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Analysis of the Status of a Mixed Semi- arid Woodland in Response to Charcoal Production in Elangata Wuas, Kajiado District, Kenya

By

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Dedication

This work is dedicated to my late father George William Oguna Malo who I wish could have lived to read this work. Rest in peace. God has remained God.

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ACRONYMS AND ABBREVIATIONS

ASAL	Arid and semi arid lands
a.s.l	Above sea level
dbh	Diameter at breast height (1.30 m above the ground)
DFO	District Forest Office
EWEMP	Elangata Wuas Ecosystem Management Programme
FD	Forest Department
Fig	Figure
GNP	Gross National Product
KEFRI	Kenya Forestry Research Institute
KIFCON	Kenya Indigenous Forest Conservation Project
GOK	Government of Kenya
MENR	Ministry of Environment and Natural Resources
MOE	Ministry of Energy
Se	Seedling
Sp	Sapling
Sph	Stem per hectare
UNESCO	United Nations Educational Scientific and Cultural Organization

ABSTRACT

Understanding charcoal production impact on the woodland status is vital for sustainable management given increasing charcoal demands from growing urban populations. The status of a mixed semiarid woodland was assessed in relation to charcoal production in Kajiado district southern Kenya. Status of the woodland was assessed from 72 circular sample plots and the historical perspective established using maps and discussions with elders. Plots measuring 0.05ha were assessed counting seedlings and saplings and measuring tree diameter at breath height along altitudinal gradient from the hilltops to the plains. Charcoal production process and efficiency from traditional earth kilns were investigated by comparing outputs and inputs to understand loses.

Results show that tree cover (woodland) has increased with discontinuity in species along altitudinal gradient. Tree density decreases from the hilltop to the plains with failure in regenerates especially at the sapling class. Charcoal recovery rate averaged 8% and preference was for *A. tortilis*, *A. mellifera* and *B. aegyptiaca* in that order with basal diameter >15cm for charcoal production. Estimates show supply balanced with demand and points the problem of charcoal production to the low recovery rates and divergence between state and community forest management objectives. Reconciliation of state and community objectives, "boma" enclosures and "mbuzi" woodlots, selective cutting entrenched in enforcement and making of enabling rather than restrictive legislation among others are recommended as strategies that may be pursued to enhance dry woodland contribution to sustainable development.

Keywords: **Dry woodlands, charcoal production, sustainable extraction**

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 Forest decline

The accelerated forest decline of many of the world's forests represents one of the greatest threats to the conservation of biodiversity. Forest loss constitutes the profound and often irreversible degradation of both the biosphere and humanity's prospects for future survival (Myers, 1996). First and most obvious among the goods and services supplied by forest are timber, other wood products and non wood forest products. Forests are worth well over 1.8 % of the global economies and 4.1% of the economies of developing countries (Alexandratos, 1995; Dudley *et al*, 1995). Already there is a growing shortage in African countries due to over harvesting that has continued to impose severe economic limitations on many tropical nations and especially tropical forest nations where timber revenue have a sizeable contribution to the GNP (Barbier and Burgess, 1994; Sharman, 1992).

Kenya is not an exception as economic fortunes are greatly dependent on the environment in general and natural resources in particular. Kenyan forests generate revenue, employment opportunities and provide a wide range of ecological services. Importantly, the forests provide 95% of the rural energy supply and generate value added products amounting to US$ 200 million annually, an estimated 3.3 % to the GNP (GOK, 2003). Despite the significant role that forest resources play in Kenya's economic life, they are being rapidly depleted, reducing opportunities for future economic development. The loss could be associated to population growth, corruption leading to loss of forest land, and over harvesting among others accompanied by limited replanting, afforestation and reforestation programs.

Moreover, concern of the Forest Department (the major custodian of forest resources in Kenya) over the value of forests point to over concentration on timber forest products. Limited budgetary allocations have been made over the years to cater for aspects of non timber forest products such as fuel wood. With Kenya's land area of 583,000 km^2 only 17.7 per cent is traditional agriculture and forest with the rest as either arid or semi-arid lands (Gicheru, 1996). This represents a sizeable portion of approximately 80% comprising arid or semi-arid lands (ASAL) and contain more than 70 per cent of the country's forest resources that consists of grasslands, wooded grasslands and the woodlands (Lumasia, 1996). Therefore, the potential of the dry woodlands in the semiarid lands in terms of biodiversity conservation, economic fortunes and livelihood support can not be overstated.

1.2 Dry woodlands

Woodland, as defined by UNESCO (White, 1983), refers to an open stand of trees at least 8 metres tall with a canopy cover of 40% or more with the field layer usually dominated by grasses. Wooded grassland is land covered by grass and other herbaceous plants, with woody plants covering 10-40% of the ground (MOE, 2002). Dry woodlands are the natural vegetation cover in a significant proportion of the tropics. Also known as savanna, dry woodland is an area of rolling grassland dotted with trees. Savanna is an intermediate biome, which lies between desert and tropical rain forest. They are the transition between semi-humid and semi-arid zones.

Dry woodlands are found within the drylands that represent a sizable portion of the earth's potentially arable land surface. More than 5.1 billion ha of the earth surface is arid, semi-arid and dry sub-humid land. These are concentrated in the land surface between latitudes 72° North and 57° south, particularly in Africa and Asia and are the habitat and source of livelihood for about one quarter of the world's population. Roughly 12 million ha of sub-Saharan Africa is arid or semi-arid. It houses about 40 million people and 80 million livestock (Harrison, 1987). It is estimated that 26% of the total land area and 85% of the total African dryland area has suffered, or is undergoing, moderate or severe desertification as a result of land degradation (Timberlake, 1985).

In Kenya, dry lands comprise about 88% of the land area supporting about 30% of the countries human population and 60% of the livestock population (IFAD/UNDP, 1988). They are characterized by low annual rainfall ranging from 250 mm to 1000 mm (UNESCO, 1979) typically of short duration, but of high intensity and therefore highly erosive. The average woodland productivity is 0.64 cubic meters / ha / year yielding a total of 1.3 million cubic meters annually (MOE, 2002). Population trends in the arid and semi-arid lands (ASAL's) show an annual immigration rate of 3 %, from the congested high potential areas (GOK, 2003). This results in land degradation due to increased demand upon the environment to support growing numbers of people leading to destruction of the natural resource base (Clark and Munn, 1986).

Pastoralism is the most important economic activity for most of Kenyan dryland communities. Most occur in the North Eastern and Rift Valley Provinces followed by Coast and Eastern Provinces. Various county councils own most of the woodland vegetation under powers vested in them by the Trust Lands Act with communities and individuals owning the balance.

1.2.1 Factors affecting dry woodland structure and composition

Numerous factors affect the structure and composition of the dry woodlands. These can be categorized into biotic and abiotic factors. Abiotic factors include edaphic components such as nitrogen or phosphorus concentrations (Chidumayo, 1994) and climatic factors (Kikula, 1986). Biotic factors can be divided into natural occurring forces such as damage by herbivores, especially by elephants (Cumming *et al.*, 1997); and anthropogenic factors, including commercial charcoal production (Malo, 2001), collection of fuelwood (Abbot and Homewood, 1999) and cutting of building poles (Luoga *et al*, 2000).

Of these, anthropogenic factors are of the greatest concern with respect to maintenance of forest diversity (Schwartz and Caro, 2003). Although wild animals and especially elephants can have a dramatic effect on the regeneration of some species their population is relatively stable or declining in most areas (Western and Gichoki, 1993). In contrast, human population is growing rapidly in African countries and woodfuel is still the cheapest form of fuel in most areas (Schwartz and Caro, 2003).

1.2.2 Dry woodland dynamics

Sustainable management and use of dry woodland ecosystems requires proper understanding of vegetation dynamics and the role of environmental factors in determining such dynamics. Succession suggests that a community migrates through a sequence of several stages until arriving at a climax if not affected by an environmental factor. The woodland has been interpreted in terms of a single- state equilibrium model, with fire and other disturbances by people or wildlife as the main driving factors (Kikula, 1996). This is depicted by a three- state regressive series: dense dry forest, open woodland, Savannah, assuming that woodland is a sub-climax formation and dense dry forest the climax vegetation (Biaou, 2001).

One aspect in woodland dynamics is the increasing density in the woody component at the expense of the grass layer, in grassland and savannas (West, 1947 as cited by Michael and Suzanne, 2003). *Acacia* is a major contributors to the phenomena referred to as bush encroachment. African *Acacias* are able to produce large quantities of hard-coated seeds and often accumulate high densities of viable seeds (up to 9400 m^{-2}) in the soil (Coe and Coe, 1987).

This dynamic system is controlled and maintained by biotic and abiotic factors. Charcoal production is one of the rising abiotic factors in the drylands and its nature, magnitude and shock expected on the environment need to be understood. Moreover, such factors could reduce tree populations to levels where genetic and natural factors take effect (Lande, 1996).

1.3 Charcoal production

Woodfuel is the dominant source of energy for over 2 million people, particularly in households in developing countries (FAO, 2003). Biofuels especially fuel wood and charcoal, currently provide more than 14 per cent of the worlds total primary energy. In Africa, they accounted for about 91 percent of round wood production in 2000 (FAO, 2002). Projections of wood fuel consumption (Table 1) to the year 2020 show East Africa consumes over 30% of total wood fuel in Africa.

Table 1: Estimates of wood fuel consumption in Africa

Subregion	2000 (million m^3)	2010 (million m^3)	2020 (million m^3)
North Africa	60.08	67.29	72.22
East Africa	199.21	233.73	268.87
Southern Africa	84.32	99.05	115.79
Central Africa	116.42	137.16	157.83
West Africa	175.09	204.29	235.49
Total Africa	**635.12**	**741.52**	**850.19**

Source: Broadhead *et al*, 2001.

In Kenya, up to 82% of the urban household use charcoal regularly as compared to the 34% household in some rural areas (GOK, 2001). Over 16 million tonnes of wood is used annually as charcoal raw material. Charcoal consumption came fourth in the countries energy consumption in 2000 after electricity, gas and kerosene as shown in Table 2. Comparatively consumption of charcoal remains high as the other three are due to industrial activities.

Table 2: Annual consumption of various energy types in Kenya (year 2000)

Fuels	Amount
Electricity Kwh/yr	1,169,946,197
LPG Kg/yr	25,312,028
Kerosine litres/yr	325,611,584
Wood charcoal Tonnes/yr	16,506,498
Firewood Tonnes/yr	14,890,858
Wood waste Tonnes/yr	2,662,813

Source MOE, 2002

In the urban areas, charcoal remains the option at the household level based on the cost per unit MJ (mega joules). It is the cheapest household fuel ($ 261 p.a) for cooking followed by kerosene ($ 360p.a), liquid petroleum gas-LPG ($ 397p.a) and electricity ($747 p.a) (MOE, 2002). The rising urban population has raised demand and making charcoal production an important economic activity especially among the rural and often poor communities. National charcoal trade is estimated to cover over Ksh. 30.4 billion using the estimated annual consumption of 2.4 million tons and retail price of Kshs. 15,000/ton (Githiomi and Chikamai, 2004). That is, about 53% of the 1998 bill for imported oil.

Most of the charcoal sold in Nairobi and its suburbs, Central, Nakuru, Naivasha and Eastern comes from the drylands of Kenya. Preferred are indigenous species having high calorific value. The traditional earth kilns that are commonly used have a recovery range between 10 to 20%, indicating that a considerable amount of energy is wasted (Beijer Institute, 1980; MOE, 2002). Despite the low recovery rates charcoal does not smoke, has twice the calorific value per unit weight of wood and is accessible to low-income consumers. It is convenient to use indoors and is therefore preferred by many urbanites. Its availability is also assured in comparison to other energy sources as it is easy to package and transport over long distances. These factors combined with social and economic conditions in Africa are projected to increase its demand. Consumption forecast between 2000 and 2020 give indications of an increase by about 34 % (Broadhead *et al*, 2001). In Kenya a rise is expected from 35,119,615 tonnes recorded in 2000 to 53,416,327 tonnes projected for 2020, giving indications of about 50 % increase (MOE, 2002).

1.3.1 Sources of woodfuel material

In Kenya, biomass comes from various forest formations such as indigenous vegetation mainly closed forests, woodlands, bushlands and wooded grasslands (16,307, 703 m^3); farmlands consisting of exotic tree species such as *Grevillea*, *Eucalyptus* and remnant natural vegetation (14,380,951 m^3); plantations, mainly of *Eucalyptus* (2,717,972 m^3); and residues from agriculture and wood based industries (3,085,800 m^3) (MOE, 2002). The provincial biomass production shows variation (Table 3) with the Rift Valley having the highest (30.9%) and Nairobi only consuming and not producing. Most of the sources of fuelwood are concentrated in the drylands South of the equator. Places such as Narok, Kajiado, Kiboko, Kibwezi, Taru, Bachuma and Samburu are major sources of charcoal for Nairobi and Mombasa (Lumasia, 1996).

Table 3: Areas of standing biomass sources by provinces (Year 2000)

Provinces	%
Nairobi	0.0
Coast	16.6
N. Eastern	24.9
Eastern	21.0
Central	2.6
R. Valley	30.9
Nyanza	2.5
Western	1.6
Total	100.0

Adapted from MOE, 2002

Although there are apparently large wood volumes available from the various vegetation types, not all of it is accessible for energy. Accessible wood depends on a number of factors: legal issues, environmental issues, ownership, objectives of management, distances, and infrastructure. Closed forests are gazetted and their use is restricted and controlled by the Forest Department under the Forests Act. Other vegetation types are also in theory inaccessible due to environmental features e.g. they form part of a water catchment, have been purposely planted to control water run-off and soil erosion, or they protect and conserve biological diversity. As such, only about 5% closed forest and 30% woodland, bushlands, and wooded grasslands is legally accessible for wood energy (MOE, 2002). Accessibility for charcoal production is further curtailed by charcoal production bans.

Estimates of accessible wood for energy have further been complicated by concerns over the "wood fuel crisis". A desire to avoid over exploitation makes estimates on charcoal production difficult as researchers and policy makers became cautious over their estimates of wood fuel stock availability. On one hand underestimating on the availability of wood fuel stocks and yields can undermine the operation of wood fuel projects. The paradoxical consequence of such an assumptions is that it may lead to serious underestimation of the value of the natural woodlands and their potential for profitable management on a sustainable basis. On the other hand, if the wrong woodland management decisions are taken in an environment of exploitation reduction to volumes that are not viable or local extirpation could occur.

