IMPACT OF CHARCOAL EXTRACTION ON THE MIOMBO WOODLANDS: THE CASE OF KITULANGALO AREA, TANZANIA

BY

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ABSTRACT

This study was carried out to determine the impact of charcoal extraction to the miombo woodlands of Kitulangalo area, near Morogoro, Tanzania. Both socio-economic and ecological aspects of charcoal production were studied. While the socio-economic study involved interviewing 50% of charcoal makers in two villages of Gwata-Ujembe and Maseyu, ecological survey was done in Kitulangalo SUA Training Forest Reserve and the adjacent public lands. Systematic sampling design used in an inventory in 1996 was repeated in 1999 in order to determine current stand parameters and the forest change in general, including mean annual volume increment. A total of 46 sample plots were laid out in the forest reserve. In public lands stratified random sampling was applied where a total of 30 plots were laid at an interval of 500 m apart on three and two transects laid perpendicular to the access road and highway respectively at 0 km, 5 km, 10 km and 15 km interval. An average charcoal making household was found to produce 43 bags of charcoal per month, sold at Tshs. 1,000/= (USD 1.25 , 1 USD = Tshs. 800/- in 1999) per bag. The household realizes an income of Tshs. 43,000/= per month which is above the minimum salary rates paid currently to government workers and hence attracts more people to join the business. The kiln efficiencies were observed to range from 17.5% to about 30%. There is therefore a need to explore desirable ways of kiln preparation and carbonization that can improve kiln efficiencies right at the field and not from modern technologies which in most cases are expensive. The mean charcoal kiln efficiency was found to be 23%. Preferred tree species for charcoal making include:

Julbernadia globiflora, Brachystegia boehmii, Tamarindus indica, Acacia nigresces, A. gerrardii, A. nilotica, A. goetzei subsp goetzei, Combretum adenogonium, C. molle, C. zeyheri, C. collinum, Boscia salicifolia, Diplorhynchus condylocarpon, Pseudolachnostylis maprouneifolia, Terminalia mollis, Pteleopsis myrtifolia, Diospyros kirkii, Xeroderris stuhlmannii, Mimusops kummel, Albizia harvey, Lonchocarpus capassa and *Lannea schimperi*. These species were having standing wood volume of 24.5 m^3ha^{-1} and 56.5 m^3ha^{-1} in public lands and reserved forest respectively with corresponding basal area of 3.7 m^2ha^{-1} and 7.2 m^2ha^{-1} suggesting low biomass in public lands compared to reserved forest. Stem numbers were 909 stems ha^{-1} in public lands and 354 stems ha^{-1}in forest reserve showing a reversed trend compared to basal area and volume. This indicates more regeneration in public land following disturbance than in the forest reserve. The public lands at roadside are dominated by large trees of *Acacia polyacantha*, a pioneer tree species which is not preferred for charcoal making due to its hooked thorns and lighter charcoal which breaks easily during transportation. Other un-preferred tree species for charcoal making were *Sterculia africana* and *Adansonia digitata* due to their low density charcoal. The *Important Value Index* (IVI), indicated that *J. globiflora* is the most important tree species in both public lands and reserved forest. The species is among the suitable tree species for charcoal making. The *Index of Dominance* (ID) was 0.092 and 0.065 in public lands and reserved forest respectively, indicating high species richness in forest reserve compared to the public lands. The *Shannon-Wiener Index of Diversity (H')* calculated using natural logarithms were 2.9 and 3.13 in

public land and reserved forest respectively, also suggesting high species diversity in forest reserve compared to the public lands. Considering a conversion factor of fresh wood volume to wood biomass of 0.85 and kiln efficiency of 23%, the weight of charcoal that can be extracted from the woodland at the roadside is 56 kgs of charcoal, equivalent to only one bag of charcoal per hectare. Similarly 54 bags may be expected at 5 km distance while 125 bags may be extracted from beyond 10 km from the highway. With the established stand growth rate of 2.3 $m^3ha^{-1}year^{-1}$ for the re-growth miombo woodland at Kitulangalo, charcoal production could be sustained at the levels observed at beyond 10 km away from the highway within felling cycles range of 8 to 15 years for degraded forest at 5 km away from the highway and at roadside.

DECLARATION

I, Eliakimu Zahabu, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has not been submitted for any degree award in any other University.

Signature: .....

Date: 8th March 2001 .....

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DEDICATION

To my grandfather Mzee Eliakimu Zahabu and his wife Helen whose educative guidance made my parents Mnkondo and Rachel value education, the fruit of which among others is this work.

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ABBREVIATIONS

GNP	Gross National Product
USD	United States of America Dollar
SADC	Southern Africa Development Cooperation
FAO	Food and Agriculture Organization of the United Nations
SUA	Sokoine University of Agriculture
TAFORI	Tanzania Forestry Research Institute
DBH	Tree Diameter at Breast Height
Tshs.	Tanzanian shillings
STD	Standard Deviation of the Mean
USA	United State of America

CHAPTER 1

1.0 INTRODUCTION

1.1 Tanzania overview

Tanzania (2^0-11^0S and 29^0 - 40^0E) is the largest country in East Africa with an area of about 945,000 km^2. Based on the 1988 census the population of Tanzania is estimated to be more than 30 million with an annual rate of increase of 2.8 per cent (in 1988 the population was 23.127 million people). About 80% of the population live in rural areas, mostly in about 9000 villages. Agriculture is the mainstay of the economy providing about 45% of GNP and 80% of employment (URT 1992). The country's per capita income in 1990 was USD 120.

Tanzania has about 33.55 million hectares of forests and woodlands, of which about 90% is covered by woodlands (URT 1998), the rest being mangrove, plantation and catchment forests. These forests have unique environmental and biodiversity values, and also make available a wide range of products for subsistence use. In terms of legal status of the land, 43% of the forested land is designated as forest reserves and national parks (protected) while the remaining 67% is forest in public lands. Forest reserves are gazetted forests under the management of central and local governments. And according to the new forest policy these forests are supposed to be managed for production and or protection based on forest management plans (URT 1998). Forests on public lands are without any legal protection and in

accessible areas their utilization is without any control.

Miombo is the type of tropical woodland, which is dominated by the genera of *Brachystegia and/or Julbernardia* or *Isoberlinia* of legume sub-family Caesalpinioideae (White 1983 in Campbell 1996). Woodlands are low-stocked open forests commonly with interlocking tree cover, sparse shrub layer and grass rich field strata. The miombo woodlands occurs in seven eastern, central and southern African countries namely Angola, Malawi, Mozambique, Tanzania, Zaire, Zambia and Zimbabwe (White, 1983). In the SADC region alone these woodlands present one of the most important natural resource and a source of wood energy to over 100 million people which is one fifth of the population of sub-saharan Africa (SADC Energy Sector 1993).

Miombo woodlands are the chief source of firewood and charcoal in Tanzania. The most important use of wood in Tanzania is for fuel and about 95% of the country's energy supply is met by fuelwood (Iddi & Håkan 1997). Woodlands trees produce a heavier and more concentrated fuel than most fast growing softwood species (Gauslaa 1988) and tropical rain forests. Attributes that have major effects on the dynamics of miombo woodlands are fuelwood extraction, wildfire, shifting cultivation and selective harvesting of trees for different purposes.

Generally forest is one of many sources of fuelwood production and there is a recognition that plantations of different types (e.g. coconut, rubber and oil palm plantations, fruit orchards and trees in homesteads and homegardens) have also been important sources of fuelwood supply (URT 1998). Forest and non-forest sources produce fuelwood through felling of trees which have grown naturally, or trees which were raised on single or multi-purpose plantations (i.e. as the main products of dedicated woodfuel plantations or as by-products of plantations). Alternatively, woodfuels are obtained as lops and tops from forest harvesting; as dead wood, fallen branches, twigs and dead stumps at site; as by-products of wood-based industries (e.g. waste and scrap wood, sawdust); as surplus non-commercial wood derived from land clearing; or as recovered wood from replacement or demolition of old structures and constructions (e.g. wood from old poles, posts, buildings, scaffolding). Agro-residues like rice husk and straw, coconut husks and shells, palmoil kernel shells and fibre, and bagasse are the other main sources of biomass fuels. The potential of these bioenergy resources is considerable. They are important for both the domestic and the industrial sectors.

Households consume about 97% of wood energy in SADC region mostly for cooking, heating and cottage industries while industrial sector is the second to household sector (SADC Energy Sector 1993). Most of the industrial wood energy is consumed by small-scale industries which include food processing industries and service sectors such as brewing, fish smoking, salt production, baking, restaurants, schools, hospitals and food vending; agro-processing industries such as tobacco

curing, tea drying and beeswax processing; and production of building materials such as burnt bricks, lime, smiths, foundries, pottery and ceramics. These industries and domestic activities which rely upon wood energy provide employment and income for rural people particularly during off-season in agricultural production (Monela & Kihiyo 1999). High fuelwood consumption in Tanzania is ascribed to low per capita income and limited investment in alternative energy supplies.

1.2 Problem statement and justification

The Tanzania energy policy of 1997 stresses development and use of indigenous energy sources such as bio-energy, coal, natural gas and hydropower (URT 1997). However, due to poverty, the majority of people in Tanzania can not afford or have no access to energy sources other than wood energy (i.e. firewood and charcoal), the single most important source of energy particularly for households (Monela & Kihiyo 1999). Wood based energy accounts for about 76% of the total primary energy consumed in Tanzania (Kaale, 1995).

In spite of the importance of wood energy supply, less than two percent of energy development budget in Tanzania is allocated to wood energy programs, fuelwood being regarded as minor forest product with little market value (TFAP 1989). Efforts have focused more on alternative commercial energy sources such as hydro-electric power, fossil fuels and petroleum-based sources of energy. The vast majority of fuelwood consumers cannot afford the high investment costs associated with those

alternative commercial energy sources (Moyo *et al.* 1993). Availability, reliability of supply and cheaper prices render, fuelwood more preferable than alternative sources of energy.

According to the present economic forces the majority of urban population in Tanzania will continue to depend on fuelwood for a long time to come (Moyo *et al.* 1993, URT 1998). Furthermore due to the anticipated steady increase in population (at an annual rate of increase of 2.8%), it is expected that actual consumption of firewood and charcoal will continue to rise. This can put pressure on the natural forests from where most of the charcoal is obtained, in most cases resulting in degradation of the forest ecosystems.

