season of each species.
- New shoots usually occurs for a period 1 to 2 months and it important to inspect the clumps for new shoots.
- The new shoots should be kept moist at all times to retain their quality. This can be achieved by adding mulch around the clump.
- Young shoots should be harvested within one to two weeks after they appear from the ground since shoots harvested too late will be tough and of poor quality as food.
- The young shoots (normally 10-20 cm tall depending on the species) should be cut using a sharp harvesting blade (resembling a large chisel). The cut should be made about 10 cm to 15 cm below the soil at the soft section where the shoot emerges from hard rhizome.
- Overgrown shoots should not be harvested since they are fibrous, tough and nonpalatable. They should be allowed to grow into culms.
- Emergence of new shoots should be checked periodically after the first harvest. It is not unusual for a second round of shoots to appear, especially during period of high rainfall and intensive growth.

- All shoots in a clump should not be harvested instead several shoots should be left to grow in to culm.
- Harvested shoots should be handled with care and sorted according to size and species.
- The harvested shoots should be stored in a cool place, away from direct light and humidity to prolong theit shelflife.

APPENDIX 6: PERFORMANCE OF BAMBOO SPECIES IN MUGUGA

Species	Ht	D	Wt	Dm	Ac	Ey	Cy
D.hamiltonii	9	10	10	10.3	28	29.0	11.6
B.tulda	6	7	10	4.7	17	8.0	3.2
D.membranaceus	7	6	6	2.9	17	4.9	2.0
B.vulgaris	7	7	9	5.0	28	14.0	5.6
D.brandisii	10	10	18	19.8	17	33.7	13.5
D.strictus	5	6	23	6.7	11	7.4	3.0
B.bambos	4	6	9	2.4	22	5.3	2.1
T.siamensis	5	3	9	2.4	28	6.8	2.7

Source : Bria

Ht=Average height of mature culms in meters; D=average diameter of mature tapered culms in meters; WT=Average wall thickness in millimeters; DM= estimated average air dry weight of culms in kilograms; AC=Average number of culms per clump; EY=Estimated potential yield(air dried) in tons per hectare per year based on 5m*5m planting with harvesting of only 25% of mature culms and extraction of dead or rotting culms; CY= commercial yield (tons)/per ha per year of top quality culms assumed to be 40% of estimated potential yield.