1.3.2 Response of the dry woodlands to charcoal production

Surprisingly, the response of the dry woodlands to most of these forms of disturbance has received little attention. Indications are that, tree resources in areas close to urban centers have been affected by charcoal production. In major urban centers supply is external and places a continuous impact on fuelwood availability on fragile areas. Areas such as Isinya (30 km from Nairobi) and Narok (150 km from Nairobi) wood stocks have been adversely affected with unsustainable wood offtakes (Ngibuini, 2001). Although demand and supply are reported balanced in the aggregate, there are areas of acute deficit, resulting in extraction far above sustainable supply levels and is particularly the case close to urban centers (FAO, 2003).

To obtain response of the dry woodlands and estimate vulnerability due to charcoal harvesting a number of factors need to be considered. Important is the amount of wood exploited for charcoal production *vis- a- vis* status and regeneration potential. The impacts should be measured in terms of its relative effect on population viability that is, whether it results in a significant increase in the probability of reduction to volumes that are not viable. The purpose would be to quantify status in an apparent move to choose between management options and explore impacts (Possingham, 1995; Gilpin and Soule, 1986).

1.3.3 Interventions towards sustainability in fuelwood production

Typically, countries have focused on increasing wood supplies by improving forest and woodland management and establishing wood fuel plantations. These include urban, peri-urban and rural plantations focusing on both private and public lands. Tree planting initiatives particularly in private farms have led to tree resources increment as noted by the Kenya Forestry Master Plan (FD, 1994). The share of on-farm contribution to biomass supply has increased from 47% in 1980 to 64% in year 2000.

Interventions have also focused on reducing demands on wood fuels. Such measures include increasing efficiency through use of improved cooking devices and alternative fuels. Hopefully, several countries in Africa, including Angola, Nigeria and Sudan, are being looked at to bring about energy substitution and supply commercial fuel to neighboring countries. The partial liberalization of the petroleum sector has significantly improved supplies of petroleum products though they remain expensive particularly to the low-income households.

In addition to programs to increase supply and reduce demand, Kenya imposed a charcoal production ban in 1986. Experts hoped people would shift to other energy sources and environmental degradation scaled down. Eighteen years since the ban, charcoal demand and use has risen tremendously and about 82 % of the urban population now relies on charcoal as a source of energy. Out of Nairobi's over 3 million residents, 2.5 million use charcoal (Bess, 1989 as quoted by Swatrzendruber, 1992). With increasing charcoal demand from urban areas, illegal charcoal production has risen to unprecedented levels with severe consequences and strain on the environment.

Charcoal advocates maintain that it is foolhardy for the government to intervene through charcoal ban and think poor people particularly in urban centers will be pressured to shift to other energy sources. In any practical sense and against other sources, charcoal remains the cheapest energy source for the middle classes and the urban poor.

1.4 Justification

A forest inventory is a costly and time consuming undertaking, which must be justified. In the case of dense tropical forest the commercial value of the inventoried resource suffices to justify the operation. In a forest whose main product is fuelwood or poles, an inventory is fully justified whenever there is the risk of an imbalance between the needs of the population and the resources available (FAO, 1989). It is absolutely essential to avoid a shortfall, since this will lead to such pressure as to bring about a deterioration of the forest environment.

In Kenya, the future of forestry as anchored in the forestry master plan and the new draft Forest Bill 2000 lies in farm/community forestry given that gazetted forests represent less than 2.5 percent of the total land area in Kenya (FD, 2001). The survey indicates that the total volume of trees planted by farmers equals that of closed canopy indigenous forests and government forest plantations combined. This explains the concerted efforts on private and community lands.

Land in the study area was previously communally owned and is being subdivided into individual holdings. The new land use arrangements coupled with social and economic changes has put the community in a form of transition and has followed a change in lifestyle and land uses aggravated further by recurrent droughts. The new land system, is presenting unique problems to the community and the existing natural resources. Among these under threat are the indigenous floral community dominated by tall trees of *Acacia, Balanites, Commiphora* and *Ficus* species.

Lucrative opportunities for commercial charcoal harvesting is encouraging charcoal production in Elangata Wuas (Ngibuini, 2001). Pessimism is high over the woodland capacity to sustain charcoal production. The dry woodlands are regarded as vulnerable posing threat to dryland biodiversity conservation. This study assesses vulnerability due to charcoal exploitation.

1.5 Objectives

1.5.1 General objective

To assess the woodland status, charcoal production and response of woodland to charcoal production.

1.5.2 Specific objectives

(i) To assess tree species composition and structure in relation to environmental gradient.

(ii) To assess charcoal production process and efficiency from the traditional earth kiln.

(iii) To examine charcoal production level in relation to woodland status.

1.5.3 Research questions

i) Does the woodland structure conform to response curves normally observed under undisturbed conditions?

ii) What criterion is followed in selecting trees for charcoal production?

iii) What is the charcoal recovery rate from the traditional earth kiln used in Elangata Wuas?

iv) What is the current rate of charcoal production in Elangata Wuas?

v) Are the dry woodlands of Elangata Wuas vulnerable due to charcoal production?

vi) What conservation measures are necessary in relation to charcoal production in Elangata Wuas?

2.0 THE STUDY AREA

2.1 Location

Elangata Wuas is located latitude 1^0 50' South and longitude 36^0 35' East in Central Division of Kajiado District (Fig. 1). The district is divided into Central, Ngong, Mashuru, Loitokitok and Magadi Divisions. Kajiado town in Central division is the District Headquarters.

Elangata Wuas is located 25 km south west of Kajiado town and 91 km by road to the capital city Nairobi. Centers in the location include Kenya marble quarries (KMQ), Elangata Wuas, Olootepes, Toroka, Singiraini and Mile 46 (area named after Magadi railway stop over marked 46 miles) the trading center.

2.2 Geographic features

River Toroka (Swahili word that means run away), a seasonal river meanders though the division with its wide and dry banks. Its high intensity flow of water during the rainy season erodes sand from the upstreams. River Toroka is dry three-quarters of the year and evident are water wells along the riverbed. They are covered up during the wet season and re-dug with increasing depths every failing rainy season.

Elangata Wuas is made up of a series of hills and plains that occupy the lower grounds. The main hills are Elangata Wuas and Kilonito. The features combined with vegetation and wildlife makes Elangata Wuas very attractive for ecotourism. Overall the land undulates between 1000 m and 2100 m (Aerophoto systems, 2001).

2.3 Climate

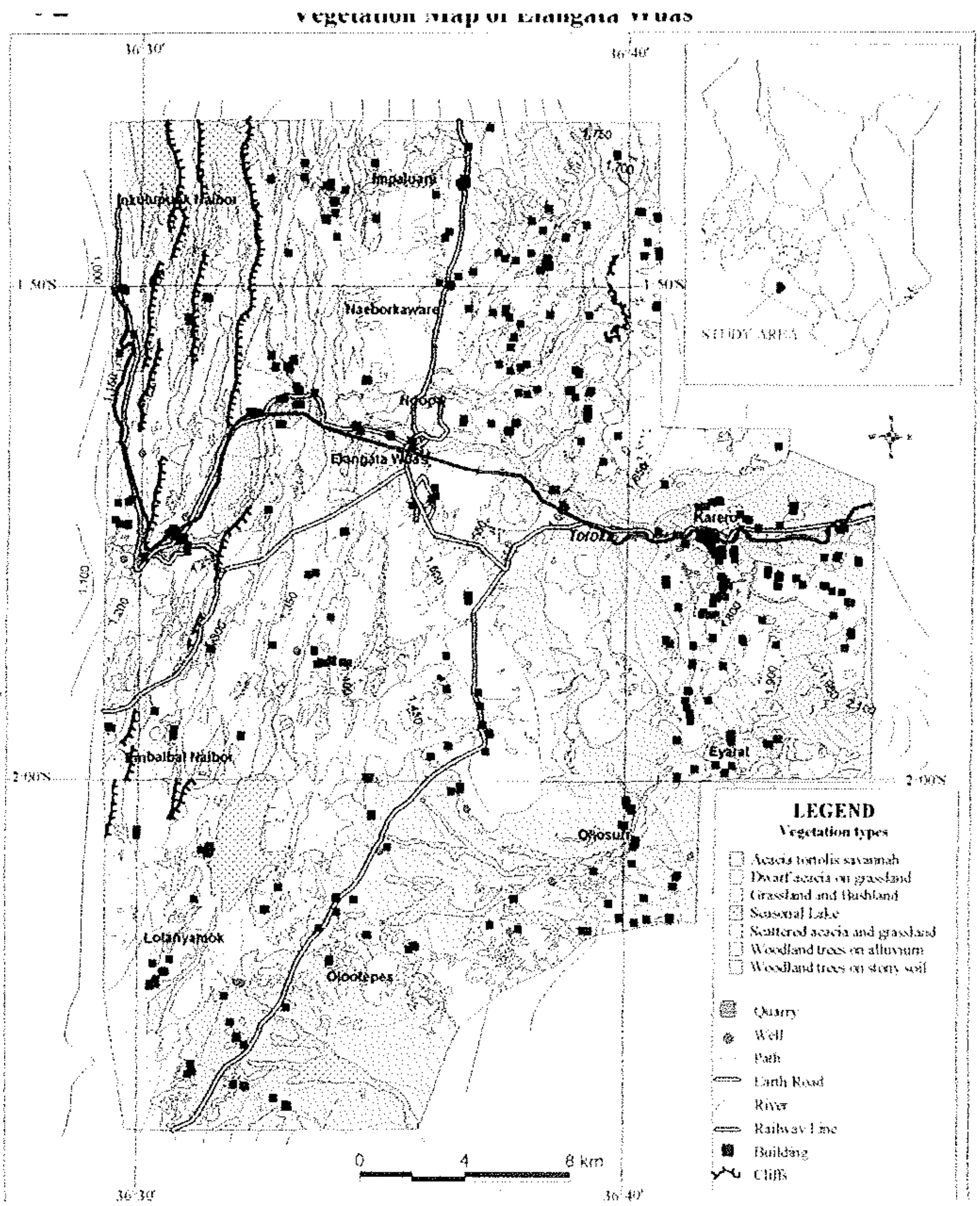
The rainfall of the area is bimodal with the long rains falling between March and May of up to 1300 mm and the short rains between October and December of up to 1000 mm. The mean annual rainfall is 750 mm. The rains are mostly erratic and short leaved.

Temperature varies with maximum temperature at 34° C during the day and a minimum of 12° C on the slopes. Potential evaporation is 1600 - 1800 mm (Meteorological, 2003).

2.4 Soils

Soils consist of light to medium texture and are low in Cation Exchange Capacity (CEC). The soils are subjected to compaction and are susceptible to erosion. There are pockets of heavy clay soils. The soils are saline and/ sodic and have a pH range of between 6.3-8.6, with varying infiltration rates from moderate to rapid. Phosphorus is the main limiting mineral in these soils (Ministry of Agriculture, 2000).

Figure 1: Map showing study area and vegetation



Source: EWEMP, 2001

2.5 Natural vegetation

The main vegetation types are wooded grassland, bush grassland and open grasslands. Tall trees dominate the wooded grassland that stretch from the plateaus into the plains. Tree species present include *Acacia tortilis, Commiphora schimperi, Commiphora africana, and Balanites aegyptiaca* (Ochuodho, 2001).

Grasses in the area include *Themeda triadra, Pennisetum mezaicum, Pannicum coloratum* and *Chloris gayana* that are important for the livestock population.

2.6 Human Population

According to the last national census held in 1999, the population of Kajiado District was estimated at 382,000 persons (GOK, 2001). Population density is estimated at nine persons per square kilometer and the population growth at 3% per annum.

The study area covers 980 km^2, and is occupied by 1810 households with a population of 8856 persons (GOK, 2001). The population is predominantly of the Maasai tribe. They are pastoralists and subsist on livestock keeping.

2.7 Land Use

Livestock keeping is the main form of land use in the area. Livestock is periodically affected by the recurrent drought with farmers loosing more than half of their livestock during such periods. The year 2000 drought adversely affected livestock with losses of up to 80% per farmer. Costing the losses, EWEMP study (2001a) revealed that certain farmers had lost livestock worth over Kshs. 1 million.

Drought leads to temporary migration to other areas as far as Tanzania and Mount Kenya. Women, children and the elderly are mostly left without much livelihood support. In such instances, commercial charcoal production becomes a viable option and a source of income among this pastoral community. Lorries leaving the program area carrying sand, marble or limestone catalyze the demand by transporting charcoal as a secondary or supplementary good.

Two group ranches (Elangata Wuas and Kilonito group ranch) owned and managed the land through group ranch committees. In the late 1990's, the government abolished the group ranch systems that were mostly in the ASAL's. They had to undergo massive and strenuous reorganizations. As a result Elangata Wuas and Kilonito group ranch areas are being subdivided into individual holdings with title documents to support ownership. According to a report on the subdivision, the process is theoretically completed in Kilonito group ranch and over 80% of Elangata Wuas is done (EWEMP, 2003a). Beacons have been placed to mark the boundaries and are enhanced by branches. However, use of land is still largely communal, as the process remains controversial and delicate. This new land use arrangement has put the community in a form of transition and the impact is yet to be fully felt and understood.

2.8 Industrial activities

The main industrial activity in the area is mining of marble done at large scale by the Kenya Marble Quarries company (KMQ) and Athi River Mining Company. The mining area is located at KMQ (named after the company). Mining has been going on for over three decades. An average of about 80 lorries transport marble daily to the capital Nairobi to be used for construction (EWEMP, 2003b).

Sand harvesting carried out along river Toroka, is another industrial activity. An average of 10 lorries per day transport sand from the area.

2.9 Transport

Transport consists of open rear land rovers (pick- ups) that operate between Mile 46 and Kajiado. Train is also available on selected days as per the schedule of Magadi Soda Company that operates the Magadi rail. The rail stations in the location are at Mile 46 and KMQ.

Lorries especially, those that transport marble from KMQ offer cheaper transport for both people and goods. The marble lorries are preferred than those of sand due to their reliability.

Plate 1: Donkeys carrying charcoal bags to KMQ

3.0 MATERIALS AND METHODS

3.1 Assessing woodland status

3.1.1 Woodland survey

Two transects with plots situated at four stations (hilltop, steep slope, down hill and the plains) constituted the main design adopted in the field data collection to determine woodland status. Transects are of a considerable importance in the description of vegetation structure along an environmental gradient or in relation to some marked feature of topography (Chapman, 1986). Transects are a form of systematic sampling in which samples are arranged linearly and usually continuous.

a) Transect layout

The transects were from hilltops of Elangata Wuas and Kilonito to the plains as shown in figure 2. The hills are about 18 Km apart. The purpose of this alignment is to identify any variation due to elevation variation.