Commercial fuelwood extraction such as charcoal production requires large volume of wood, which in turn depletes tree stocks resulting into various forms of soil erosion. Nevertheless little is known about the actual extent of deforestation due to urban charcoal use, the social and economic patterns, which determine the exploitation, or the policy options available to mitigate the problem. According to FAO Forest Resources Assessment, deforestation is defined as a change of land use with the depletion of tree crown cover to less than 10 percent (Adger & Brown 1994). Furthermore the extent of forest resource, use impact, their growing stock and Mean Annual Increment (MAI) are not known with any degree of precision. The understanding of the potential of the forests to supply firewood and charcoal over a medium time perspective is limited. This has implications on the country regarding

its ability to design and implement appropriate energy policies that can address production sustainably. It is known that rational decisions in management of natural forests depend on information available on their growing stock. It is also known that the acquisition of forest growth information is prerequisite to any forest management system and sustainable land use (Mgeni & Malimbwi 1990). This study was therefore initiated with the following objectives:

1.3 General Objective

To determine impact of charcoal extraction and the potential of the miombo woodlands for supplying charcoal.

1.4 Specific Objectives

The specific objectives were:

- To investigate the socio-economic status of charcoal makers in relation to charcoal extraction.
- To investigate suitable tree species preferred for charcoal making.
- To determine and compare abundance of preferred and non-preferred tree species for charcoal in reserved and communal woodlands.
- To investigate forest stand growth rate.
- To propose possible interventions that can be carried out in order to sustain the supply of charcoal and to mitigate adverse effects of charcoal production.

1.5 Hypotheses

In the light of the above stated objectives the following hypotheses were tested:

- Charcoal makers earn considerable income from charcoal extraction that attracts more people to join with the activity.
- Due to increased demand for charcoal and depletion of preferred species, other tree species are used for charcoal making.
- Accessible forests are exploited more for charcoal compared to less accessible forests in terms of institutional arrangement and means of transport.
- Tree cutting for charcoal encourages regeneration of tree species.

CHAPTER 2.

2.0 LITERATURE REVIEW

Miombo woodlands have high potential to supply a variety of forest products and services to local communities who live within or around them (Monela *et al.* 1993). Quantitatively, fuelwood is the major product from miombo woodland (Temu 1979). Fuelwood entails both firewood and charcoal. Firewood is mostly used in rural areas and charcoal in urban areas where its ease of storage, high energy content, lower levels of smoke emissions, make it more attractive than firewood (World Bank 1988).

Charcoal production was found to contribute substantially to the economy of rural people in eastern Tanzania (Monela *et al.* 1993). And there is mounting evidence of increasing population in these areas which could probably be due to plenty natural resources base including fertile virgin land for agriculture. The main economic activity of people was agriculture of both food and cash crops. However, in recent years most people have started to engage themselves into extensive forest product exploitation and trade for cash incomes due to reduction in government spending and hence decreased agricultural support in terms of extension services and subsides on farm inputs (Monela *et al.* In press).

2.1 Charcoal production at Kitulangalo

2.1.1 Size and tree species preferred for charcoal

Particular tree species are favoured for charcoal production due to dense and hard charcoal they produce. best trees for charcoal are deforested close to Dar es Salaam highway to up to 30 km from the road (Monela *et al.* 1993). *Brachystegia boehmii, Combretum spp. Julbernardia globiflora, Acacia nigrescens* and *Tamarindus indica* were highly preferred tree species for charcoal in miombo woodland areas of eastern Tanzania (Monela *et al.* in press). Nduwamungu (1996) estimated an average of 12 stems per ha with dbh greater than 20 cm removed annually in miombo woodlands of Kitulangalo SUA Training Forest Reserve. Most of these trees cut were intended for charcoal production and were mainly *Julbernardia, Combretum* and *Brachystegia* species. About 90% of above ground biomass in miombo woodlands is suitable for charcoal making by the earth kiln method and usually only logs with a butt girth of greater than 10 cm are used (Chidumayo 1991).

2.1.2 Charcoal making process

Generally, biomass fuels are consumed by direct combustion in their primary form after drying and resizing, or in the form of charcoal. New conversion technologies such as gasification and anaerobic digestion have been developed to provide alternatives and to match biomass resources with modern end-use devices. Charcoal

is produced in kilns by a process called pyrolysis, i.e. breaking down the chemical structure of wood under high temperature in the absence of air. During the process, first the water is driven out from the wood (drying), and then the pyrolysis starts when the temperature in the kiln is high enough. When the pyrolysis is complete, the kiln gradually cools down, after which the charcoal can be removed from the kiln. Because some of the wood is burned to drive off the water, dry wood produces better charcoal at a higher efficiency. Typically, around two-third of the energy is lost in the process, but charcoal has advantages over firewood because of its higher efficiency and convenience in handling, storage and distribution (Hofstad 1995).

The oldest and probably still the most widely used method for charcoal production is the earth kiln. Two varieties exist, the earth pit kiln and the earth mound kiln. An earth pit kiln is constructed by first digging a small pit in the ground. Then the wood is placed in the pit and lit from the bottom, after which the pit is first covered with green leaves or metal sheets and then with earth to prevent complete burning of the wood. The earth mound kiln is built by covering arranged pile of wood on the ground with earth. The mound is preferred over the pit where the soil is rocky, hard or shallow, or the water table is close to the surface. Mounds can also be built over a long period, by stacking gathered wood in position and allowing it to dry before covering and burning.

In eastern Tanzania usually charcoal is produced in earth mound kilns made by covering a pile of logs with earth, igniting the kiln and allowing carbonization under

limited air supply (Monela *et al.* 1993). Wood carbonization is undertaken in two main ways namely, carbonization by partial combustion and carbonization without access of air. In carbonization by partial combustion, wood is converted into charcoal without recovering by-products and in this case charcoal is a main product. In carbonization without access of air both charcoal and by-products such as char, tar, water and gases are produced (Ishengoma and Nagoda 1991). The use of traditional earth mound kiln utilizes the process of carbonization by partial combustion in which only charcoal is produced.

Earth kilns can be made at minimal cost, and are often used near wood resources. Earth kilns can be made in any size, with the duration of the process ranging from three days to two months. Gross variations in the quality of the charcoal can occur, because in one batch some of the wood is burned and some of the wood is only partly carbonized. Efficiencies are generally low and vary depending on the construction of the kiln (e.g. walls can be lined with rocks or bricks and external chimneys can be used), and the monitoring of the carbonisation process. The conversion efficiency of traditional earth mound kilns when green woods is being used for its preparation range from 10-20% (Chidumayo 1991, Kaale 1998, Sawe & Meena, 1994). However Hofstad (1995) reported the efficiency of 16-30% under the assumption that, the biomass/fresh wood volume ratio is 0.85 (Malimbwi, *et al.*, 1994).

According to Hofstad (1995) factors contributing to kiln efficiency variation were

moisture content of wood involved in kiln preparation and specific weight of the wood material. Hence tree species involved in kiln preparation contribute greatly to kiln efficiency variation. Also moisture contents of the charcoal influences charcoal biomass and ultimately kiln efficiency. Lack of proper control during carbonization process was also reported to reduce efficiency due to some complete combustion of wood (Ishengoma & Nagoda 1991).

In Tanzania trials to reduce consumption of biomass fuel were carried out through the introduction of efficient charcoal production technologies. Some of the proposed technologies and techniques include: portable steel kiln, improved traditional earth kiln, and thirteen half-orange brick kiln. These methods have been under investigation for over thirty years (FORINDECO 1992). Also studies by TAFORI enabled development of improved earth mound charcoal kiln reinforced with burned bricks but dissemination of the results has not been successful due to the high cost involved (Sawe & Meena 1994). The average carbonization efficiency of these improved technologies was estimated to be in between 27-35 %. Portable steel kiln achieves considerably higher conversion efficiency but has not been adopted because of its higher initial cost, manpower and skill required for viable management. Problems with marketing of softwood charcoal (low calorific value) in which production by improved methods was found to be technically most feasible is also a limiting factor towards the adoption of these technologies. Due to these deficiencies it has not been possible to expand these technologies (FORINDECO 1992).

2.1.3 Household income from charcoal

Along the Dar es Salaam – Morogoro highway, a household was found to make 36 kilns per year at an average production rate of 10 bags per kiln and average price of Tshs. 95 (USD 0.49) per bag (1 USD was equivalent to Tshs. 193, in 1992) (Monela *et al.* 1993). Furthermore, it was revealed that the unit price of charcoal has risen from USD 0.49 to USD 1.6 between 1992 and 1996 (Monela *et al.* in press). In Mozambique the average price per bag at production site which was found not to be determined by distances from the Maputo city was 2.3 USD (Falcao, 2000). The unit price of charcoal however, was found to be higher during rainy season and lower in the dry season of the year (Monela *et al.* 1993, Falcao, 2000).

Monela *et al.* (1993) further reported that in 1992 charcoal contributed substantially to the annual household income of communities adjacent to the Morogoro – Dar es Salaam highway who earned about USD 176 annually. Another study by Monela *et al.* (in press) revealed that about 278 bags of charcoal were produced per household per year which when sold at Tshs. 1000 (USD 1.6) is equivalent to about USD 445. This indicates a growing dependence on charcoal for household income.

2.2 Woodfuel consumption

The total annual consumption of biomass energy in Tanzania is estimated at about 27 million m^3 of solid wood (TFAP 1989). About 22 million m^3 is assumed to be

household energy at 1.0 m^3 per capita, the balance being used in agriculture (tobacco curing and tea drying), urban industries (brick, potteries, fish smoking, salt drying and lime burning) and in service industries (restaurants, schools, hospitals etc.). There is considerable variation in the estimate of per capital consumption on woodfuel which range from 0.5 m^3 to almost 4.0 m^3 (Kaale 1995). Part of the variation is due to the abundance or scarcity of supply and the distances over which wood has to be collected, also whether the survey was in the dry or wet seasons and whether it was at high or low altitudes. However in Zimbabwe less demand for fuelwood is observed due to widespread urban electricity and cheap subsidized kerosene (Campbell & Mangono 1994).

Inadequacies of energy policies in addressing woodfuel problems have contributed to deforestation particularly around major cities and in more distant areas close to main roads and railways (Leach & Mearns 1988 in Campbell 1996). Monela *et al.* (1993) estimated that charcoal is brought from a distances of up to 200 km for the Dar es Salaam city. And on average, over 75,000 ha of woodland are being cleared annually to meet the woodfuel needs of Dar es Salaam alone (Hagman 1984). For dwellers in Dar es Salaam the cost of using electricity was comparatively similar to that of charcoal though the electric stove costs are 38 higher than times that of charcoal stove in 1992 (Monela *et al.* 1993). In addition charcoal stoves were more commonly available on the market at lower prices. Frequent electricity cuts and difficulties in obtaining liquid fuels such as kerosene also makes consumers switch back to charcoal.

2.3 Woodland regeneration

Miombo species regenerate largely through coppice regrowth and root suckers rather than seeds (Robertson 1984 in Campbell 1996). Chidumayo (1988) observed that stumps of almost all miombo woodland trees have the ability to produce sucker shoots. Although seeds of majority of miombo trees and shrubs also germinate immediately after dispersal when there is enough moisture, tree density in regrowth miombo woodland decreases with time due to moisture and heat stress. The majority of seedlings of miombo trees therefore experience a prolonged period of successive shoot die-back during their development phase in order to cater for these stresses. Shoot die-back is caused by water stress and/or fire during the dry season. Also with the case of suckers and coppice, fire can either slow or accelerate growth. If a destructive fire occurs before dominant shoots attain a safe height to escape mortality, the process of sucker shoot domination reverts to the initial stage and stumps respond by producing an equal or larger number of replacement shoots (Chidumayo 1988). However resistance to these environmental factors varies with species.

Fire was found to be the major ecological factor, which leads to the development of miombo woodland (Lawton 1978). The impact of fire on miombo depends on time and frequency of burning and on the flammable biomass. Based on burning experiment from 1933 in Ndola (Zambia), Trapnell (1959) reported that repeated late and hot fires may destroy the woodland. About 50% of the trees died after

eleven years of late fires. While early burning allowed a maintained regeneration, complete protection leads to the development of a more closed, partly evergreen forest.

2.4 Useful stand parameters

Parameters commonly used to describe forest stands are number of stems per hectare (N), basal area per hectare (G m^2ha^{-1}) and tree volume per hectare (V m^3ha^{-1}). In even- aged stands the number of stems per hectare is a useful parameter for defining stand stocking if it is accompanied with information on age, mean height and diameter (Malimbwi 1997). Stand basal area (G) is the sum per hectare of cross sectional areas of all trees estimated at breast height. Basal area is a useful measure to compare stocking of two stands of same species, age and height and also is a good measure of site potential (Philip 1983). Due to high variation in stand age, size and species in natural forests, average number of stems, basal area and volume per hectare are less effective unless quantified with diameter frequencies by species and diversity indices (Malimbwi 1997).

2.4.1 Number of stems per hectare in miombo woodlands

About 2075 and 444 stems ha^{-1} have been reported in a regrowth miombo of 16 years and in old growth miombo respectively in Morogoro, Tanzania (Ek 1994). Nduwamungu, (1996) observed 691 stems per hectare in miombo woodland of

Kitulangalo SUA Training Forest Reserve which was recovering following wood harvesting for various purposes including charcoal extraction, building poles and timber. These stem numbers are comparable to those of miombo woodland in Katanga, Zaire, estimated by Malaisse (1978) ranging from 520 to 645 stems ha^{-1} with canopy tree accounting for about 65 stems ha^{-1}.

2.4.2 Basal area and wood volume

Strang (1974) studying the miombo woodlands of Zimbabwe observed that wood basal area stabilises at 10-11 m^2ha^{-1} after 50 years since last clearing. Studying the miombo woodlands of Tanzania Bystrom *et al.* (1987) reported mean basal area of 8.8 $m^2ha^{-1}$and 16.5 m^2ha^{-1}in Iringa and Tabora respectively. Wood volume was observed to range from 39 to >120 $m^3ha^{-1}$for miombo woodlands of Tanzania (Temu 1980, Kielland-Lund 1990, Malimbwi *et al.* 1994). Nduwamungu (1996) observed mean total volume and basal area of 71 $m^3ha^{-1}$and 10 m^2ha^{-1} respectively at the Kitulangalo SUA Training Forest Reserve. In Rufiji district, Tanzania, Malimbwi & Mugasha (2000) reported maximum volume and basal area of 110 m^3 ha^{-1} and 12.5 m^2 ha^{-1} respectively in miombo woodlands.

2.5 Woodlands growth rate

Much literature on miombo woodlands remains deficient in precise data on growth rate. In a study at Kitulangalo based on three permanent sample plots of 625 m^2 an

average stand volume increment of 0.54 $m^3ha^{-1}year^{-1}$ was found for regrowth miombo woodland (Malimbwi *et al* 1998). On the other hand the same study in other miombo communities resulted to 7.4 $m^3ha^{-1}year^{-1}$ and 7.3 $m^3ha^{-1}year^{-1}$ in the old growth miombo and semi-evergreen miombo respectively. Due to the small sample taken for the study by Malimbwi *et al.* (1998) it was found unwise to conclude on the rate of growth. Chidumayo (1988) reported a mean annual fuelwood increment of 1.96 m^3/ha in dry miombo of Zambia. This rate is in line with Nilsson (1986) who estimated an annual growth rate of 1-2 m^3/ha/year for disturbed woodlands in Tanzania. The differences were explained as due to ecological factors and management practices. Woodland trees invest large resources in different kinds of stress tolerance adaptation (eg. drought, nutrient poor soil and fire). This provides security against catastrophic events. Soil moisture and fires are important factors determining growth of the woodland. Under a constant burning regime, height and density of trees increase with increasing rainfall. Seasonal water logging and late fires reduce the tree component and increase the herbaceous component.

2.6 Miombo ecosystems diversity

2.6.1 Meaning of diversity

Huston (1994) defined diversity as the structural and functional variety of plants and animals at genetic, species, population, community and ecosystem levels. Forest land is the habitat for most of plants and animals (Misra 1989). Diversity has two

components: species richness and evenness of the community. While species richness is the actual number of species contained within a community, evenness is the spread of individuals between the species within the community (Kent & Coker 1992). Many ecologist use the term species richness interchangeably with diversity where in all instances they often mean a community containing a large number of different species. This however should not mean that the second component of diversity is not important. The community containing the same number of species may have different abundance of those species that in turn influence their diversity.

High species diversity is considered a desirable property for a community and hence a useful parameter for comparison of two communities. The knowledge of species diversity is particularly useful when one wishes to study the influence of biotic disturbances or the state of succession and stability in the environment (Misra 1989).

2.6.2 Measures of diversity

Shannon-wiener index of diversity (H')

Many diversity indices such as Shannon-wiener, Simpson and Brillouin are in existence (Krebs 1989). The most widely used index of diversity, which combines species richness and evenness and also not affected by sample size, is the Shannon-wiener index of diversity. The index is calculated as follows (Kent & Coker 1992):

$$H' = -\sum_{i=1}^{s} (P_i \log_a P_i)$$

Where:
- H' is the Shannon Index of Diversity:
- Σ is the summation symbol:
- s is the number of species:
- P_i is the proportion of individuals or the abundance of species i in the sample:
- $\log_a$ is the logarithm to base a (any base of logarithm may be taken)
- \- is the negative sign multiplied with the rest of variables in order to make the H' positive .

Krebs (1989), explained Shannon-Wiener index of diversity as a measure of information content of a sample and since information content is a measure of uncertainty, the larger the value of H', the greater the uncertainty. The index increases with the number of species in the community but in practice, for biological communities H' does not exceed 5.0 (Washington, 1984 in Krebs 1989).

Species importance value index (IVI)

The Importance Value Index (IVI) of a species is the sum of the relative: frequency, density and dominance of that species. These constituent parameters are calculated as follows (Kent & Coker 1992):

$$\text{Relative Frequency} = \frac{\text{Frequency of occurrence of a species}}{\text{Frequency of occurrence of all species}} \times 100$$

$$\text{Relative Density} = \frac{\text{Number of individuals of a species}}{\text{Number of individuals of all species}} \times 100$$

$$\text{Relative Dominance} = \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$$

Index of dominance (ID)

The index of dominance is a measure of the distribution of individuals among the species in a community. This index is also called Simpson's Index of diversity and is equal to the probability of picking two organisms at random that are of different species (Krebs 1989). The greater the value of dominance index, the lower is the species diversity in the community and vice versa. This index is calculated as follows (Misra 1989):

$$ID = \sum(n_i/N)^2$$

Where ID is the Index of Dominance;
n_i is the number of individuals of species i in the sample;
N is the total number of individuals (all species) in the sample and
$\sum$ is the summation sign

2.6.3 Tree species diversity in miombo ecosystem

Miombo woodland is extremely rich in plant species, many of which are endemic; about 54% of 8500 higher plant species found in miombo region are endemic (White 1983). The dominant tree species in miombo are those of the family Fabaceae, subfamily Caesalpinioideae, particularly in the genera *Brachystegia*, *Jurbernardia* and *Isoberlinia* (Frost 1996). There are 21 species of Brachystegia in miombo woodland and three species of each of the related genera (White 1983). Kielland-Lund (1990) identified 25 tree and shrub species with DBH>4 cm distributed in 11

families on a plot of 0.5 ha and observed that dominant tree species were. *Julbernardia globiflora*, *Brachystegia boehmii* and *Pterocarpus rotundifolia*.

in the north while the Tanzania - Zambia highway makes the southern border. In the western part, the forest is bordered by Kitulangalo government forest reserves and other sides are farms and public land forests. Figure 1 shows the location of this area.

3.1.2 Climate

The climate of the area is tropical, semiarid and sub-humid. The area is within the 700 mm to 1000 mm rainfall belt with wet season from October to May and dry season from June to October (Holmes 1995). The mean annual temperature is 24.3^{0}C while the annual minimum and maximum temperatures are 18^{0}C and 30^{0}C respectively (Mugasha 1996). January is the hottest month while June is the coldest.

3.1.3 Soil and Geology

Type of soils in this area is related to topography. The Alfisols soils occur on the undulating to rolling convex slopes on the piedmont of the Kitulangalo hill. Mollisols and Inceptisols are found on the gentle undulating concave valley bottoms (Msanya *et al.* 1995).