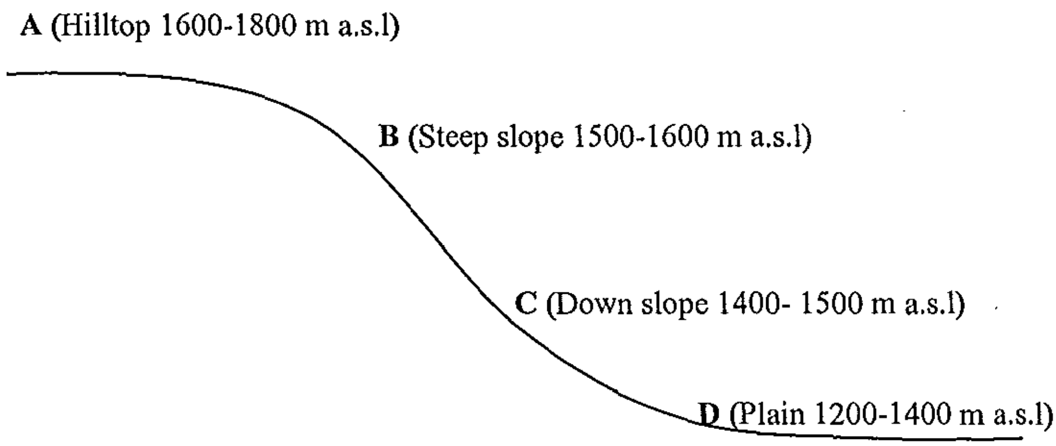


Figure 2: Transect station layout

b) Field data collection procedure

In each station nine circular sample plots of radius 12.6m (0.05ha) were established systematically. One at the center and four to the left and right of the center plot respectively. They were about 6 km from each other. A sisal string of 12.6m tied with a stick on both ends was used to mark the boundary of the plot. One person held one end on the middle point and the other marking the ground around. Thirty-six plots were studied per transect giving a total of 72 sample plots.

c) Data collected

Species were identified by both scientific and local names with the help of two locally recruited community members. Seedling and sapling were counted and tree diameter at breast height (dbh) measured. Seedlings were determined as regenerates whose height does not exceed 150 centimeters (cm); saplings as those with a height of more than 150cm but dbh less than 5cm and trees were determined as those with dbh above 5 cm (Schwartz and Caro, 2003).

Evidence of human activities within the sample plots was recorded. The disturbance signs were assessed as follows: charcoal burning (counts of charcoal kilns), tree stumps (counts, species identification), debarking (species identification and counts), branch cutting (counts and species identification) and soil erosion (type).

Due to the studies focus on charcoal production it only concentrated on trees. Other growth forms such as shrubs, herbs and climbers were not considered.

Plate 2: Research team at one of the sample plots

3.1.2 Elangata Wuas Woodland history

The historical perspective of Elangata Wuas woodland was sought through focus group discussions and interviews.

a) Focus group discussions

Focus group discussion was employed to address qualitative issues concerning communities' attitude towards charcoal burning, felt needs and design appropriate solutions. This method involved 5-10 people. Participants are asked questions and they make up responses, in a social context. They hear each other's responses stimulate one another and consider each other's presence when responding. Whereas they do not necessarily have to reach a consensus and give like-minded responses, there is nothing to stop them from doing so, neither to discourage them from giving divergent responses (Yeraswork Admesie, 1997). Developed by Robert K. Merton and his associates in the 1950's, the focus group interview has become a widely- used standard form of interview (Patton, 1990).

The focus group discussion was found appropriate for this study because the elders would provide quality control especially on the historical perspective of the woodlands. In that, participants tend to provide checks and balances on each other that weed out false or extreme views. Also, the group dynamics typically contribute to focusing on the most important topics and issue. Thirdly, information can be obtained from different people with the task of finding out about the potential willingness and capacity of communities to participate in future management activities.

In this way, the elders of Elangata Wuas were interviewed with the help of detailed listing of relevant issues. The groups were asked to respond to questions relating to factual data on past occurrences and present conditions of the forests as well as their future aspirations. With this technique, information of the woodland was obtained.

b) Semi- structured interview

In order to gather in depth information on woodland status and charcoal burning, it is better to hold interviews with people who are knowledgeable about the topic at hand. Such respondents are those referred to as key informants. During semi structured interviewing respondents are asked to respond to predetermined questions or topics and some questions that arise as the process continues (Grinier, 1995).

Most semi-structured interviews are conducted with a single person at a time. This allows people to express personal viewpoints, discuss disagreements in the community and speak freely without being interrupted or contradicted by others as normally the case with group interactions (Martin, 1995). Therefore, the study encompasses independent views from officers of Elangata Wuas Ecosystem Management Programme (EWEMP), researchers who have worked in the area previously and currently and current and past community leaders. Questionnaire used for the group discussion was used to guide the interviewing (Appendix 4).

3.2 Charcoal recovery studies/Production efficiency

One hundred and twenty charcoal burners were contacted and requests made for their involvement in the study. Upon consent their areas were visited during charcoal making. Observation was undertaken to understand the process and sequence of events.

3.2.1 Charcoal production efficiency

Charcoal efficiency was understood through comparing wood input and output. Input was determined through the stacked volume method obtained during the kiln preparation stage by measuring the length, width and height of kiln before covering by soil using a measuring tape in meters. Stacked volume was preferred against other methods of determine input given the field conditions in which this survey was carried out. Experimental methods such as the volume displacement methods take much more time and are therefore cumbersome if used with charcoal burners (Githiomi and Chikamai, 2004).

Output was determined by weighing directly the packed charcoal bags using a weighing machine in kilograms. Pieces of charcoal that were not collected and put in the charcoal bags (hence left in the field) were determined as loss therefore not considered as output.

3.2.2 Species preferred for charcoal production

A list of the species commonly used for charcoal production was produced from the kiln data and taken back to the charcoal producers for direct matrix ranking and scoring. The procedure for this technique requires the charcoal burners to compare, score and rank individual tree species according to their preference for charcoal burning. During the survey, seven important tree species were identified to determine the order of preference.

Each respondent was asked to score each species. This free scoring was explained to the respondents so that they could indicate the relative importance of each species compared to others (FTP, 1995). They number from the most preferred species to the least preferred. Respondents were told to give the highest score (7) for the species they thought was the most preferred and (1) for the one they felt they least preferred. Scoring is a comparative measure which provides an indication of their magnitude of importance in relation to each other while ranking indicates, the degree of importance given to each item (People and Plants, 1996).

3.2.2 Charcoal production per day

The number of charcoal bags leaving Elangata Wuas was recorded from a checkpoint at Kenya marble quarries (KMQ) for eight months beginning July (Appendix 3).

An assistant was stationed at KMQ daily from 9.00am to 5.00pm recording number of charcoal bags hoarded into lorries. It was assumed that the total number of bags transported equals to the total production in the area. The rural community uses mainly firewood for domestic cooking.

3.4 Data Analysis

3.4.1 Woodland Status

a) Woodland composition

Scientific names and family of the plants were determined and the information summarized in tables. Local names of the recorded species applied by the community (Maa) were provided as additional information to species composition.

For all individuals having > 5cm dbh, relative density, relative frequency, relative basal area and importance value index (IVI) (Curtis and McIntosh, 1950) were calculated for each species using the following formulas.

i) Relative density = $\frac{\text{Number of species A}}{\text{Total number of individuals of all species}} \times 100$

Density is defined as the number of individuals of particular species per unit area.

ii) Relative frequency = $\frac{\text{Number of plots occurrences}}{\text{Total number of plots}} \times 100$

Frequency is the chance of finding a species in a particular area in a particular trial sample. The frequency value obtained reflects the pattern of distribution as well as diversity.

iii) Relative basal area = $\frac{\text{Total basal area of individuals of a specie}}{\text{Basal area of all species}} \times 100$

Basal area is the cross-sectional area of the tree at 1.3 meters above the ground.

iv) Importance value Index (IVI) = Relative density + relative frequency + relative basal area

b) **Woodland structure**

For each station, the number of stems per hectare (sph) for each dbh class was plotted against dbh (using dbh classes mid-points) to show the pattern of size (diameter) distribution. The width of each dbh class was 5 cm with the lowest dbh class limit of 5 cm.

Parameter quotient "q" values between successive size classes were computed for the sampled forest zone, based on the number of stems per hectare to examine how balanced the size distribution was (Devis and Johnson, 1987).

$$Q = \frac{D_{i-1}}{D_i}$$

Where D_{i-1} *= density in the lower class;* D_i *= density in the immediate upper class*

The results of "q" values verses dbh classes were plotted. Generally, constant "q" indicates a regular regeneration and recruitment, which portrays a balanced diameter distribution.

c) Regeneration

For regeneration (seedlings and saplings), density were calculated for each species in the respective stations and compared with trees. Relative density was compared graphically to understand future coverage.

d) Types of man-induced disturbance

Relative frequency was used to determine the most prominent disturbance type in the stations. The frequencies of occurrence were calculated and results displayed in a figure.

3.4.2 Woodland history

Information solicited from the different sources was collated to make a continuous and consistent preamble to the dry woodland. Information presented by more than three people or two groups was regarded as valid if consisted with information on the 1970 and 2000 maps.

3.4.3 Charcoal production

a) Charcoal production process

Observations made were compiled and procedure and process of charcoal production developed.

b) Charcoal production efficiency

Charcoal recovery rate was calculated by comparing the initial wood input and the resultant output after the carbonization process. Stacked volume was used to determine input.

Stacked volume= ½ lwh x 0.56

Where l is length, w- width, h- height and 0.56 the stacking factor

Out put was deduced directly from weights of charcoal bags.

$$\% \text{ Recovery rate} = \frac{\text{Total Volume of charcoal}}{\text{Total volume of input wood}} \times 100\%$$

Fuelwood assumed at 15% moisture content,

Conversion rate 1.4 m^3 *=1 tonne or Im*^{3} *= 700kg = 0.7 tonne*

(Sigh, 1980 as quoted by FAO, 1989; MOE, 2002)

c) Preferred tree species for charcoal production

Summing points assigned and ranking obtained the preferred species. The most preferred had the highest points.

3.4.4 Number of bags produced in the area

The total number of bags produced per month was added from daily bags transported and tabulated for the eight months. The total for the eight months was added and average number of charcoal bags per month obtained.

3.4.5 Charcoal production level in relation to woodland status

Based on the tree species, size preferred for charcoal burning, areas were charcoal burning occurred and the amount of charcoal produced per month the woodland structure was re-examined. Density was re-constructed and compared with the number of bags produced per month taking into consideration the recovery rate to produce simple scenarios.

4.0 RESULTS AND DISCUSSION

4.1 Woodland Status

4.2.1 Species composition along altitudinal gradient

Thirty-four tree species representing 12 families were identified during the course of the study in Elangata Wuas (Appendix 7). Of these, 11 species were identified from the 72 sample plots along Elangata Wuas and Kilonito transects. An overall picture from the hill tops to the plains show dominance of *Acacia drepanalobium, Commiphora africana, Balanites aegyptiaca* and *Acacia tortilis* (Table 4).

Table 4: Relative basal Area, Relative density, Relative frequency and Importance Value index of the dominant tree species recorded in the various stations

Species Name	Basal Area	Relative Density	Relative Density	Importance value index (IVI)	RANK
Station A					
Acacia drepanalobium	34.1	31.6	40.44	106.1	2
Acacia mellifera	5.3	5.3	3.5	39.6	3
Acacia nilotica	0.1	1.8	0.3	2.2	9
Acacia senegal	4.1	10.4	0.3	14.8	5
Acacia seyal	1.1	6.5	0.5	8.1	6
Boscia angustifolia	0.7	1.0	0.3	2.0	8
Commiphora africana	45.9	28.1	40.1	114.1	1
Commiphora schimperi	8.1	12.3	9.8	30.2	4
Ficus capensis	0.3	3.5	0.3	4.1	7
Station B					
Acacia mellifera	27.9	26.7	27.6	82.2	2
Acacia tortilis	16	17.1	10.4	43.5	4
Balanites aegyptiaca	30.7	29.3	40.2	100.2	1
Commiphora africana	5.6	9.8	5.7	21.1	5
Commiphora schimperi	19.7	17.1	16.1	52.9	3

Station C					
Acacia etbaica	0.6	2.9	1.6	5.1	6
Acacia mellifera	0.1	17.1	5.4	22.6	3
Acacia tortilis	66.0	40.0	58.1	164.1	1
Balanites aegyptiaca	22.3	28.6	27.9	78.8	2
Commiphora africana	1.7	5.7	2.3	9.7	5
Commiphora schimperi	3.5	5.7	4.7	13.9	4
Station D					
Acacia mellifera	16.5	21.4	18.4	56.3	3
Acacia tortilis	35.3	14.3	14.3	63.9	2
Balanites aegyptiaca	31.7	39.4	26.5	97.6	1
Balanites glabra	4.0	7.1	26.5	37.6	4
Commiphora africana	12.0	10.7	8.2	30.9	5
Commiphora schimperi	0.5	7.1	6.1	13.7	6

Location of station is as given in fig 1

There was no pure homogenous tree species stand at any altitudinal gradient at both Kilonito and Elangata Wuas transects. It conformed to a mixed specie semi- arid woodland with dominance of *A. drepanalobium/ C. africana* on the hilltop, *B. aegyptiaca/ A. mellifera* on the steep hill, *A.tortilis/ B. aegyptiaca* down hill and *B. aegyptiaca/ A. tortilis* on the plains. The results revel noticeable trend as altitude showed to be a major discrimination among species types.

The hilltop, exclusively dominated by *A. drepanalobium*, is devoid of human settlement and is commonly used for dry season grazing. According to Coppock (1994), goats and sheep prefer to feed on *A. drepanalobium* only in cool dry season. This could explain community's preference to the area for dry season grazing. The almost pure stands of *A. drepanalobium* species on the hilltop suggest to poorly drained or waterlogged black vertisols. According to Haugen (1992), *A. drepanalobium* is among the few dry land *Acacia* species that grow in poorly drained soils. The growth of the species at the altitude is consistent with studies by Asfaw Hunde and Thulin (1989) in Ethiopia and Young *et a.l.* (1997) in Mpala Research Center in the semi-arid Laikipia ecosystem. They found *A. drepanalobium* to become gregarious over large areas of grassland, which is liable to flooding at altitude of 1000- 1900m a.s.l.

On the steep slope, *A. mellifera* formed dense impenetrable thickets. Pitman and Palmer (1972) also reported the species on the rocky hillsides in the Southern Africa drylands at altitudes of up to 1500 m a.s.l. The presence of *A. tortilis* (Plate 3) and *A. mellifera* species down slope and along the steep slope could be attributed to grazing as these are the commonly grazed areas. Coe and Beentji (1991) found *Acacia* species with robust pods that don't split and have to be eaten by animals to be spread along grazing zones.

On the plains, *B. aegyptiaca* was the main species. Though it tended to be well spread, it was conspicuously absent at the hilltops. According to Ojimbo (1978) *B. aegyptiaca* can grow in areas of altitudinal range between 300 – 2000 m with slightly impeded drainage but best on slopes of rocky hills. This probably explains their absence on the hilltops and dominance on the plains. Its survival in the slopes an area characterized by heavy livestock activities is due to its resilient nature.

Commiphora africana and *C. schimperi* species grew along the entire altitudinal ranges. They could be said to support the widest range of sites. The dry river channels of River Toroka were associated with large *Acacia xanthophlea* trees.

Plate 3: Mature *A. tortilis* highly preferred specie for charcoal production

Results suggest discontinuity can be distinguished in the tree species along the altitudinal gradient. This reaffirms works of Zerihun *et al.* (1989) on partitioning an elevation gradient of vegetation that reported altitude as the most important factor in the tree- herb layer though the herb layer is controlled by several other factors with relatively equal magnitude.

4.1.2 Densities

Demography of the woody species (> 5cm dbh) was compared in different stations. The plateau had the highest number of stems per hectares and decreased as one moves down the plains in both transects as shown in figure 3.

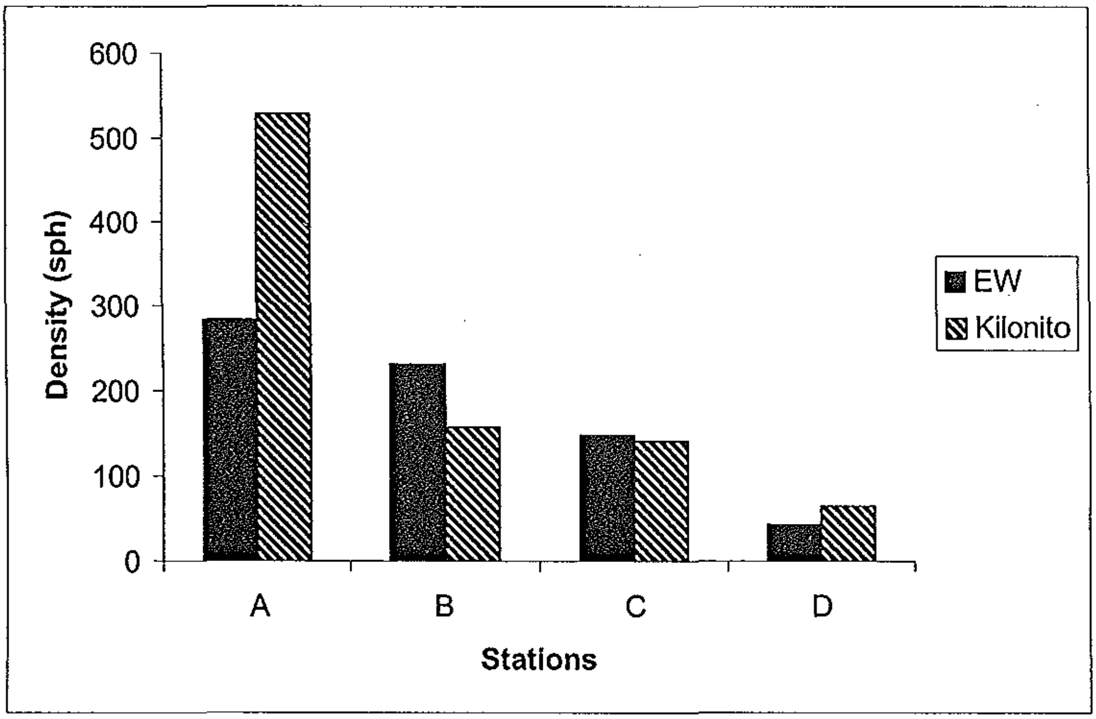


Figure 3: Tree densities in stations in Elangata Wuas and Kilonito

The hilltops high densities could be associated with the steep hill that inhibits human activities such as charcoal burning and grazing. They are not as frequently trumpled by cows if not browsed by goats and sheep leading to high survival of regenerates and subsequent growth. Moreover, there are no human settlements in this area hence it has reduced interference. Down hill to the plains the trees are few due to high livestock numbers and human activities creating a suppressing environment for seedlings and trees.

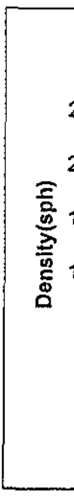
From the seventy-two sample plots a total of 718 trees was recorded in 3.6 hectares giving an average of 200 stems per hectare (sph) in Elangata Wuas location.

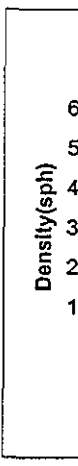
4.1.3 Woodland structure

The pattern of diameter distribution in the four stations is as shown in figure 4 and 5. The species frequencies in the mixed species woodland have negative exponential distribution with gaps in some size classes suggesting selective removal. The distribution tailed off quickly after the 32 cm diameter class. These results are in agreement with Atta- Boateng and Moser (1998) who on classifying commercial tree species of uneven-aged mixed species tropical forest for growth and yields found distribution tails off quickly after the 30 cm diameter size class.

Density in size classes shows dominance of small sized individuals. The pattern of such density is an indicator for community dynamics in the forest. The forest pattern is formed by the species structure with reversed J shape response curve in dbh class distribution. More than 60% of the individuals in the forest have dbh in range between 5- 17cm indicating the potential of the forest for future production and improvement if an appropriate management practice is applied.

Fig


Density(sph)

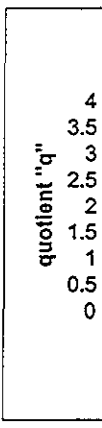

Density(sph)

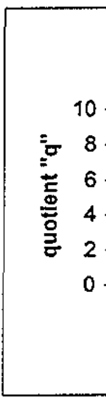
The appearance of the reversed J structure pattern does not confirm a classical case using one series data. Time series data need to be collected to enable this resultant curve be tested against the negative power function according to Hett and Loucks (1976). This would describe a classical reverse- J curve and gauge compliance of the size distribution curve. The function model being:

$$Y = Y_0 X^{-b}$$

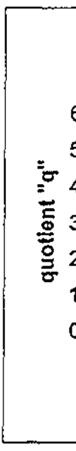
Where y is the number of stems or sapling in any diameter class X, Y_0 the initial input into the population at time zero, b the mortality or depletion rate with time.

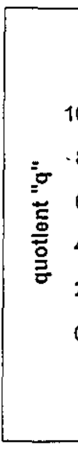
Analysis of subsequent size classes indicated how balanced the size distribution was revealing a near constant regeneration in stations B, C and D in Elangata Wuas and A and C in Kilonito (Figure 6 and 7). The near constant "q" values is indicative of a regular regeneration and recruitment that portrays balanced diameter distribution. In Kilonito on the steep slope and on the plains regeneration and recruitment is decreasing a negative sign in forest development.





Figure





Figur

The curves, reveal the ratio of the younger population to that of the adults above showing tendency towards smaller trees in station A in Elangata Wuas and Station B and C in Kilonito. Regeneration was steady with stations B in Elangata Wuas and Station A in Kilonito being the most steady. The unevenness in graduation could be due to different growth rates in the mixed specie woodland. Tree species in the same diameter class in say year X do not graduate to the next diameter class together in year X+1 in such uneven aged mixed specie stands. However, this requires further understanding of growth patterns of mixed specie semi-arid woodlands.

4.1.4 Dbh in comparison with density

Comparison of the dbh and density could reveal areas within the environmental gradient that have the wood biomass for charcoal production (Figure 8).

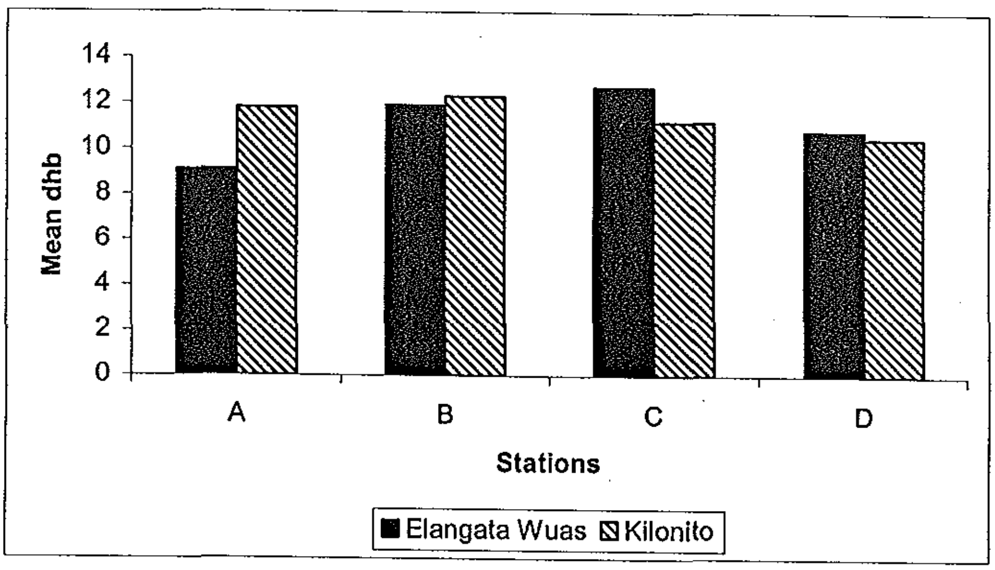


Figure 8: Mean dbh of trees in the respective stations

The plateaus has the highest density (more trees) but smaller in size looking at the average while on the steep slope and down slope (station C and D respectively) are few trees but big in size. The plains (station D) have the fewest trees but comparatively larger in size than those at the hilltop. Figure 9 shows the relative basal areas of respective tree species in the stations that reflects contribution to average size.

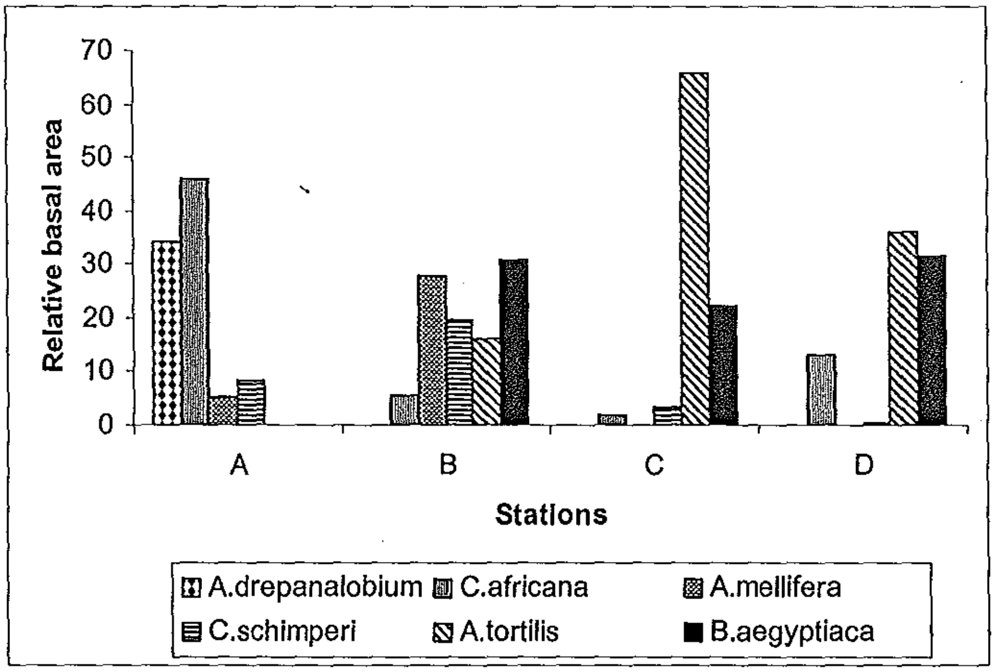


Figure 9: Relative basal areas of the dominant tree species in the stations

The size of the trees in the various stations is dependent on the dominant species present in the stations than the density (Table 4). *A. drepanalobium* one of the main species at the hilltop do not grow as large sizes as *A. tortilis and A. mellifera* in the steep slope and down slope. Dbh at the hilltops was raised by the presence of *Commiphora* species. Therefore, with regard to charcoal burning despite the presence of many trees in the hilltop, they possibly would not be candidate material for tree felling. The steep slopes and down slope contains the best tree size species for charcoal production followed by the plains. The presence of *C. africana* and *A. drepanalobium* combined with the steep slope makes charcoal production at the hilltop difficult.

4.1.5 Regeneration Status

Acacias constituted the majority of the seedlings were recorded. Regeneration was highest at the hilltops with up to 400 sph and lowest at the plains with about 80 sph (Figure 10). Seedlings of Acacias were numerous after the rains and in some instance over 400 seedlings were counted. This supports works by Coe and Coe (1987) that showed ability of African *Acacias* to produce large quantities of hard coated seeds and accumulate high density of viable seeds in the soil. There is however doubt of their ability to grow to maturity. This could be attributed to the episodic regeneration dependant on infrequent and irregular rains. The failure is more remarkable especially when assessed in relation to age-size distribution curve. Saplings are expected to be more than trees.