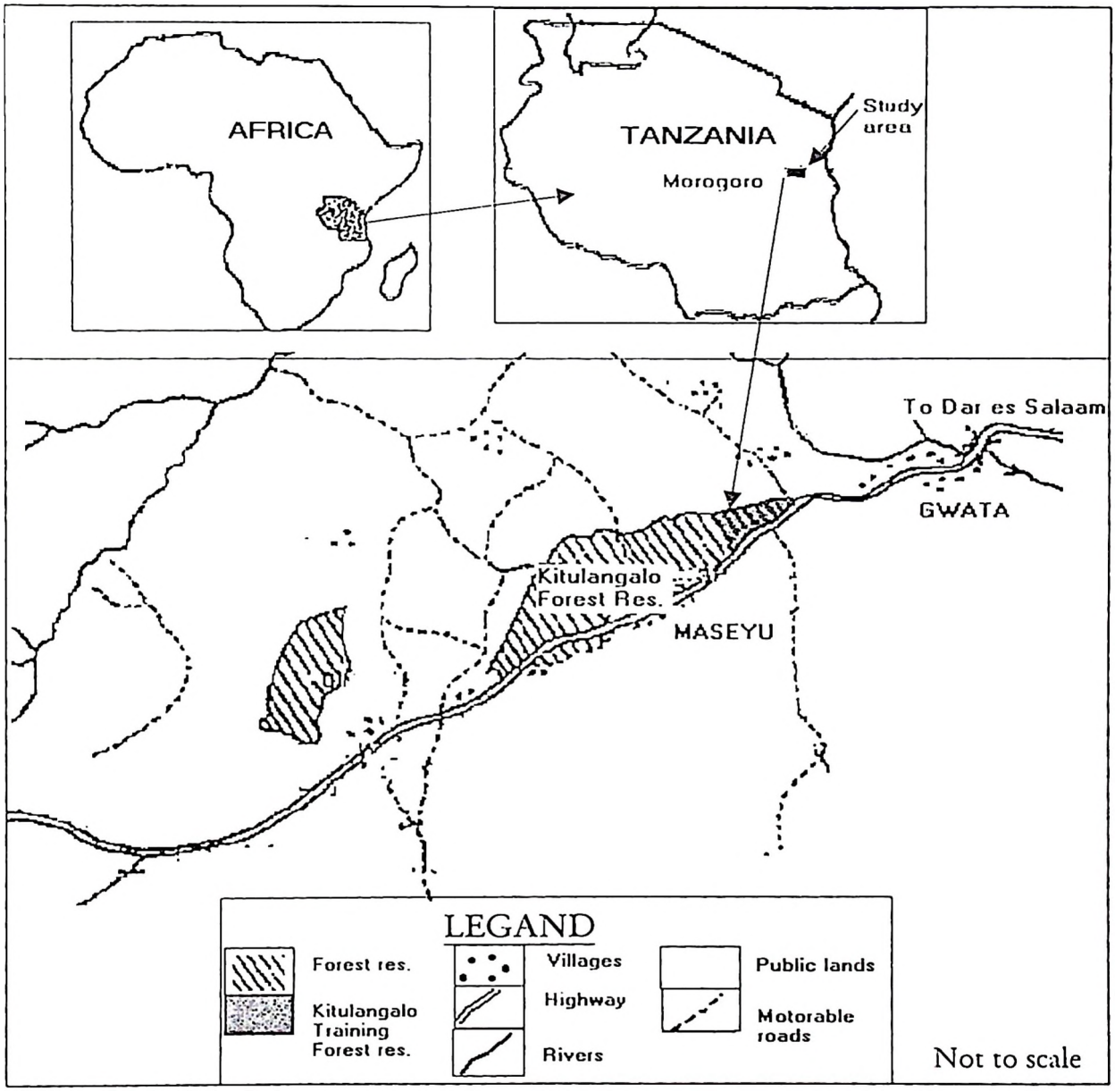

Figure 1. The location of the Kitulangalo area

The miombo soils are generally nutrient poor (Campbell *et al.* 1991). At the particular site the soils are well-drained red sand clay loams with brown friable top soil covered by more or less decomposed litter (Mugasha 1996). The pH of the soil is between 5 and 5.5.

The geology is precambrian Usagaran metasedimentary rocks consisting of garnet-biotite gneiss with some kyanite bearing bands. In low lying area, mixed alluvial and colluvial deposits derived from these rocks are present while at highland limestone and dolonite rocks are found (Msanya *et al.* 1995).

The topography of the study area has rolling relief on convex slopes (10 to 12%), undulating to rolling relief on dissected linear slopes (6 to 19%) and fairly uniform slope in valley bottoms (Msanya *et al.* 1995).

3.1.4 Vegetation

Most of the reserve and public lands are covered with regrowth open miombo woodlands with some scattered *Julbenardia globiflora, Brachystegia spp.* and *Pterocarpus rotundifolia* reaching a height of 15-20 m, while most of trees are in an understorey, at 5-10 m height composed of *Diplorhynchus candylocarpon, Combretum zeyheri, C. apiculatum* and others. The herbaceous layer is covered by dense *Themeda triandra* grass reaching a height of 1.5 m. Grass fires are very common in miombo areas and substantial woodlands are burnt annually (Mugasha

1996).

3.2 Methodology

3.2.1 Socio-economic survey

This survey was aimed at collecting information concerned with socio-economic status of the people involved with charcoal making activities, tree species and size preferred for charcoal, cultural practices and their influence on forest regeneration and views of stakeholders on the potential of the woodland to supply charcoal. Structured questionnaire, and focused group discussions with the help of check lists and participant observation were employed in this survey.

(i) Structured questionnaire

A mixture of both open and close-ended questions was used. Pre-testing of the questionnaire was done in order to see if questions are understood and address the problem under investigation. The questionnaire used in this study is attached as Appendix 1. The sampling units in this study were households. A household is defined as a number of people living under the same roof and sharing meals. In each household, the head of household was interviewed. Pilot testing was done to a sample of four households involved with charcoal making selected at random. About 50% of the charcoal making household heads in each village were selected and interviewed. According to Boyd *et al.*, (1981), a random sample should at least

constitute 5% of the total population. Due to few number of charcoal making households, it was decided to sample about 50% of them from each village.

The questionnaire aimed at collecting information about same variables from more than one person in order to end up with a data matrix that could be analyzed statistically.

(ii) Focused Group Discussions

Checklists were used to guide focused discussion with key informants who were the stakeholders. These involved: regional, district, division and village forest officers: long-lived people in the village and religious leaders. Appendix 2 shows the checklists used.

(iii) Participant Observation

Participant observation is one among the techniques used by researchers on arriving to the village in order to overcome problems of orientation in the new community. In this technique researcher pretends to be part of the community being studied. In so doing the researcher gain the confidence of the persons being studied, so that the presence of the researcher does not interfere with the natural course of events and so that they will provide the researcher with honest answers to questions and not hide important facts. The technique was thus used as an initial medium for learning about social and physical environment interrelationships. Curiosity and willingness to learn are the main tools in the new surrounding environment (Kajembe & Luoga 1996).

Social data analysis

Statistical Package for Social Sciences (SPSS) and Microsoft Excel computer programs were used for data analysis. Quantitative data collected were summarized to ensure that they could be in the form suitable for addressing both the research questions and the method of analysis used. This was done while ensuring that original meanings of the statements made by respondents were maintained. The summarized data were then coded and used for subsequent statistical analysis. Descriptive statistics were used and the results were presented as means and percentages.

3.2.2 Ecological Survey

This survey was aimed at determining woodland growth rate and charcoal extraction dynamics.

Data collection

Forest growth rate

Inventory procedures used by Nduwamungu (1996) studying the same forest were repeated in order to determine current stand parameters and derive volume mean annual increment. The stand was divided into ten transects laid perpendicular to the

highway at 320 m apart covering the whole Kitulangalo SUA Training Forest Reserve (approximately 500 ha). A total of 46 sample plots were laid at an interval of 320 m apart. For better layout of both transects and sample plots, the first of each was laid at half distance i.e. 160 m from the boundary. Figure 2. illustrates this layout.

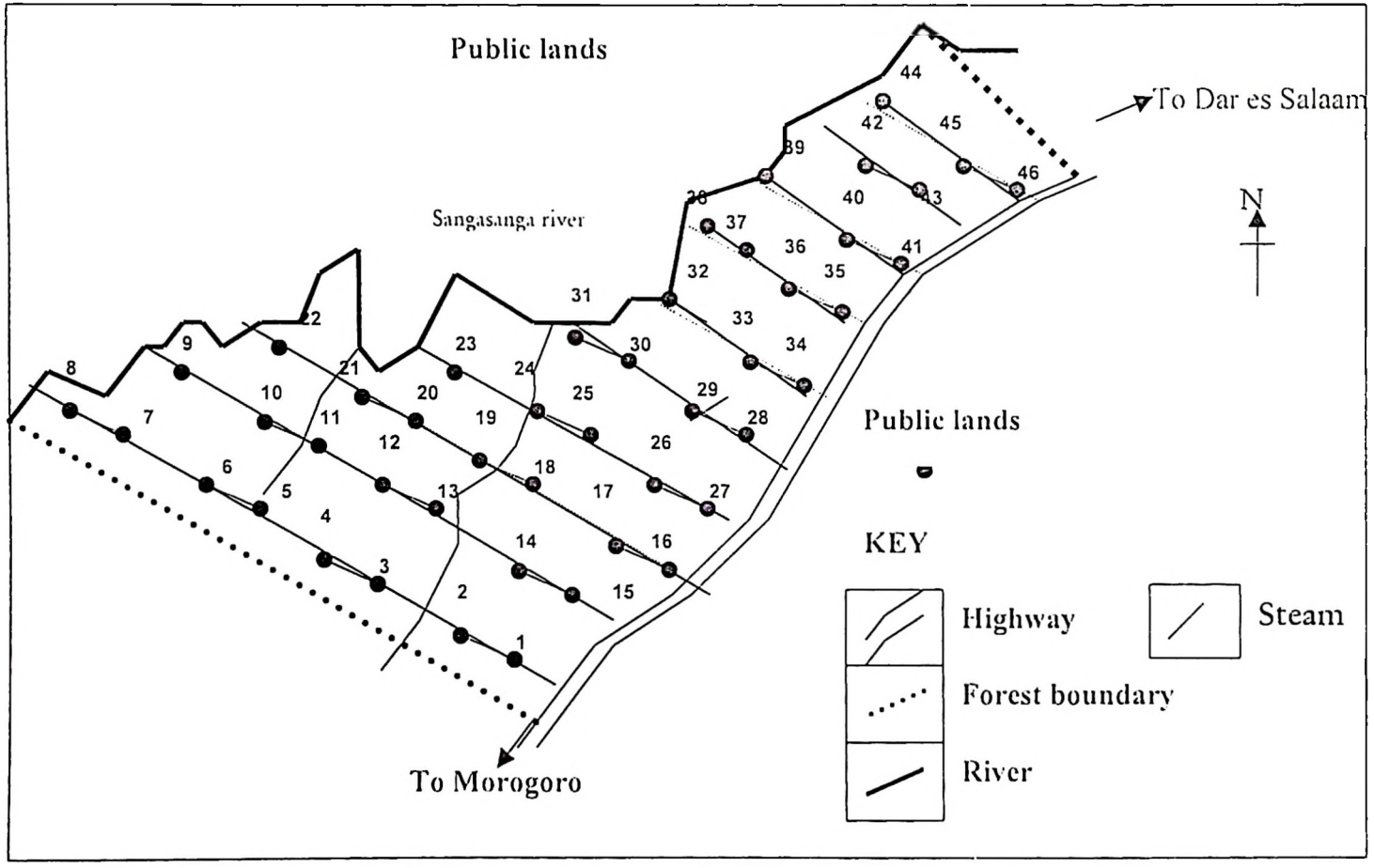

Figure 2. Lay out of sample plots in Kitulangalo SUATraining Forest Reserve

Charcoal extraction dynamics

A total of 30 plots were laid out in public lands of the two villages bordering the Kitulangalo SUA Training Forest Reserve. In the laying out of these plots stratified random sampling was applied. The parameter used for this stratification was distance from the highway into the public lands. The first two strata were laid each at opposite sides of the highway while the others were at 5 km. 10 km and 15 km interval away from the highway alternatively on the sides of one access road shared by both villages.