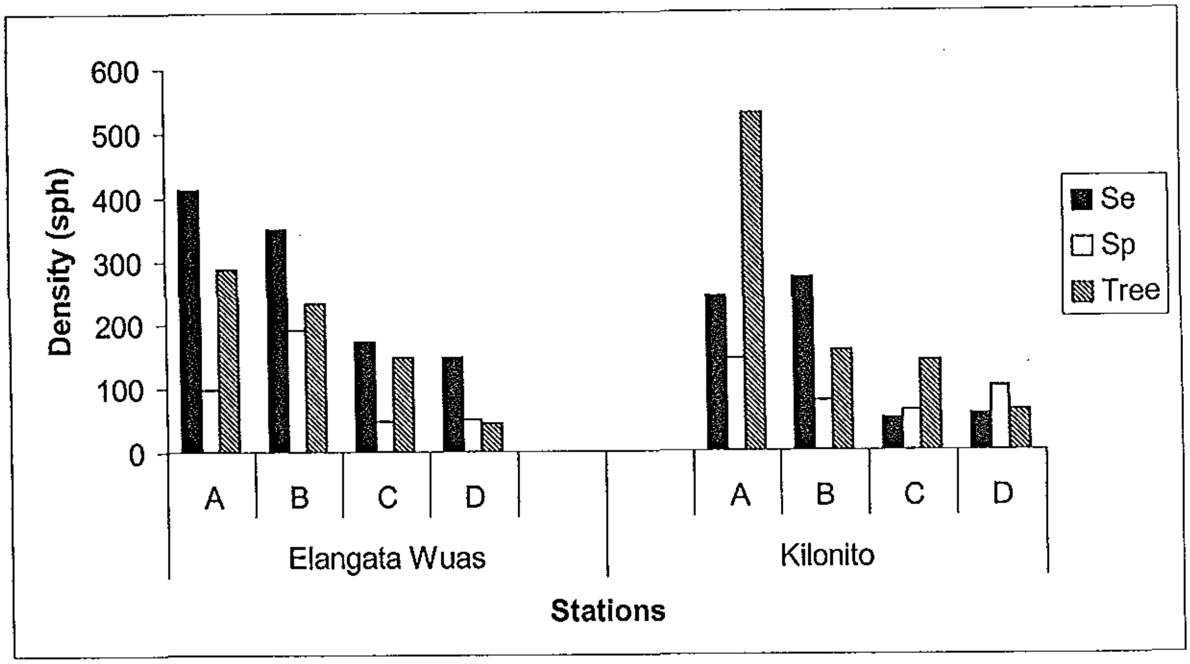


Figure 10: Règeneration status of seedlings, saplings and trees

The relative failure of saplings across the stations points to a higher degree to the dry spell rather than grazing as evidenced by higher survival of saplings at grazing zones. However, grazing and other human disturbances are impounding on regeneration and recruitment from the low sapling density in settled areas especially down hill. There is need for enclosures to understand the magnitude of grazing and other human activities on regeneration and recruitment. Activities that impacts on trees seems minimal especially at Kilonito where there are more trees than seedlings and saplings in all stations except on the plains. Tree, vulnerability at Elangata Wuas is highest at the sapling class.

In terms of the future outlook of the dry woodland, the relative densities of the six main woody species seedlings and saplings ware compared as shown in figure 11. Seedlings and saplings of *A. drepanalobium* were only in plots on the hilltop. *A. mellifera* seedlings were present in all the stations with the highest density at the steep hill and lowest on the hilltop. *A.tortilis* seedlings and sapling densities were highest down slope while *B. aegyptiaca* had high density in both seedlings and saplings across the stations with absence on the hilltop. Remarkably the density of *A.mellifera* was high at the plains while the density was very low at the tree growth form stage (Table 4). This imply very few graduate from the sapling class to tree probably due to grazing in the plains as the species could be more vulnerable compared to the others.

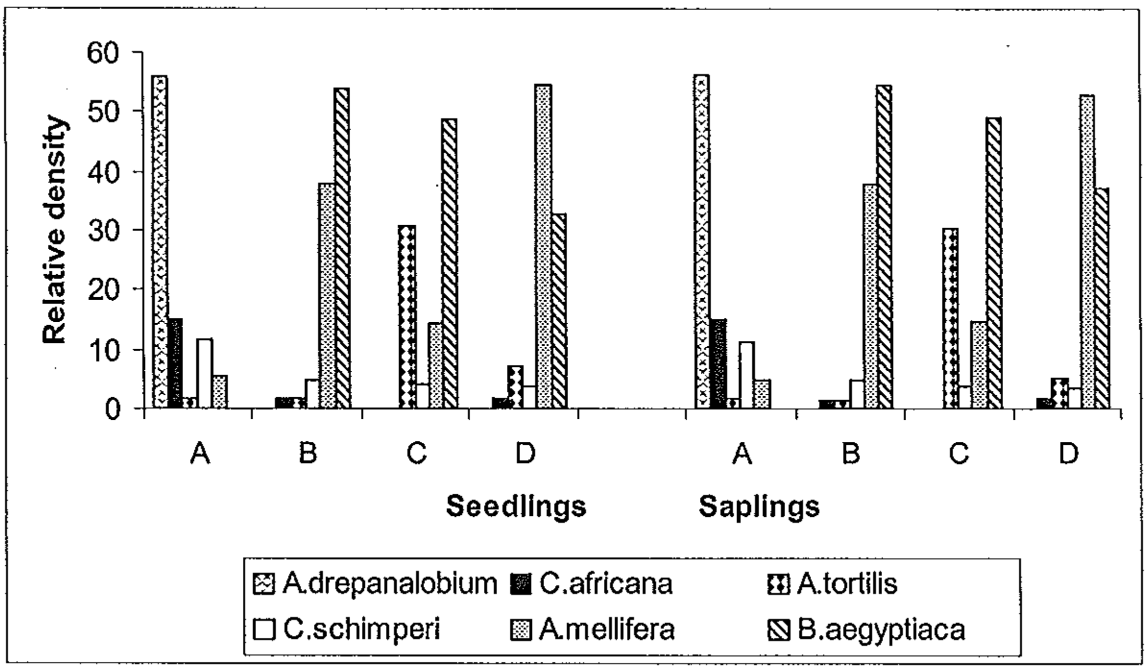


Figure 11: Comparison of species densities in the stations

Seedlings of most tree species cropped up across the altitudinal gradient with some failling to graduate to the sapling class. This demonstrates a rich and near similar seed bank within the stations. However, environmental factors inherent in the stations favor growth and development of certain species. From this analysis, *A. drepanalobium, A. mellifera, A. tortilis* and *B. aegyptiaca* will continue to future prominently in the hilltop, steephill, downhill and on the plains, respectively.

Commiphora species would gain marginally against other species because they are used for few community social activities and are also regarded as too light to be used for charcoal production. The increase in regenerates of *B. aegyptiaca* could be due to the physiology of the seeds, ability to coppice from exposed roots and adaptability because they are less browsed.

4.1.6 Indicators of anthropogenic induced disturbances

Human disturbance ranging from charcoal kiln, debarking to soil erosion was present in 34 plots out of the 72 sample plots. Six were in plots on the hilltop, 10 on the steep slope, 13 down slopes and 5 on the plains. The nature and occurrence of the disturbances are as shown in figure 12.

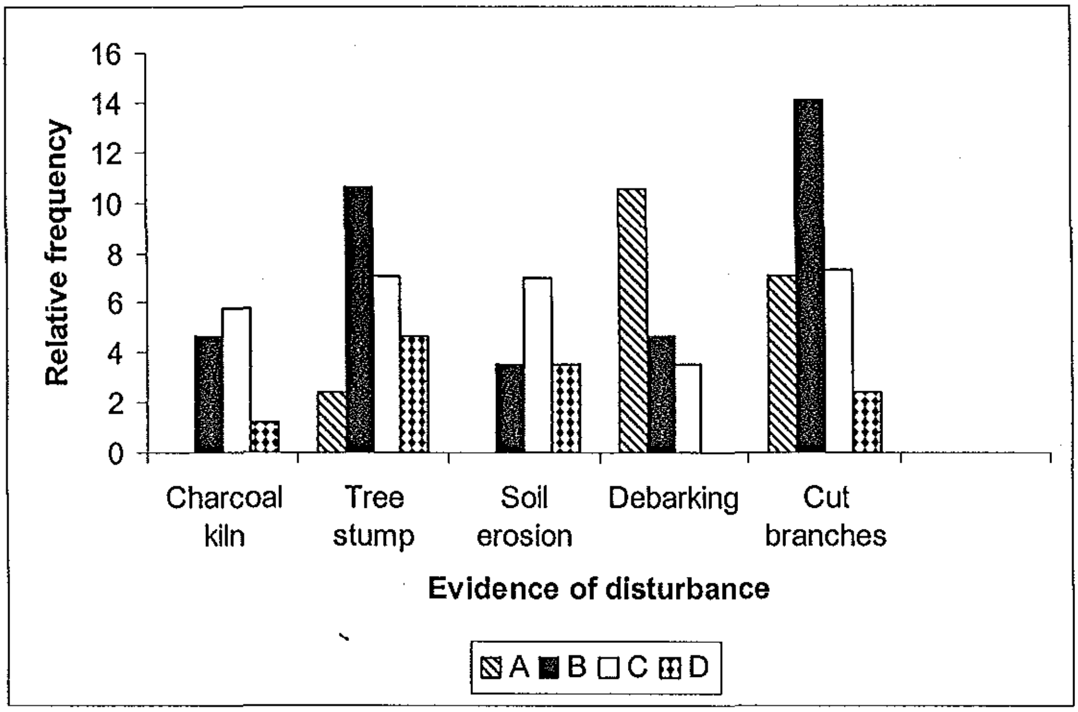


Figure 12:Showing frequency of disturbances in the stations plots

Indicators of anthropogenic-induced disturbance were highest along the steep slope and down hill and lowest at the hilltops. Disturbance at the hilltop was in the form of branch cutting and debarking for medicine. Charcoal kiln and tree stumps were numerous on the steep slope (station B) and down slope (station C) with no charcoal kilns at plots on the hilltops (Station A) and on the plains (station D).

Plots along the steep slope and down hill were affected by all the above human activities. This is attributed to homesteads found within these areas making them susceptible to anthropogenic interferences. Cut branches were mainly of *A. mellifera* that are used for fencing homesteads. Branche cutting was the most common form of disturbance and was recorded in all the stations.

Deep gully erosions cut across stations B and C beginning as small run offs along footpaths. Most roads in this station have been converted to as deep as two meters gulleys by the high intensity rainfall. Cut branches placed on the grounds to control run offs was evident in plots along the steep slope especially in Elangata Wuas indicating awareness towards disturbances and steps undertaken to curb the situation.

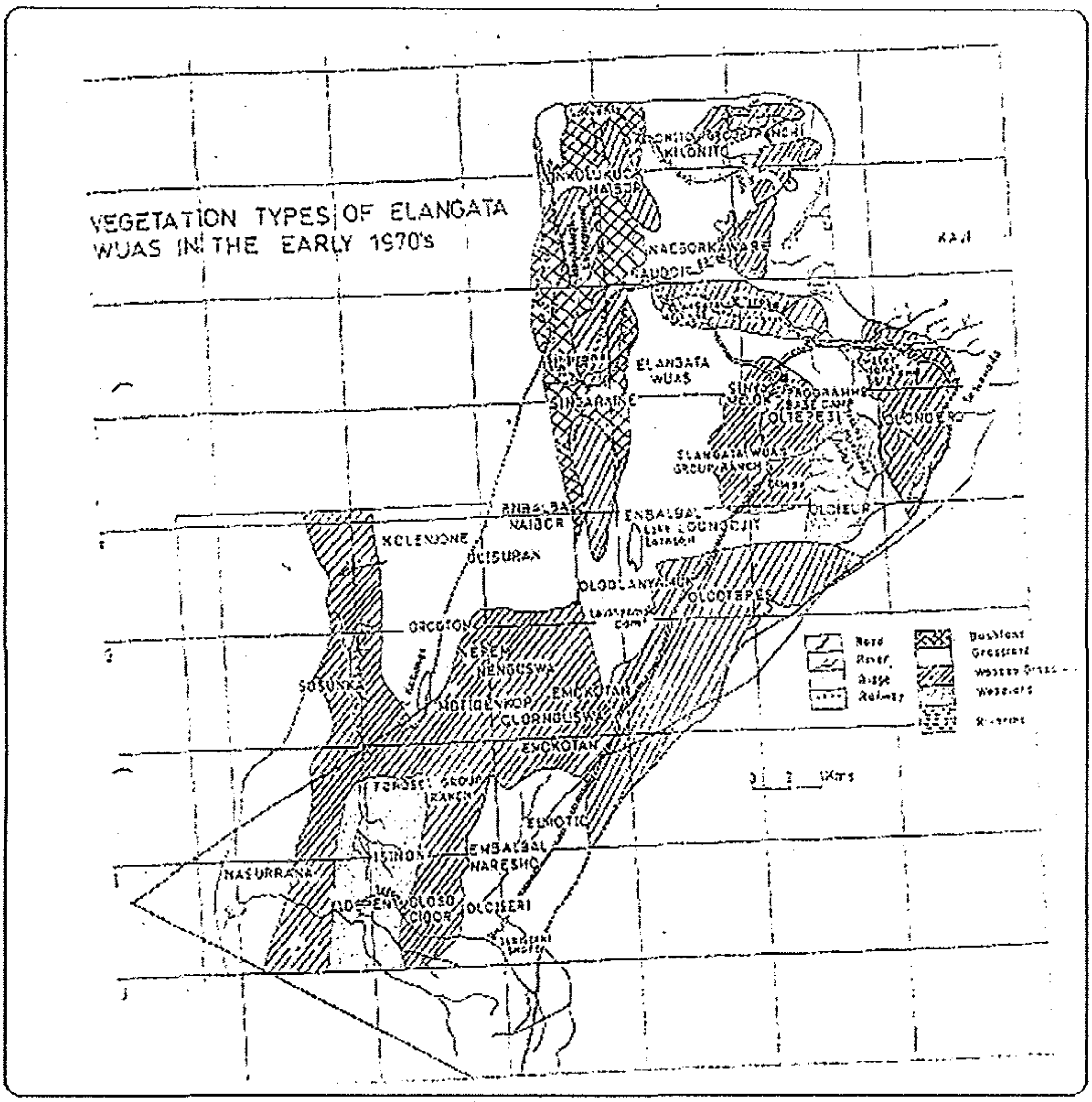
4.2 Historical perspective of dry woodland

It is postulated that changes in woodland have taken place in phases in response to various factors. The maps indicate that a dramatic change in forest cover has taken place during the past 30 years (Aerophoto systems, 2001; EWEMP 2001).

From the 1970 map (Figure 13) it can be seen that most portions of Elangata Wuas was grassland and bush land. Wooded grassland were around KMQ and Oltepesi and woodlands around Oloisur and Torosei. Kilonito was mostly bushland with occasional wooded grassland. The Year 2000 map reveals a different picture with woodlands in areas that were initially grassland and bushlands (Figure 1).

Comparison of the two aerial photographs shows the grassland and bushes occupied 65% in 1970 and had reduced to 50% by the year 2000 (Aerophoto Systems, 2001). Mapping vegetation changes of the same area by satellite imagery Ngibuini (2004) confirm that the area in the 70's was mainly a grassland region and woodlands have encroached over the years.