In each stratum a transect was laid out approximately perpendicular to the highway or access road. In each transect three clusters of two plots each were laid at an interval of 500 m. The distance between plots in a cluster was also 500 m. Figure 3 illustrates this layout.

The layout was meant to study how the richness and wood stocking of preferred tree species for charcoal vary with proximity from the highway. Also comparison was made on the preferred tree species richness and wood stocking in public land and forest reserve.

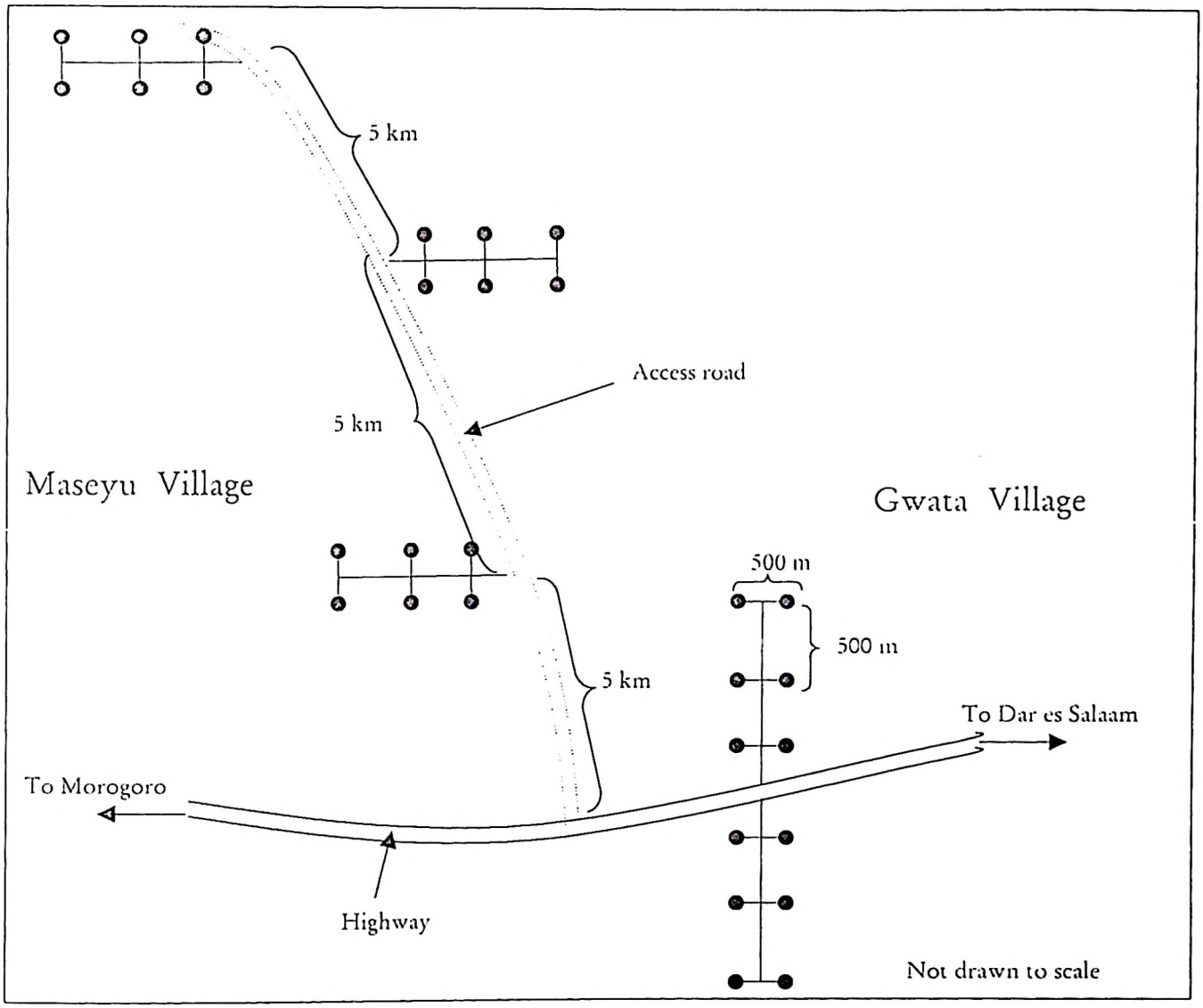

Figure 3. Lay out of sample plots in the public lands

Plot shape and size

The common structure in most natural forests with variation in the distribution of age, size and species is the reversed J-shaped distribution of number of stems per hectare characterised with many small trees with the number decreasing with increasing tree sizes (Philip 1983). The natural woodland at Kitulangalo was expected to have such structure and in order to measure approximately the same number of trees for each size class, circular concentric plots with radius depending on the dbh of the trees were established and measurements taken as follows:-

i) within 5 m radius: all trees with dbh ≥ 4 cm were recorded

ii) within 10 m radius: all trees with dbh ≥ 10 cm were recorded

iii) within 15 m radius: all trees with dbh ≥ 20 cm were recorded

Similar shape and size of plots was used in the National Inventory in Tanzania (Haule & Munyuku, 1994) and in several other small scale natural forest inventories (Nduwamungu, 1996 and Malimbwi & Mugasha, 2000). Species name and dbh of all measured trees were recorded in each plot. Local tree identifiers were used to identify tree species for later translation into botanical names using checklists of the area. The number of stems was determined from the dbh tally. The total height of the closest tree ("sample tree") to the plot centre was also measured and recorded. Appendix 3 shows the field form that was used to record this data. A tree caliper was used to measure tree dbh while total tree heights were measured using a hypsometer.

Data analysis

From the collected data the following parameters were computed:

- Density i.e. the number of stems per ha (N)
- Basal area per hectare (Dominance)(G) and
- Volume per ha (V)

The total tree volume of individual trees was calculated using a general miombo tree species equation developed by Malimbwi *et al.*, (1994):

$$V_i = 0.0001 d_i^{2.032} h_i^{0.66}$$

Where: V_i = the volume of the i^{th} tree (m^3)
d_i = the diameter at breast height (1.3m) for the i^{th} tree (m) and
h_i = the total height of the i^{th} tree (m)

Since this equation required height of each individual tree recorded, height-diameter equation was fitted using the 'sample trees' to derive heights for the other trees which were not measured for height.

The following parameters were also calculated:

- Frequency; i.e. the number of sample units in which a species is found,
- Relative density, dominance and frequency as the percentage of the sums of values obtained for all species.

- ***Importance Value Index*** (IVI) for a species i.e. the sum of the relative density, dominance and frequency (Ambasht 1990).
- ***Index of dominance*** (C) and
- ***Shannon-wiener index of diversity*** (H')

These parameters were calculated separately for the Kitulangalo SUA Training Forest Reserve and for each stratum in the public lands. The separate analysis allowed comparison of tree species abundance in the two forests and within strata in the public lands. Also tree species richness and wood stocking for the preferred tree species for charcoal making was compared between the two forests.

Charcoal kilns efficiency

Tree species and biomass to make up fifteen kilns were determined and compared to biomass of charcoal obtained from the kilns. To facilitate this a record of tree dbh, total tree height and local name was done for all trees felled to constitute a kiln. The local tree species names were later translated into botanical names using available checklists (e.g. Mbuya *et al.*, 1994). Log sections from each tree were also measured for mid diameter and length. The number of bags from each kiln was counted and their weight measured.

From the collected data, Huber's formula was used to estimate volume of individual log sections and hence volume of each tree as the sum of individual log section

volumes. The formula was (Malimbwi 1997):

$$V = \frac{\prod d_m^2 L}{4}$$

where: V = the volume of log, m^3
L = the length of log, m and
d_m = diameter at mid-length of log, cm.

Tree volume was converted to biomass using the conversion factor of 0.85 (Hofstad 1995, Malimbwi *et al.* 1994). This volume/biomass ratio was found to have small variation with miombo species at Kitulangalo. The biomass of each tree was therefore calculated as follows:

$$Y = 0.85V$$

where: Y = the biomass of the tree, kg
V = the volume of tree, m^3
0.85 = volume-biomass conversion factor

Charcoal kiln efficiency was hence calculated as percentage of the measured charcoal biomass from each kiln to biomass of trees constituting the kiln. The formula used can be expressed as:

$$K = (Ct/Yi) \times 100$$

where: K = the kiln efficiency (%)
Ct = total biomass of charcoal produced from the kiln (kg)
Yi = total biomass of the wood constituting a kiln (kg)

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 Charcoal extraction activities at Kitulangalo

Charcoal is usually extracted from the public lands, where there is no direct tree harvesting control. Main factors that determine levels of cutting are individual charcoal making household effort, availability of suitable tree species and charcoal market forces.

4.1.1 The charcoal makers

The charcoal makers sampled in this study were all males and belong to the ethnic groups of Waluguru, Wakwere, Wadoe, Wazaramo, Wazigua and Wakami. About 60% of these people were not born in their respective villages, which implies that most of them have their origin outside the area. The mainstay of the livelihood of people in the studied villages is agriculture but most of them are doing both agriculture and charcoal extraction. About 81% of the interviewed respondents were doing the two activities essentially in their effort to subsidize income from agriculture while the rest were doing only charcoal making. It was also deduced that 80% of the interviewed people in these villages formally were peasant farmers while the rest were young and have just started to earn life through charcoal making and little

farming.

The marital status of charcoal makers in this area is shown in Tables 1. About 60% of the charcoal makers in these villages are married, the remaining proportion being still single or divorced. In terms of education level, 40% of the interviewed people have no formal education while the rest have either standard four or seven education. Generally most of the people making charcoal in this area have low education level.