Figure 13: The major vegetation types in Elangata Wuas in the early 1970s



Source: EWEMP,2001b

Discussion with the elders and the camp manager at EWEM programme was consistent with information in the maps. They indicated that in the early 60's visibility was high and one could see the rooftops of buildings of the local trading center 'Mile 46' from most of their respective homesteads (*bomas*). This is now impossible even within a few kilometers to the trading center because trees have grown over.

They indicated the woodland encroachment was a process and had not occurred drastically. However, they were keen to point out that changes were not uniform as there are areas that have remained as grasslands and others were as wooded.

4.2.2 Driving forces for changes in forest type

There are a number of potential agencies that could have brought about part of the changes observed in the maps. These include climatic change, natural migration processes, changes in the disturbance regime- particularly fire frequency and grazing pressure and direct human activities.

Many elders agree woodland encroachment is due to introduction of goats and sheep. Until the early 1960's, Elangata Wuas was largely a cattle zone. Later, due to factors such as inter marriages sheep and especially goats were introduced and vegetation changes followed. Goats are reported to act as agents of *Acacia* seed dispersal distributing them over large foraging areas, a fact well supported by Coe and Beentji (1991).

Although the introduction of goats and sheep is not disputable, spawned policies to regulated land use ought to be considered. These include the ban on seasonal grass fires and charcoal production. These have led to new resource management problems in ASAL's by allowing populations of some trees such as *Acacias* to increase. The vigor and ability of *Acacias* to regenerate makes them potential weeds and may encroach on poorly managed pastures, becoming weeds according to studies by the National Academy of Science (NAS, 1984). Moreover, in such natural regeneration's the absence of heavy browsers such as elephants and giraffes that dwarf, trample and scorch seedlings of woody plants combined with the reduction of seasonal fires hastens the encroachment process.

4.2.3 Implication of woodland encroachment

Implication of woodland encroachment especially to livelihood varied widely. To others, the prime pastures that represent the base of the pastrolist life has been heavily degraded. The lowlands and open savannas lose their nutritious perennial grasses to creeping woody bushes of *Acacias* and *Commiphora* species. This has lead to a sharp decline in the carrying capacity of the range and combined with recurrent droughts to a greater risk to of loss of livestock. Therefore, bush encroachment and proliferation of aggressive woody plant species poses serious problems in the rangelands in relation to grazing.

However, others see an opportunity through improved aesthetics and charcoal burning. These would present a better chance to ecotourism, increase cash and diversify economic opportunities. To them, these are much needed intervention among rural and often poor communities. According to Elangata Wuas Ecosystem Management Programme (EWEMP), a conservation initiative working in the area, the community identified the need for an appropriate intervention to accommodate a combination between range improvement and diversifying economies through opportunities presented by the woodlands. For instance, charcoal burning could be used to open up areas that are too wooded as to inhibit grazing and ensuare the community benefits two folds. According to the programme co-ordinator, this form of intervention is in the planning stage and awaits more quantitative data and an environmental impact assessment.

4.2.4 Communities view on charcoal production

Community members including charcoal burners were aware that charcoal burning could lead to a decline of tree resources. They also took cognizant of the economic benefits derived from tree resources. On the effect of charcoal burning on the woodland status there was general disagreement. Some reported that it had reduced the woodlands immensely (this included some who reported that the area was now more wooded) while others reported a non-significant reduction.

Disagreements witnessed between elders on this question reaffirm the need for collaboration between communities and professional in natural resource management to bring to fore technical aspects. However, this disagreement is not only limited within local community members only as issues touching on charcoal production tend to be taken emotionally. During discussions with peers on the course of this study, the same trend emerged with others out-rightly stating that charcoal burning results to deforestation. Importantly, a number of community members could distinguish by names charcoal burners that had maintained their farms and others that were burning indiscriminately. This indicates that there is an inborn criterion for sustainable production that could be tapped and harnessed to determining sustainable off takes.

Community members expressed the need for development of sustainable production models. They affirmed it would attain genuine and voluntary participation of members if it tackled two main issues. First, aim to open dialogue with government on procedures that pertain to charcoal production and secondly work with community members towards an organized grouping for charcoal production enterprise. The need is supported by Sarin (1993) and Ngibuini (2001) who report that, in stimulating joint forest management effective local institutions have to be created as viable units of organization. These have to be functional units with clearly defined norms and ability to carry out management functions.

Based on the findings, it is clear that community members have vested interest to participate in the management of tree resources.

4.2.5 Implication of sub- division on woodland status

Community members are divided as to the implication of the ongoing subdivision to natural resource and livelihood support. Some are optimistic that subdivision will lead to better resource use and trees will be more protected. For instance, some people produced charcoal because it was not in their land and production would be scaled down by the current land subdivision and subsequent individual allocation.

Analyses reveal land under the group ranches was more of communal management than community management. In systems of communal management, access is more closed reserved exclusively for members of the group and no other. While in community management access is more open, more inclusive of the whole. According to FAO (1993), the term community includes all people living in one place (village) but communal refers to different people in a community with common interest to a discreet part of the community. In the group ranches of Elangata Wuas and Kilonito not every community member was a member of the group ranch but, it composed of registered families and later individuals within Elangata Wuas division. Thus, the group ranch system was a communal entity. The group ranch committees had enormous powers and sanctioned activities. Such communal powers for example ensured that the neighboring communities did not convert trees to charcoal.

In essence, community members that support individual land ownership would identify with Hardin's school of thought of the 'tragedy of the commons'. They view the group ranch collective management as being destructive and leading inevitably to over exploitation of resources. This was one of the main arguments that culminated to the government disbarnment of the group ranches. On the other hand, those who support the group ranch and believe it did not lead to destruction of the environment would identify with Wade (1987) and FAO (1993). Both argued that Hardin confused collective management and open access situations. Their works demonstrate that there is a role for collective action in resource management in both resource utilization and nature conservation. To proponents, the group ranches were a complementary management system and the effects of their dissolution would emerge later in resource over-exploitation and lack of resource management co-ordination.

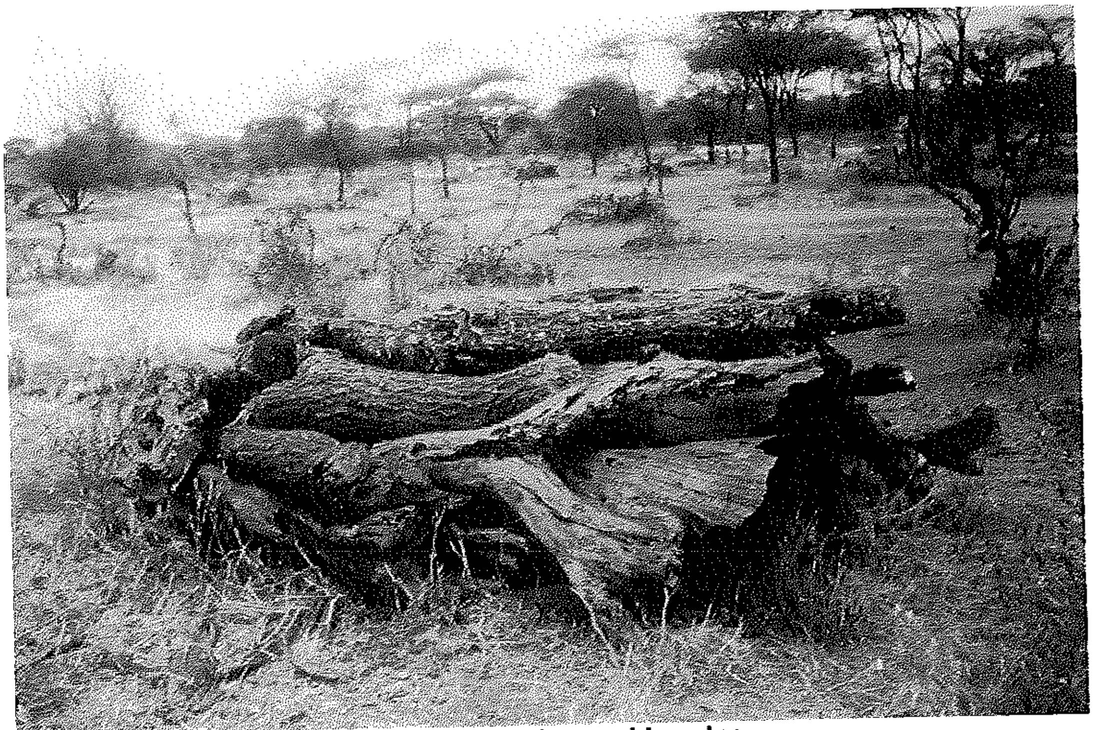


Plate 4: Stake of Dry *A.tortilis* awaiting charcoal burning

The carbonization process takes between 4-6 days after which it is allowed to cool. Research carried out elsewhere reveals that it may take only two to four days (Githiomi, 2000). Dense white smoke is emitted indicating that the carbonization process is progressing well. After carbonization the kiln would sink to about a third of its original height and the smoke emitted would be thin and reduce in amount. Once cool they are packed in sacks as shown in plate 5 and transported using donkeys to local middle people or to merchants during market days. Some kilns are partially harvested due to impromptu buyers and during market days for immediate cash. In partial harvesting, the kiln is put off and ready charcoal selected and packed. The remaining is covered up to complete the carbonization process.

So far, the gains or the losses made under the group ranch system can be assessed but we await and can to some extend pre-empt the impact of the individual land system in this pastoral community. However, whatever management style evolves in the feuture it needs to be participatory and directed towards rural needs.

4.3 Charcoal production

4.3.1 The kiln

The traditional earth kiln is prepared on flat ground with occasional clearing close to felled trees. A lighting zone of about a foot deep is dug and wood placed perpendicular with no particular arrangement of log according to size but rather to obtain stake with few spaces plate 4. The kiln is completely covered with grass and a layer of soil leaving the lighting point uncovered. Once the woods at the lighting zone catch fire, the lighting point is also closed using grass and then soil.

4.3.2 Labor

From the sixty-one kilns 40 kilns were managed by women and 21 by men. Men made big kilns tending to increase from the source of lighting while women had smaller kilns thus tending to be square. Women given house work lack sufficient time to engage in cutting more/larger trees compared to men. This is further exemplified by the mode of cutting the trees where majority of the women lit the base of the trees while men cut physically with 'pangas' (Machete) and axes.

Women mostly carry out charcoal activities by themselves with occasional help from their younger children. However, a majority of men engage laborers in the activities and share profits on a 50-50 basis. If twenty bags were harvested collection from ten bags would go the laborers. Laborers are often not indigenous residence. Majority come from the neighboring Eastern province the Kamba. The community has practiced charcoal burning for a long time.

Charcoal activities include cutting and chopping trees, wood arrangement, covering with soil, monitoring (between lighting time to complete carbonization), packaging into sacks and transporting to the market/ middlemen yards.


Plate 5: Maasai women packing charcoal into gunny bags

4.3.3 Species preferred for charcoal production

Out of the 33 tree species observed during the study (appendix 7) there was segregation of species for charcoal production with the following species preference: -

Table 5: Species preferred for charcoal production inorder of preference

Maa Name	Scientific Name	Points
Oltepesi	*Acacia tortilis*	280
Oiti	*Acacia mellifera*	192
Olng'osua	*Balanites aegyptiaca*	177
Oisiyiamalili	*Acacia etbaica*	138
Olderkesi	*Acacia seyal*	132
Osaragi	*Balanites glabra*	113
Olerai	*Acacia xanthophlea*	101

Inorder from the most preferred

The above species are preferred based on their high heat content value and the long duration of time in burning during consumption. Preference of species is also influenced by availability. *Acacia xanthophlea* scored the least because it is scarce due to its riverine nature, making it unavailable while *B. glabra* is mostly found in Kilonito. Selectivity in woodfuel tree species could result in localized scarcities of the preferred species as preference is first driven by availability of mature *A. tortilis* and *A. mellifera*. The study found *B. aegyptiaca* to be a fill-up species to increase the size of the stake and not a motivating species towards charcoal production. It was present in all kilns apart from the seven single log kilns of *A. tortlis* and five pure stakes of *A. tortilis* and *A .mellifera* leading to very high cutting and use in charcoal kilns figure 14. However, *B.aegyptiaca* has high calorific value but is probably not favored because of its crumbling nature. Among the minor tree species in charcoal kiln were *Cordia monoica* and *Cordia synesis* noted in two and three kilns respectively.

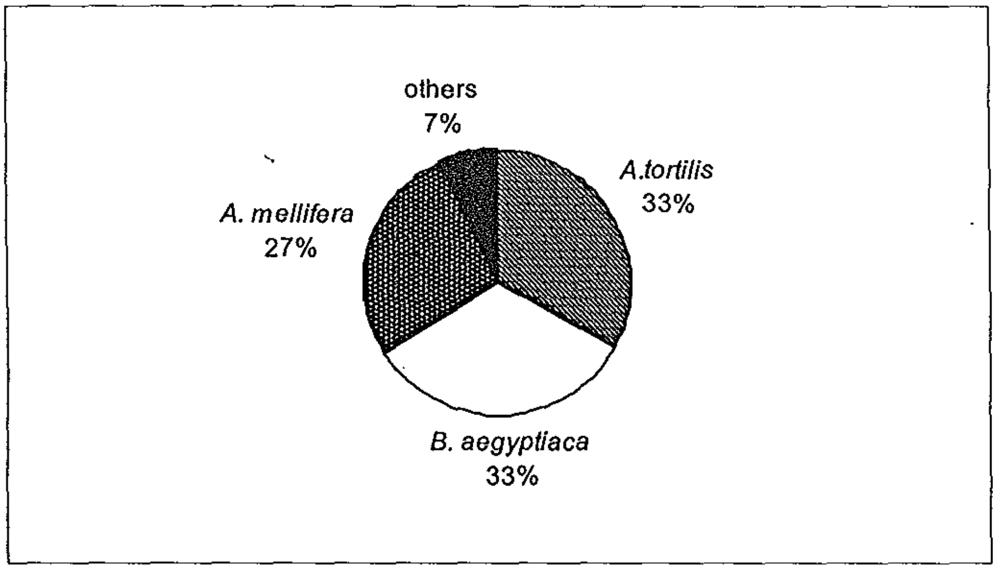


Figure 14: Percentage of trees by species cut for charcoal production

Other than preference for species, there is preference for trees of a particular size (Figure 15). Trees of basal diameter 11- 30 cm accounted for over 55 %. Majority of the trees cut were in diameter class 16-20 cm accounting for 28 %. Charcoal production studies complimented by field studies in Kenya showed that wood species with diameter of 5 cm were considered reasonable; a 2 cm base limit was shown to provide realistic assessment in Uganda (Uganda

Forestry Department, 1992). Majority of trees cut for charcoal production are of a diameter less than 12cm in drylands of Kenya (Lumasia, 1996). Woody species with less than 5 cm stem diameter were considered unsuitable and often uneconomical for charcoal production.

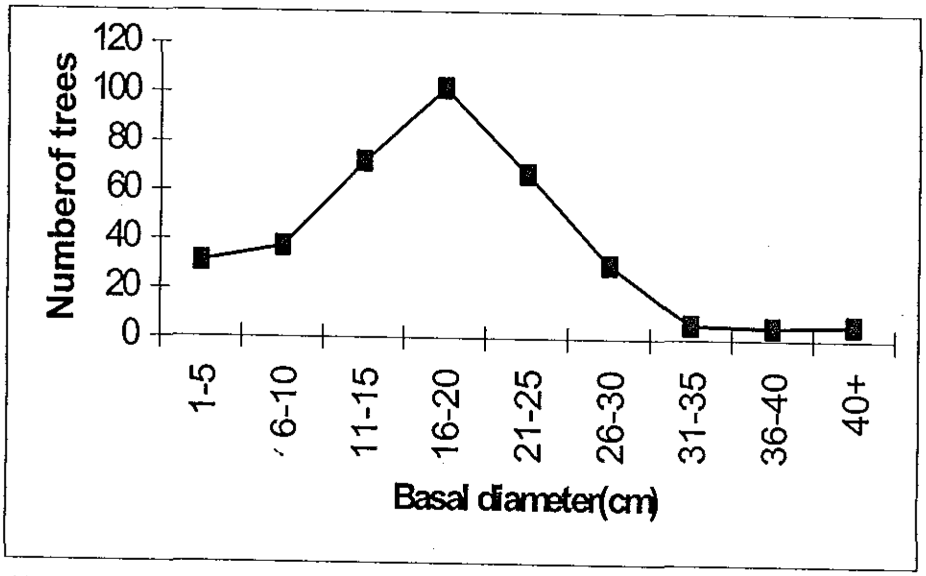


Figure 15: Basal diameter of cut trees for charcoal production

There is need for larger size trees to obtain more charcoal but this is curtailed by availability as evident from the woodland status data. Evident in the charcoal production is the mixed species non-uniform size structure of the woodland. The only uniform basal diameter kiln were the seven single log kilns of *A. tortilis* demonstrating a mixed species woodland.

Thus, in relation to preference, the choice of the tree used is guided by the availability of charcoal tree species and in particular *A. tortilis* and *A. mellifera.* Secondly, trees of merchantable size (>11cm dbh) and thirdly, need to obtain a high stake to guarantee more charcoal. The later accounts for the lower basal diameter size trees cut.

4.3.4 Charcoal recovery

Charcoal recovery stood averaged 8 % with the lowest recovery at 4.2 % and the highest at 17 % (Fig. 16). Over 65 % of the kilns had recoveries ranging between 6-11%. The average was lower than the nationally recorded 10% from the study by Beijer (1980) but was within the range of the MOE studies (2002) of 10-20%.

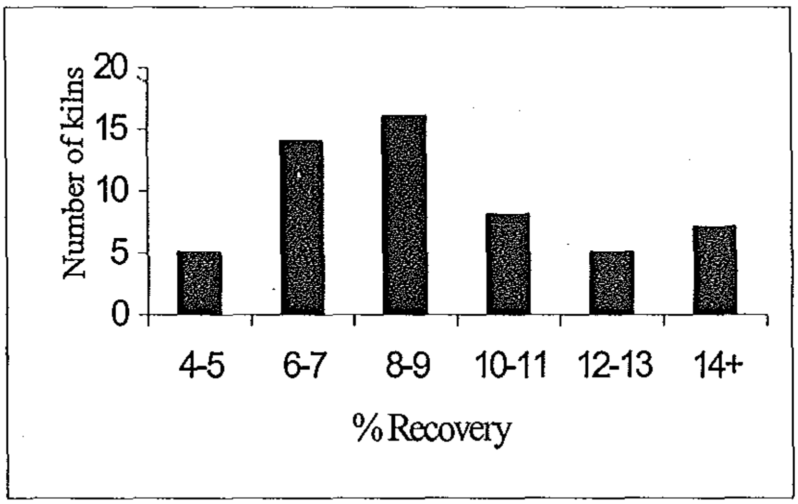


Figure 16: Charcoal recovery from traditional earth kiln

Partial harvesting accounted for majority of recoveries below 6%. The professional charcoal burners specifically those from the Kamba communities had charcoal recoveries of over 12 %. This was due to consistent monitoring during carbonization and experience in charcoal burning. The findings are in agreement with French (1986) who noted in a series of trials in Malawi that carefully tended earth kilns produced charcoal at higher efficiencies up to 24.2%. Most of the indigenous people are relatively new in the exercise and are learning the trade. The study associates low recoveries to lack of experience and workmanship. Over 30 % of the kilns had recoveries over 10% in line with traditional earth kiln averages.

Other than efficiency in burning, low recovering could also be attributed to collection or harvesting process. It was observed that a lot of charcoal was left behind when packing into sacks for subsequent sale. The charcoal burners were not keen enough to collect all the charcoal recovered during carbonization process. It is thus paramount that future studies document this remaining amount. Moreover, other people do not come back to collect the charcoal pieces as is often the practice with charcoal kilns close to urban centers due to the availability of firewood which is the main source of household energy.

At an average 8% recovery, 337 charcoal bags were produced from 356 trees of the different basal diameters from the 61 charcoal kilns studied. The ratio of tree to charcoal bag is 1: 0.95. That is, one tree produces slightly less than one 36-kilogram sack. If recovery was improved and operated at 20% efficiency, a ratio of about 1: 2.38 would be achieved. That is, one tree would produce approximately over two charcoal bags. Assuming the 61 kilns used in this study were operated at 20% efficacy we would require approximately 141 trees from the mixed semi-arid woodland to produce the same number of charcoal sacks theoretically saving 196 trees.

An equivalent of over 6,000 trees would be saved annually. In addition, if permitted to grow in their habitats, the trees would continue to support millions of biodiversity and produce tons of oxygen among other benefits.

4.3.4 Cost of tree

On the cost of the trees, over 70 % of the charcoal burners (n=61) regarded trees as available and free access resource with 30% taking time to calculate how much they would obtain if they converted the tree to charcoal.

This reflects the relative ease at which trees are obtained. This could go a long way to undermine incentive for improved charcoal recovery. The lack of the wood biomass cost in terms of the cost of purchasing the tree holding other costs constant means that they could make profits at any level of efficiency. For this reason, they may not be inclined to be more economical in the use of the resource.

4.3.5 Number of charcoal bags produced from the area

The average number of charcoal bags transported per month varied widely. Charcoal is often transported as a secondary good by lorries and is dependant on availability of space. During some months strict surveillance by company managers reduce the amount transported. Charcoal bags remain in the yards for long periods of time and concurrently production reduces.

The average number per month was stood at 1100 ± 230 (Fig. 17) bags giving an annual production of approximately 13,200 bags.

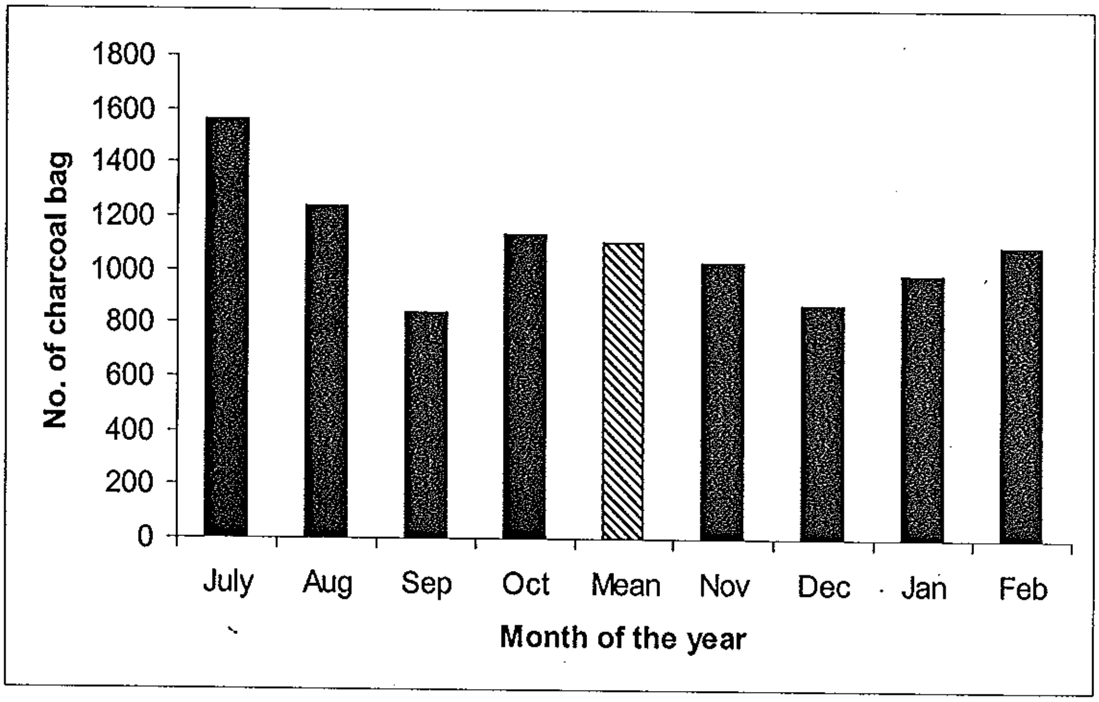


Figure 17: Monthly number of charcoal bags produced

The earth road becomes impassible especially during the two rainy seasons (May –June and August- September). Production also decreases during holiday seasons such as December and January as quarrying is scaled down. However the subsequent months have high transportation due to demand and pile up. Thus, transportation and subsequent production is greatly influenced by climatic conditions, communal activities and calendars of the mining companies.

4.4 Charcoal production in relation to the woodland status

4.4.1 Availability of wood stocks

a) Estimates from production mode

One indicator that points to availability of wood biomass is preference to *A. tortilis*, *A. mellifera* and *B. aegyptiaca* species in charcoal making. In general, most tree species in Elangata Wuas can be used for charcoal production. If wood biomass were low the order of prefence would decrease with the less preferred species such as *Commiphora* also used. This means that when suitable wood species are cleared any other species can be cleared to meet the charcoal demand. However, use of preference to determine availability of woodstocks fails to quantify. For instance how much of this wood biomass is available, for how long and at what production level?

b) Estimates from standing wood stocks

Though analysis of tree density is important from a harvesting and relative value perspective, the most important component of value for charcoal production is the amount of merchantable material per hactare. It can be seen in section 4.3.3 that charcoal production targets trees of ≥ 16 cm dbh. Table 6 below indicates the available wood stock with disregard of species of ≥ 16 cm dbh in the various stations.

Table 6: Density of trees ≥16cm dbh in the stations

Station	Elangata Wuas (sph)	Kilonito (sph)
A (hilltop)	33	149
B (Steep hill)	84	71
C (Down hill)	53	33
D (Plains)	16	11

Charcoal production is not carried out in all these stations. Areas where wood biomass is obtained for charcoal production are the steep hill, down hill and the plains. The hilltops are relatively inaccessible for charcoal production and *A. drepanalobium* and *Commiphora* species abundant in the areas are not preferred for charcoal production.

The steep hill, down hill and the plains have an average tree density of 45 sph (≥16cm dbh). This is the potential wood biomass that could possibly be converted to charcoal. In the 9,000 hectares therefore, there is approximately 405,000 trees. With tree to charcoal conversion ratio of 1: 0.95, the 405,000 trees in the area if burned could produce approximately over 384,750 charcoal bags (Charcoal bags used in this estimates/ study weigh 36 kg) if clear felled. At average production of 1,100 bags per month the 384,750 charcoal bags can be produced for approximately 349 months. That is, 29 years theoretically holding other things constant and assuming annual biomass increment and recruitment.

b) Estimates using annual increment rate

The Kenya Forestry master plan (MENR/FINNIDA, 1994) reports an annual woody biomass increment rate for the programme area of 0.23 m^3 per hectare. This is 22,500 m^3 annually for the area. This is amount available for domestic use and other purposes.

Community members rely on firewood and cut trees for other domestic use especially building. MOE study (2002) revels domestic firewood consumption of 3,527 kg / household / year on Low Potential Zone (LPZ) areas such as Elangata Wuas. With a population of 1,810 households 6,383,870 kg (4560 m^3) of wood is required for domestic cooking and at most 5,000 m^3 for other domestic purposes such as building. That is, 10000 m^3 annually is required for domestic purposes.

If domestic fuel wood requirement is off-taken a balance of 12,500 m^3 is potentially available for charcoal production annually. At 8% recovery rate the wood biomass yields 1,000 m^3 of charcoal annually assuming all was used for this purpose. It translates to 1,400 tonnes or 38,800 charcoal bags annually. That is, 3,200 charcoal bags per month. Currently, at most 1,600 sacks are produced per month.

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

(i) The woodlands are healthy as the structure conforms to the reversed J shaped distribution, a response curve observed under undisturbed conditions. Supply and demand is balanced at the aggregate and the woodland structure could sustainably bear increase in production to a certain extent.

(ii) Points of discontinuity can be distinguished in tree species along altitudinal gradient. With careful characterization of tree species precise management plans can be developed with indicators for assessing and monitoring sustainability at specific sites.

(iii) Charcoal burning would not be the only factor to determine equilibrium or non-equilibrium only that natural factors are less likely to create such impacts. The impacts are likely to be anthropogenic, interacting with natural phenomena. One hypothesis for example is that the current subdivision of the former group ranches into individual holdings could set in a new woodland dynamics that could work for in the case of farmers protecting trees and seedlings more or disrupt with sale or move to other land uses. Understanding such interactions is likely to be the key to understanding dry woodland dynamics.

(iv) The major problem associated with charcoal is in the kind of losses incurred in its production. The earth kiln used are about 10% efficient, implying that in the process of producing charcoal from wood, 90% by weight is lost. From 100 tonnes of wood therefore, one only expects to get 10 tonnes of charcoal.

(v) Harvesting methods segregate on tree species, size and the need to obtain a high stake.

(vi) The relative ease at which wood is sourced could discourage prospects towards better charcoal production methods. The lack of the raw material cost in terms of the cost of purchasing the tree means that they can make profits at any level of efficiency, and for this reason, they may not be inclined to be more economical in the use of the resource.