Table 1. Marital status of Gwata and Maseyu charcoal makers (all were males)

Village	Gwata Village	Maseyu Village	Total (respondents)	%
Single	3	2	5	20
Married	5	10	15	60
Divorced	3	2	5	20
Total	**11**	**14**	**25**	**100**

4.1.2 Charcoal making process

Usually charcoal in this area is produced in earth mound kilns made by covering a pile of logs with earth blocks, igniting the kiln and allowing carbonization under limited air supply (Fig. 4). Source of labour for charcoal making activities is mainly household labour with some few cases of hired labour at Gwata village and communal labour at Maseyu village (Table 2).

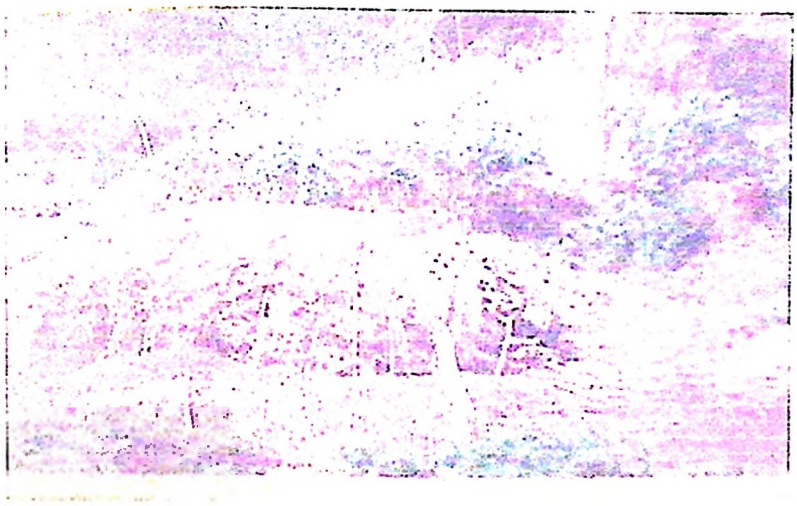

Figure 4. Typical charcoal kiln under preparation at Kitulangalo area.

Table 2. Source of labour for charcoal making

Labour source	Gwata village	Maseyu village	Total (respondents)	Percentage
Household	10	12	22	88
Hired	1	-	1	4
Communal	-	2	2	8
Total	11	14	25	100

Charcoal making process involves wood cutting, kiln construction, carbonization and finally unloading charcoal from the kiln. Generally the works are muscular and time consuming, usually done by male members of the family. An average household in the study area has 1-2 active male members.

The average numbers of days spent by an average charcoal-making household for each charcoal making activity are shown in Table 3. While it takes an average of about 17 days for woodcutting activity at Gwata village, the activity takes only 9 days

at Maseyu. The difference can be explained by the fact that communal labour in kiln preparation is used at Maseyu village while at Gwata there is no such practice (Table 2). However the average number of days spent per kiln in both villages is 45 including about 15 days of waiting for carbonization. During the time of waiting for carbonization the household may decide to prepare some more kilns. As such a charcoal making household could prepare more than one kiln in a month. The average production is about 43 bags of charcoal per month produced for each charcoal making household for sale in the studied villages. No charcoal is produced intentionally for home use.

Table 3. Number of days required in the charcoal making process of one kiln.

Activity	Gwata village	Maseyu village	Mean (days)
Wood cutting (days)	17	9	13
Kiln preparation (days)	11	14	13
Carbonization	15	14	15
Unloading charcoal (days)	5	3	4
		Total	**45**

About 80% of the respondents said there are no special months for charcoal production. During wet season some charcoal makers concentrate more in agriculture while others continue to make charcoal with easy availability of kiln construction materials. Before setting fire, the pile of wood is covered with grass and earth blocks to form a kiln. During the wet season earth blocks are more coherent and hence easy to handle and grass material becomes plenty and available. In the dry season there are difficulties in kiln construction due to loose soil for making earth blocks and scarcity

of grass material.

4.1.3 Charcoal kiln efficiency

A total of 15 kilns were studied. However charcoal from 11 kilns could not be used for kiln efficiency determination as the charcoal was wet due to rain. As such, only four kilns were used for this purpose and they revealed an average kiln efficiency of 23% (Table 4). This value is on the higher side compared to those reported by Chidumayo (1991), Kaale (1998) and Sawe & Meena, (1994). These previous studies reported charcoal kiln efficiency values ranging from 10-20%. In this study the kiln efficiency ranged from 17.5% to about 30%. Kiln efficiency is known to vary depending on the construction of the kiln and the monitoring of the carbonization process. There is therefore a need to explore desirable ways of kiln preparation and carbonization that can improve kiln efficiencies right at the field and not from modern technologies which in most cases are expensive.

Table 4. Charcoal kiln efficiency.

Kiln No.	No of Trees /kiln	Tree size range (cm) dbh	Average dbh (cm)	Measured Trees Vol. (m^3) / Kiln	Measured Biomass (kg) / Kiln	No. of Bags /kiln	Average bag Weight (kg)	Charcoal Weight (kg)	Kiln Eff. (%) *
1	14	8-37	17	2.90	2468.40	14	31	431.0	17.5
2	2	18-78	48	4.81	4088.50	25	49	1220.5	29.9
10	6	17-44.7	31	9.84	8364.00	28	69	1944.0	23.2
14	6	13-56	28	13.71	11656.73	34	70	2382.0	20.4
Mean	7		31	7.8	6644.40	25	55	1494.45	23

* Kiln efficiency was calculated as the percent of charcoal weight (kg) to measured kiln biomass (kg)

The difference between the kiln efficiency observed and previous studies could be caused by tree species involved. While this study was based on miombo tree species, species used in other studies were not mentioned. Also the small number of kilns involved for kiln efficiency determination in this study may be the source of the high kiln efficiency value. Miombo tree species are known to produce denser charcoal compared to trees of other vegetation. Studying eight kilns at Mbwewe, eastern Tanzania, Madadi (2000) reported the kiln efficiencies ranging from 11% to 25% with the mean of 17% for the miombo tree species.

Table 4 also shows that, mostly trees of above 8 cm are used for charcoal production. On average, 7 trees of average dbh of 31 cm are used for every 25 bags of about 55kg of charcoal produced from this area. Nduwamungu (1996) estimated about 12 stems per ha of at least 20 cm dbh removed for charcoal making at Kitulangalo at a time. Under his situation about 0.5 hectare of the woodland is needed if one intends to produce 22 bags of charcoal. Considering all the 15 kilns studied at Kitulangalo, the average number of trees and charcoal per kiln are 6 trees of about 30 cm dbh and 36 bags respectively (Table 5).

Table 5. Observed kiln parameters

Kiln No.	No of Trees /kiln	Tree size Range (cm) dbh	Average Dbh (cm)	Measured Trees Vol. (m^3) / Kiln	Measured Biomass (kg) / Kiln	No. of Bags /kiln	Average bag Weight (kg)	Charcoal Weight (kg)	Kiln Eff. (%) *
1*	14	8-37	17	2.90	2468.40	14	31	431.0	17.5
2*	2	18-78	48	4.81	4088.50	25	49	1220.5	29.9
3	9	15-27.3	19.50	1.89	2256.79	24	55.60	1335.00	59.2
4	5	28.5-54	41.00	5.93	4282.05	72	57.00	4082.00	95.3
5	5	21.3-43	33.30	3.97	3376.03	57	65.00	3144.50	93.1
6	7	23.6-36	29.00	4.26	3621.34	33	60.00	1980.00	54.7
7	4	44.5-55	48.38	9.77	8306.46	65	66.00	4273.50	51.4
8	4	20-33	26.00	2.32	1970.98	18	62.00	1114.25	56.5
9	6	17-30.5	24.72	4.27	3625.00	35	78.00	2504.00	69.1
10*	6	17-44.7	31.00	9.84	8364.00	28	69.40	1944.00	23.2
11	5	19-38	25.94	5.46	4641.21	29	67.28	1951.00	42.0
12	5	22-38.5	29.7	5.43	4619.68	45	69.18	3113.00	67.4
13	5	18.4-25	22.00	2.91	2475.63	22	69.20	1523.00	61.5
14*	6	13-56	28.40	13.71	11656.73	34	70.00	2382.00	20.4
15	6	13.5-25	19.80	3.01	2560.80	35	69.60	2435.50	95.1
Mean	**6**		**29.58**	**5.37**	**4554.24**	**36**	**62.55**	**2228.88**	

* Used for determination of kiln efficiency

4.1.4 Suitable tree species for charcoal making

About 84% of the interviewed charcoal makers do select suitable tree species for charcoal making. Selection of tree species for charcoal making is based on the species property to produce suitable charcoal; with high recovery, high calorific value and which do not break easily during transportation. Charcoal with high calorific value attracts market and hence more income to charcoal makers. Those charcoal makers who have no species preference (16% of the respondents) are those clearing the woodland for agriculture.

The most preferred tree species for charcoal in this area are listed in Table 6. The species preference determination was based on contribution of a species to total tree volumes while species use frequency was taken as the number of times the species was cut for charcoal making for all of the fifteen kilns. These results are in line with those reported by Monela *et al.* (in press) and Nduwamungu (1996) with addition of some more tree species such as *Lannea schimperi*, *Mimusops kummel*, *Acacia gerrardii*, *Lonchocarpus capassa*, *Albizia harvey*, *Pteleopsis myrtifolia*, *Xeroderris stuhlmannii*, *Terminalia mollis*, *Acacia nilotica*, *Pseudolachnostylis maprouneifolia*, *Diplorhynchus condylocarpon*, *Boscia salicifolia* and *Acacia goetzei subsp. goetzei*.

Table 6. Most preferred tree species for charcoal making at Kitulangalo area.

Local name	Botanical name	Mean Dbh (cm)	Tree Vol. (m^3)	Use frequency*	Use preference (%) **
Mhungilo	*Lannea schimperi*	37.0	37.00	11	45.01
Mkambala	*Acacia nigrescens*	34.9	20.56	19	25.00
Mgama	*Mimusops kummel*	46.4	5.22	3	6.35
Mkongowe	*Acacia gerrardii*	27.8	4.47	8	5.44
Mhondolo	*Julbernadia globiflora*	23.9	3.82	3	4.65
Mlama mweusi	*Combretum molle*	21.1	2.76	11	3.36
Myombo	*Brachystegia boehmii*	21.9	1.92	4	2.33
Mfumbili	*Lonchocarpus capassa*	17.1	1.57	9	1.91
Msisimizi	*Albizia harvey*	27.4	1.46	2	1.77
Mgovu	*Pteleopsis myrtifolia*	22.6	0.91	3	1.10
Mnyenye	*Xeroderris stuhlmannii*	35.0	0.87	1	1.06
Mtanga	*Terminalia mollis*	19.3	0.43	2	0.52
Kifunganyumbu	*Acacia nilotica*	16.8	0.29	2	0.36
Msolo	*Pseudolachnostylis maprouneifolia*	22.1	0.28	1	0.34
Mtogo	*Diplorhynchus condylocarpon*	19.5	0.22	1	0.26
Mlama mwekundu	*Combretum zeyheri*	20.0	0.20	1	0.25
Mguluka	*Boscia salicifolia*	17.3	0.15	1	0.18
Kisasa	*Acacia goetzei subsp. goetzei*	13.0	0.08	1	0.10
		Total	**82.21**		**100**

* Species use frequency was the number of times the species was cut for charcoal making for all of the fifteen kilns studied for kiln efficiencies.