(vii) While tree stamps, abandoned charcoal kilns and numerous bags of charcoal may be detected in charcoal yards especially in the towns, these are only a small part of a complex chain in the process of deforestation. Therefore, the notion that charcoal burning is a major contributor to deforestation in Kenya needs to be questioned.

5.2 Recommendation

What ought to be done thus focus on minimizing problems arising from the dominance of the negative tendencies in the core areas to ensure conservation of tree resources and livelihoods continue to be supported.

In this regard the following need to be undertaken: -

5.2.1 Research recommendations

a) Reconcile state management objectives and local communities objectives

Objectives of forests management have been concentrated within the traditional lines; forests protect catchment areas, bring rain, hold soil, improve aesthetics and the like. While this is undoubtedly important, local communities are mostly interested in small-scale wood as well as non- wood use for their subsistence.

Joint forest management strategic planning is vital to reconcile state forest management objectives and local community objectives. It should among its aim ensure that communities living around resources and who bore the cost of conservation derive direct economic benefit. There is need to re-assess the value of forests in general to reflect these direct benefits propelled through micro-enterprise development around wood and non wood forest products re-defined in policy and implemented through community based forest management. This remains a priority.

b) Enforcing use of efficient kilns

With traditional earth kilns at best having a recovery rate of 17% from this study, the kinds of losses incurred in its production is massive. The study recognizes an entry point in policy and legislation to enforce implementation of improved charcoal conversion methods that are being neglected on additional production cost grounds. It must be emphasized that a mechanism be entrenched that only allows those with improved charcoal kilns engage in the practice. Technologies currently exist (See appendix 8) that can enable 20% conversion efficiencies.

Such steps are likely to be regarded as hard hearted. However experience in other sectors (as the radical changes in the public transport sector in Kenya in 2004 through a legal notice) has shown to be highly effective. Similar steps are necessary to save the natural resources even if by small margins.

c) "Boma" enclosures and "Mbuzi" woodlots

"Boma" is a Swahili word for an area used to close up cows especially at night. Usually goats or "mbuzi" are put in similar enclosures but these are smaller in size. In the natural system, seedlings increased after the rains indicating viability of seeds. However, the number and recruitment into successive age class decreased. Although seedling and sapling management is not a common practice in the pastoral communities, "Boma" enclosures of about 1 ha are advocated for to ensure high survival chance.

Taking into consideration the difficulties of raising seedlings in drylands, small woodlots referred to as "Mbuzi" woodlots (0.25 ha) are recommended in private farms. Efficient enrichment planting and controlled harvesting for charcoal will improve charcoal supply greatly. A higher return can be obtained if use of high yielding species such as *E. camadulensis* and better management are adopted.

d) Selectivity with enforcement

Given the difficulty of applying cutting cycles in natural regeneration, selective cutting based on low impact harvesting entrenched in enforcement remains the option. In selective cutting, each tree is selected on the basis of a selective regime in the case of charcoal production and suitability for the intended purpose for any other use. Area specific selectivity regime should be developed for prioritization in accordance with creterion such as the one proposed below: -

Category 1: Very high value/ of cultural importance

Category 2: Straight well formed

Category 3: Branched/ Multi-stemmed

Category 4: Dead and dry

Category 5: Wood encroached areas

Selectivity for charcoal production should begin with the lower category (category 5). However, selectivity can be influenced by other factors such as an increase in the net price of charcoal or increased poverty among harvesters that reduce selectivity and cause overexploitation of woodlands. Therefore a system of surveillance and regulation enforcement should be in place. This should be by informed and trained community member's/scouts to backstop efforts of the forest department.

e) Energy Switching

While fuelwood supply- demand situation is finely balanced, it would not meet the demand if increase in urban population were followed by en masse switch to charcoal.

Thus, alternative fuels such as biogas, butane gas together with the introduction of improved stoves need to be sought. With the potential for energy switching reawakened in Kenya especially with neighboring Sudan exporting oil, its success will largely depend on purchasing power, political commitment, the resolution of conflicts of interest and whether other commercial fuels are easily available.

5.2.2 Management recommendation

a) Making of legislation and policies enabling rather than restrictive

For fuelwood as energy source to contribute to sustainable development in Kenya, policies and strategies must address the linkages between energy and social issues. Legislation is based on the assumption that it damages the resource; while this is undoubtedly true in a number of cases, by no means is it an accurate reflection of all charcoal harvesting regimes. On this note, wide ranges of state-sanctioned control are brought to bear on the use of woodland resources for commercial purposes. In many cases, these controls and often bans have been marked by failure or created and artificial scarcity.

There is need to make legislation affecting natural resource use by communities enabling than restrictive. An important element will be policy reforms, which empower communities to control and utilize resources within their areas, and facilitate the emergence of functional local resource management capacity. Devolution and decentralization of authority, to give power to community level decision-making, control and capacity should follow. This requires that communities attain a considerable level of authority as that demonstrated in Tanzania and needs to go further by helping them make full use of the administrative and statutory powers once they are in existence.

This will involve setting targets for fuel wood offtakes (as well as other offtakes) based on the woody productivity that enables both the ecosystem and the village economy to continue at current or enhanced levels of production.

b) Exploring other micro-enterprises

It would be naïve to imply that sustainable charcoal production could be achieved as long as it subsidizes the existing pastoral economy. Sustainable charcoal production would only be achieved in the existence of other income generating micro-enterprises that would help relieve the woodland out of the livelihood pressure. In the wake of survival people would cut the only tree even if it were the one they use for shelter if they have to eat. Therefore enhancing micro-enterprises within dryland community areas such as the women's art in beadwork, sand harvesting, milk processing among others offer hope for a sustainable future.

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Appendix

Appendix 1 **Woodland assessment field data sheeet**

Date________________________________

Site: A Plateau, B- Steep slope, C- Down slope, D- Plain

Transect station A☐ **B**☐ **Plot No:**________________

A. Trees

Tree species	Dbh (cm)	Tree species	Dbh (cm)

B. Recruitment - Sapling (Sp) and Seedling (Se) counts

Species	Sp	Se	Species	Sp	Se

C. Evidence of Disturbance in plot

Nature of disturbance	Present/Absent	No	Comment
1.Charcoal Kiln			
2.Tree cutting			
3.Soil Erosion			
4.Debarking			
5. Stem cutting			
6. Others			

Any other observations

____

____

____

____

____

Appendix 2: **Charcoal Recovery information collection sheet**

Block: ____

Date of kiln arrangement: _____/ _____ / 2003

Species	Basal diameter	Species	Basal diameter	Source

Length of kiln: ________________________

Width of Kiln: ________________ Height : _____________

Date of charcoal harvesting _____ / ______ / 2003

Bag No.	Weight in Kg	Bag No.	Weight in Kg
1.		11.	
2.		12.	
3.		13.	
4.		14.	
5.		15.	
6		16.	
7.		17.	
8.		18.	
9.		19.	
10.		20.	

Appendix 3: **Charcoal traffic survey sheet**

Center: ____________________ Date: ________________

Survey No. ________________

DATE	TIME	MODE OF TRANSPORT	No. of Bags

Appendix 4: **Guidelines for discussion on the history of Elangata Wuas Woodlands**

Questionnaire No. ____________ Block: __________ Date: _________

i) How would you describe the vegetation of Elangata Wuas until the 60's?

____

____

____

ii) How would you describe it now?

____

____

____

iii) Is there any difference between the two?

YES ☐ NO ☐

iv) If Yes which ones

____

____

____

v) In terms of tree composition are there new species that have come up?

YES ☐ NO ☐

vi) If yes which ones?

______________________ ______________________

______________________ ______________________

______________________ ______________________

______________________ ______________________

vii) What could have brought about this change?

____

____

____

viii) Would you describe Elangata Wuas as

- ☐ More wooded
- ☐ Less wooded
- ☐ Remained the same

ix) Is there any implication to livelihood to the difference or similarity you described above?

YES ☐ NO ☐

x) If yes which one?

____

____

____

xi) What is your view on charcoal production in Elangata Wuas?

____

____

____

xii) When did the local community begin getting engaged in charcoal production?

____

____

____

xiii) What prompted it?

____

____

____

xiv) Would you regard the current production to be sustainable?

YES ☐ NO ☐

xv) Why?

____

____

____

xvi) Is sustainable charcoal production possible?

YES ☐ NO ☐

xvii) Do you think the current land subdivision will affect the woodlands?

YES ☐ NO ☐

xviii) If yes in which way?

____

____

____

xix) If No why?

____

____

____

xx) Compare the group ranch system and individual land management, which do you, think supports better resource management?

____

____

____

xxi) Why?

____

____

____

Appendix 5: **Density - Size distribution table**

i. Elangata Wuas belt transect

dbh Class	Station A sph	Station B sph	Station C sph	Station D sph
5-9	184	80	51	20
10-14	67	67	42	9
15-19	18	36	31	4
20-24	16	31	18	2
25-29	0	11	2	7
30-34	2	2	2	2
35-39	0	2	0	0
40+	0	2	0	0

ii. Kilonito belt transect

dbh Class	Station A sph	Station B sph	Station C sph	Station D sph
5-9	193	38	51	33
10-14	187	69	53	20
15-19	104	40	22	9
20-24	31	7	9	2
25-29	11	0	2	0
30-34	2	2	0	0
35-39	0	0	0	0
40+	0	0	0	0

Appendix 6: **Distribution of woody species according to their dbh**

Elangata Wuas transect									
Station A	**5-9**	**10-14**	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40+**	**Total**
A.drepanaloibium	55	14	1	1	-	-	-	-	71
C.africana	17	2	5	3	-	-	-	-	27
C. schimperi	11	12	2	3	--	-	-	-	28
A. senegal	-	1	-	-	-	-	-	-	1
A. seyal	-	1	-	-	-	-	-	-	1
Total	**83**	**30**	**8**	**7**	-	-	-	-	**128**
Station B									
A. tortilis	2	3	4	3	2	1	1	1	17
B. aegyptiaca	26	18	4	2	-	-	-	-	50
C. schimperi		4	5	8	3	-	-	-	20
A. mellifera	2	4	3	1	-	-	-	-	10
C. africana	6	1	-	-	-	-	-	-	7
Total	**36**	**30**	**16**	**14**	**5**	**1**	**1**	**1**	**104**
Station C									
A. tortilis	1	6	8	7	1	1	-	-	24
C. africana	1	1	-	-	-	-	-	-	2
B. aegyptiaca	19	8	3	-	-	-	-	-	30
A. mellifera	-	3	-	-	-	-	-	-	3
C. schimperi	1	-	3	1	-	-	-	-	5
A. etbaica	1	1	-	-	-	-	-	-	2
Total	**23**	**19**	**14**	**8**	**1**	**1**	-	-	**66**
Station D									
A. tortilis	-	-	1	1	2	1	-	-	5
B. aegyptiaca	4	2	1	-	-	-	-	-	7
C. africana	1	2	-	-	1	-	-	-	4
A. mellifera	1	-	-	-	-	-	-	-	1
A.drepanalobium	3	-	-	-	-	-	-	-	3
Total	**9**	**4**	**2**	**1**	**3**	**1**	-	-	**20**

Appendix 7: **List of woody species identified**

MAASAI NAME	SCIENTIFIC NAME	FAMILY NAME
olpante	*Lannea schweinfurthii*	Anacardiaceae
Oolpante	*Lannea schweinfurthii*	Anacardiaceae
oloteti	*Adenium obesum*	Apocynaceae
Olngosua	*Balanites aegyptiaca*	Balanitaceae
Osaragi	*Dobera grabra*	Balanitaceae
Oldorko	*Cordia sinensis*	Boraginaceae
Olailupai	*Commiophora schimperi*	Burseraceae
Osilalei	*Commophora africana*	Burseraceae
Olapalases	*Boscia coriaceae*	Capparaceae
Olaturrudiri sapuk	*Capparis fascicularis*	Capparaceae
Oloireroi	*Boscia angustifolia*	Capparaceae
Olmaroroi	*Terminalia brownii*	Combretaceae
Olmaroroi	*Combretum molle*	Combretaceae
Olenarraan	*Euclea divinorum*	Ebenaceae
	Acacia seyal	Mimosoideae
Oljurai	*Acacia mellifera*	Mimosoideae
Oldepe	*Acacia nubica*	Mimosoideae
Olderkesi	*Acacia senegal*	Mimosoideae
Olerai	*Acacia xanthophloea*	Mimosoideae
Olliloriti	*Acacia nilotica*	Mimosoideae
Olmungutan	*Albizia anthelmintica*	Mimosoideae
Olperrelongo	*Albizia amara*	Mimosoideae
Oltepesi	*Acacia tortilis*	Mimosoideae
Oluai	*Acacia drepanalobium*	Mimosoideae
Osiyiamalili	*Acacia etbaika*	Mimosoideae
Olngaboli	*Ficus syncomorus*	Moraceae
Oreteti	*Ficus capensis*	Moraceae
Oreteti	*Ficus thonningii*	Moraceae
Olorien	*Olea europeae ssp. Africana*	Oleaceae
Olgarrooji	*Erythrina abyssinica*	Papilionoideae
Olngarooji	*Erythrina abyssinica*	Papilionoideae
Olkarasha	*Sterculia stenocarpa*	Sterculiacea
Oltimigomi	*Pappea capensis*	Sapindaceae

Appendix 8: **Improved charcoal kilns developed for community use**

KILN	SHORT DESCRIPTION	SOURCE
Improved earth kiln	Improvement of the traditional earth. Better arrangement with larger diameter wood pieces placed closest to the lighting zone then covered with light iron sheet to reduce defilement and continuation of charcoal with soil. Has two chimney KEF	Trials done in Kibwezi Kenya. KEFRI, Belgium Technical corperation and FD (2000)
Casamance kiln	Modified earth kiln. Kiln stacked in a circular way an air channel made across the cirle to assure airflow in the mould. Largest pieces of wood placed in the centre standing upright and medium and small pieces around the one chimney.	Work done in Senegal. FAO Forestry paper 63, 1985.
Subri Trench	Trench dug around 2x2m with depth 0.5m. $2m^3$ stack of wood would fit in 4-9 chimneys placed perpendicular to the wind direction to ensure homogenius carbonisation process. Wood loaded to the ground level and two metal sheets of gauge 26 placed on both ends. Four chimney (two on each side) are fitted. The third sheet, which closes the firing corridor is then placed carefully to leave space for lighting.	Developed in 1981. Forest reserve " Subri River" Ghana