** Species use preference was calculated as the contribution of a species to total tree volumes for all of the fifteen kilns.

Acacia nigrescens appears to be the most used tree species in terms of frequency and has the second highest volume to *Lannea schimperi*. However *L. schimperi* also contributes the highest volume used. The most commonly known tree species for charcoal making. *Brachystegia boehmii and Julbernardia globiflora* appear to be less conspicuous in both volume contribution and use frequencies. This can be explained by the fact that the availability of these species at present in the public lands is low due to over exploitation. Other tree species mentioned to be used but not found at the site are *Tamarindus indica, Combretum collinum, C. adonogonium* and *Diospyros kirkii*.

Most of the woodland tree species are suitable for fuelwood with few unpreferred tree species. Such unpreffered tree species mentioned by charcoal makers included "muwindi" (*Acacia polyacantha subsp. campylacantha*), "mmoze" (*Sterculia africana*) and "mbuyu" (*Adansonia digitata*). These tree species are either with thorny stem and producing lighter charcoal of low calorific value (Monela *et al.* in press) or produce charcoal which breakdown easily into small pieces during transportation.

4.1.5 Charcoal pricing at production site

The average prices for charcoal are given in Table 7. The prices were about Tshs 1000/- (USD. 1.25) and 1500/- (USD. 1.875) (USD 1 was equivalent to Tshs. 800 in

1999) at kiln site and road side respectively. Monela *et al.* (in press) reported a decline in unit price of charcoal at kiln site from USD 0.49 to USD 1.6 between 1992 and 1996. There is therefore a decline in real price of charcoal at kiln site from USD 1.6 to USD 1.25 between 1996 and 1999. Woodfuel real prices in Mozambique were also found to have a decreasing trend from 1985 to 1996 (Falcao 2000). However the actual unit price of charcoal at Kitulangalo area remained constant at Tshs.1000 between the two periods of 1996 (Monela *et al.* in press) and 1999, suggesting that the charcoal business is not influenced by inflation. On the other hand this study was done during the dry season with the possibility of having more charcoal makers and hence reduced charcoal price.

Table 7. Average charcoal prices.

Market place	Gwata village		Maseyu village		Mean
	(Tshs/bag)	Respondents	(Tshs/bag)	Respondents	(Tshs/ 55 kg bag)
Kiln site	1056	9	1125	12	1091
Roadside	1500	2	1500	2	1500

Differences in charcoal prices with seasons are caused by transport difficulties especially from the kiln site to the highway during the rain season. Monela *et al.* (1993) observed significant differences in prices with seasons in eastern Tanzania. Studies in Mozambique also have shown higher prices in the rainy season, when there is shortage of charcoal in urban centers due to limited accessibility to the production areas (Pereira *et al.* 2000).

There is also observable charcoal price differences between the kiln site and the roadside (Table 7). Transportation costs of charcoal from kiln site to roadside contribute partly to the differences. Charcoal making at roadside is limited by availability of trees of suitable size and species. However in some places where preferred tree species and sizes are available at the roadside. carbonization of the kiln can be controlled to suit the market. In so doing partial unloading of 1 to 2 bags of charcoal per day may be done while carbonization is taking place until eventually all the wood is carbonized and sold. This is a strategy for market supply control and also to cater for shortage of bags for packing charcoal. Usually people buying charcoal at roadside come with empty bags for exchange. Table 5 shows that the main charcoal market place is at charcoal making site and little charcoal is sold at the roadside. Figure 5 shows charcoal selling at roadside.

Figure 5. Selling charcoal at roadside

Charcoal transactions at the roadside is also influenced by the licensing system.

Interview of the forest officials, revenue collectors and charcoal dealers in Morogoro region showed that no licences are usually issued for charcoal dealers and instead just formal registration of dealers is made. Currently the registration fee is about Tshs. 50,000/- for the Morogoro region. However charcoal makers do not register themselves for the charcoal they make. It is the buyers who register themselves from the forest office to enable bulky transportation of charcoal using lorries to consumers in Dar es Salaam or Morogoro. Most of these bulk buyers are from outside the area (Table 8.)

Table 8. Charcoal buyers.

Buyers	Gwata	Maseyu	Percentage
Other villagers	1	2	12
From outside the villages	7	8	60
Both	3	4	28
Total	11	14	100

Charcoal sold at the roadside is normally transported using bicycles. Such buyers rarely are registered as charcoal dealers and as a result government officials often confiscate their charcoal.

4.1.6 Licensing and other payable fees

As mentioned above bulk charcoal buyers would like to be registered as charcoal dealers. However in both old and new forest ordinances, there is no license for charcoal dealers. Instead only the registration form is issued after paying the

registration fee of Tshs. 50.000/= to the government through regional catchment forest office for the case of Morogoro region. All the revenue collected from this registration goes to the government.

Apart from the registration fees, other levies collected from charcoal dealers amounts to Tshs. 500/= per bag for Morogoro rural district. The revenues differ from one district to another due to differences in district council by-laws. However in both cases the revenues are distributed equally to both central and local government.

4.1.7 Household income from charcoal

From the above results, an average charcoal making household (specialized household) produce 43 bags of charcoal per month. Assuming all the charcoal is sold at kiln site at Tshs. 1.000/= per bag, the household realizes an income of Tshs. 43.000/= per month (USD 645 per year) from the sale of charcoal. This income is almost similar to the minimum salary rates paid currently to government workers. The household income from charcoal per year in 1992 in eastern Tanzania was found to be USD 176 (Monela *et al.* 1993) while in 1996 was US$ 445. The household income from charcoal in this area is hence on higher side of the general situation in eastern Tanzania. Given the low education level of these charcoal makers, the income may be attractive enough even to other people to join the business, and thus more deforestation of the woodland.

4.2 Ecological impact of charcoal making to the woodlands

4.2.1 Tree species composition in reserved forest and public lands

In order to portray the differences in tree species abundance between the forests in public lands and the forest reserve, stand parameters and diversity indices have been employed. Stem numbers (N), basal area (G) and volumes per hectare have been shown for both public lands and forest reserve. The three diversity indices used for this purpose were *Important Value Index* (IVI), *Index of Dominance* (ID) and *Shannon-Wiener Index of Diversity* (H').

Stem numbers (N),

A mean total of 1405 and 618 stems per hectare comprised of 44 and 48 different tree species were observed in public lands and reserved forest respectively (Appendix 5, 6 &7). Many numbers of stems in public lands may be attributed to the fact that the woodland in public lands is regenerating following disturbances through harvesting (Chidumayo & Frost, 1996). About twelve species were found only in the forest reserve while eight species were found only in the public land (Table 9). Since the public land and the forest reserve are adjacent and hence more or less ecologically similar, the differences in species occurrence may be due to the disappearance of some species coupled with invasion by pioneer species in the public land following

disturbances. The phenomenon of succession however needs to be studied in more detail.

Table 9 Tree species that were found only in Forest reserve and public lands of Kitulangalo area respectively.

Spp. Code	Local name	Botanical name	Present in Forest reserve	Present in Public lands
3	Kisasamwege	*Acacia goetzei subsp.micropylla*		✔
5	Mhingi	*Ximenia caffra*		✔
7	Mnhindipori	*Lannea schimperi*	✔	
13	Mmoze	*Sterculia africana*	✔	
29	Mkwaju	*Tamarindus indica*	✔	
39	Mguluka	*Boscia salicifolia*	✔	
42	Mgovu	*Pteleopsis myrtifolia*	✔	
45	Kisakulanhwale	*Margaritaria discoidea*		✔
48	Mtwintwi	*Commiphora pteleifolia*	✔	
61	Mkusu	*Harissonnia abyssinica*	✔	
75	Msegese	*Bauhinia petersiana*	✔	
79	Mbwewe	*Lecaniodiscus flaximifolius*		✔
87	Kilumbulumbu	*Ormocarpum kirkii*	✔	
88	Mkole	*Grewia sp.*	✔	
92	Mkumbi	*Ochna holstii*		✔
107	Mnenekenda	*Elaedendron schlechterianum*	✔	
130	Mkomanguku	*Stereospermum kanthianum*		✔
150	Msezi	*Manilkara sulcata*	✔	
151	Mhungilo	*Lannea schimperi*		✔
152	Myuyu	*Makhamia sp.*		✔

Nduwamungu 1996 observed a mean total stocking of 691 stems per hectare which is comparable to 618 obtained for the forest reserve. Malaisse (1978) in Katanga (Zaire) estimated that the stocking of miombo woodlands ranged from 520 to 645 stems ha^{-1}.

The distribution of stem numbers per hectare in both public lands and forest reserve follow the usual expected reserved J-shaped trend (Fig. 6.). This is an indication of

good forest recruitment and regeneration trend (Philip 1983).

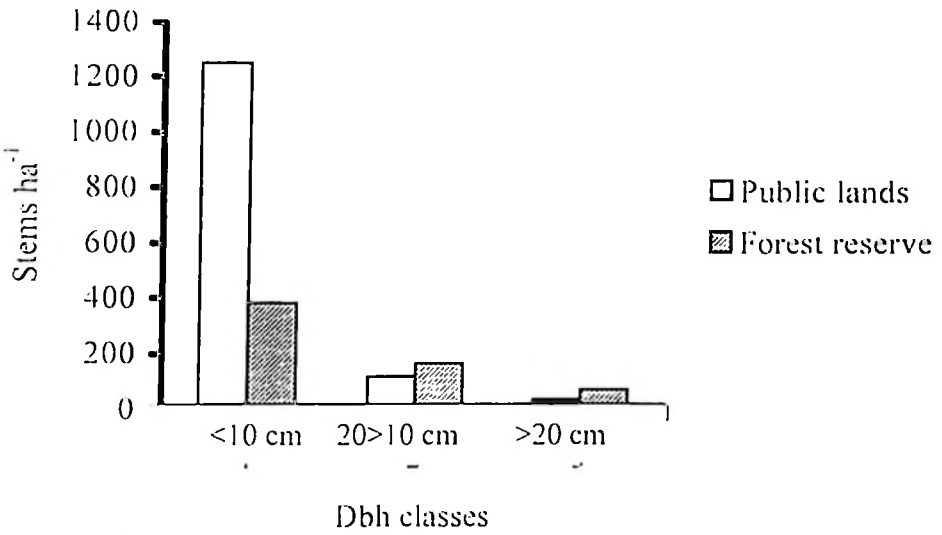

Figure 6. Distribution of stem numbers in public and reserved forests of Kitulangalo.

Stand basal area and volume per hectare

The mean total volumes and basal area per hectare were 46.2 $m^3ha^{-1}$and 7 m^2ha^{-1} in public lands and 78.8 m^3ha^{-1} and 10 m^2ha^{-1} in forest reserve respectively (Appendix 5, 6 & 7). The mean volume in the reserved forest is about two times that of public lands while the basal areas are comparable. This further signifies over exploitation in public lands. Nduwamungu (1996) observed mean total volume and basal area of 71.12 m^3/ha and 10.34 m^2/ha respectively which are comparable to the forest reserve.

The distribution of volume and basal area in both public lands and forest reserves show a J-shaped trend as expected in a natural forest with good regeneration and

recruitment (Fig. 7.)

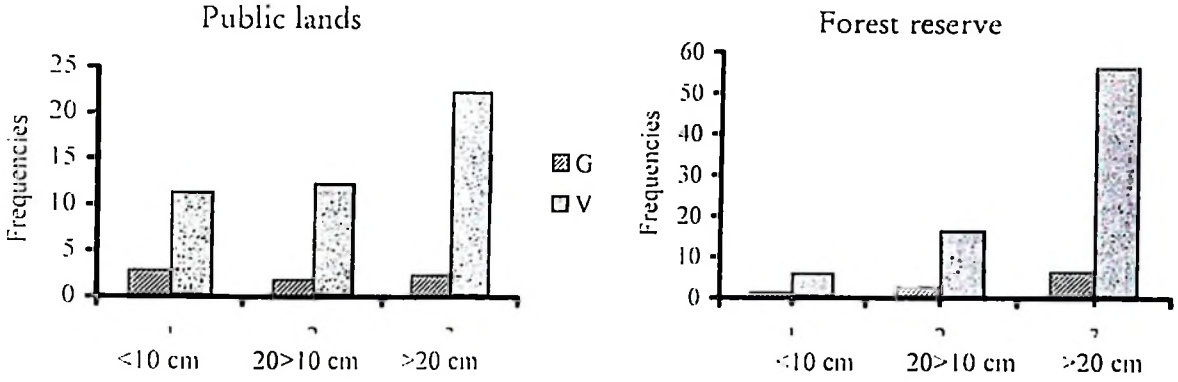

Figure 7. The distribution of volume and basal area in both public lands and forest reserves.

Tables 10 and 11 show distribution of stem numbers (N). basal area (G) and volume (V) per hectare for the suitable tree species for charcoal making. This distribution shows considerably greater values of volume and basal area in forest reserve as compared to the public lands. Charcoal making activities are said to be the most likely cause of the miombo woodlands degradation in eastern Tanzania due to ever increasing demand for charcoal in urban areas (Monela *et al.* in press).

Table 10 Distribution of N. G & V in order of increasing Volume m^3 ha^{-1} for trees suitable for charcoal in Kitulangalo public lands

	DBH CLASSES											
	<10 cm			20>10 cm			>20 cm			TOTAL		
Spp Code.	N	G	V	N	G	V	N	G	V	N	G	V
Acacia gerrardii	3	0.008	0.033				6	0.432	4.115	9	0.440	4.147
Diplorhynchus condylocarpon	52	0.124	0.551	12	0.212	1.433	3	0.196	1.873	67	0.531	3.858
Combretum molle	233	0.356	1.372	5	0.092	0.619	1	0.111	1.120	239	0.559	3.111
Acacia nigrescens	35	0.071	0.301	3	0.048	0.310	3	0.202	1.920	41	0.322	2.531
Julbernardia globiflora	286	0.543	2.248	1	0.013	0.073				288	0.556	2.321
Brachystegia boehmii	19	0.043	0.181	13	0.215	1.527	1	0.029	0.244	32	0.287	1.952
Acacia goetzei subsp goetzei	32	0.072	0.308	7	0.140	0.959	1	0.041	0.318	41	0.253	1.585
Xeroderris stuhrmannii	5	0.015	0.069				1	0.104	1.013	6	0.119	1.082
Combretum zeyheri	103	0.201	0.824							103	0.201	0.824
Pseudolachnostylis maprouneifolia	8	0.044	0.225				1	0.056	0.559	9	0.100	0.784
Mimusops kummel							1	0.075	0.674	1	0.075	0.674
Acacia nilotica				4	0.069	0.469				4	0.069	0.469
Terminalia mollis	54	0.092	0.364	1	0.015	0.090				56	0.107	0.454
Lonchocarpus sp				1	0.020	0.132	1	0.031	0.268	2	0.052	0.400
Albizia harveyi	3	0.008	0.033	1	0.027	0.183				4	0.034	0.216
Lannea sp.	8	0.025	0.113							8	0.025	0.113
Total	841	1.602	6.622	50	0.852	5.80	18	1.277	12.10	909	3.731	24.521

While the commonly known suitable tree species for charcoal making in miombo woodlands i.e. *Julbernardia globiflora and Brachystegia boehmii* appear to be abundant in the forest reserve (Table 11), in public lands they are less available Table 10). This could be explained by over use of these species in public lands where charcoal-making activities are concentrated.

Table 11. Distribution of N. G & V in order of increasing Volume m^3 ha^{-1} for suitable trees for charcoal in Kitulangalo SUA Training Forest

Spp Code.	*DBH CLASSES*									*TOTAL*		
	<10 cm			20>10 cm			>20 cm					
	N	G	V	N	G	V	N	G	V	N	G	V
Brachystegia boehmii	19	0.077	0.359	14	0.224	1.411	13	1.304	12.54	47	1.605	14.314
Julbernardia globiflora	33	0.106	0.481	19	0.307	1.919	12	0.943	8.620	64	1.356	11.020
Acacia nigrescens	8	0.019	0.076	3	0.051	0.329	6	0.899	9.362	17	0.969	9.767
Xeroderris stuhrmannii				3	0.045	0.277	5	0.509	4.872	8	0.554	5.148
Acacia goetzei subsp. goetzei	11	0.029	0.125	23	0.358	2.235	3	0.137	1.042	37	0.524	3.402
Combretum molle	53	0.191	0.879	15	0.206	1.256	2	0.060	0.477	69	0.457	2.613
Acacia gerrardii	3	0.008	0.033	3	0.058	0.374	2	0.177	1.638	8	0.243	2.046
Albizia harveyi				1	0.020	0.136	2	0.151	1.470	2	0.170	1.607
Diplorhynchus condylocarpon	28	0.093	0.417	9	0.136	0.836	1	0.306	0.010	37	0.535	1.262
Acacia nilotica	3	0.011	0.048	6	0.107	0.679	2	0.068	0.530	11	0.186	1.258
Pseudolachnostylis maprouneifolia	3	0.018	0.089	1	0.014	0.090	2	0.093	0.736	5	0.124	0.915
Lonchocarpus sp	30	0.091	0.401	1	0.022	0.135	2	0.038	0.315	32	0.151	0.851
Pteleopsis myrtifolia							1	0.083	0.717	1	0.083	0.717
Terminalia mollis	3	0.005	0.021	3	0.052	0.333	1	0.041	0.316	6	0.098	0.671
Combretum zeyheri	3	0.018	0.089	3	0.048	0.307	1	0.020	0.168	7	0.086	0.565
Mimusops kummel				1	0.008	0.045	1	0.018	0.142	1	0.025	0.186
Boscia salicifolia				1	0.020	0.122	1	0.000	0.000	1	0.020	0.122
Total	**197**	**0.665**	**3.020**	**105**	**1.673**	**10.48**	**56**	**4.848**	**42.95**	**354**	**7.186**	**56.462**

Importance Value Index (IVI)

Julbernardia globiflora appears to be the most important tree species in both public lands and reserved forest (Fig. 8 & Appendix 5. 6 & 7). This species genera together with *Brachystegia* or *Isoberlinia* are known to be among the dominant tree species in miombo woodlands (White 1983). The species is among the most preferred for charcoal making in the area.

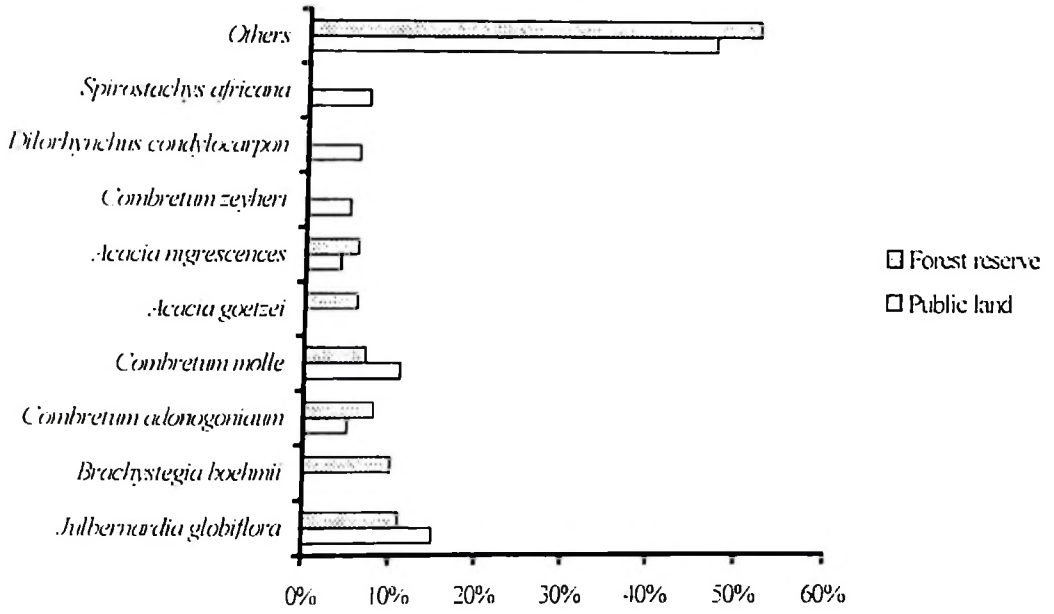

Figure 8. Distribution of tree species in both Public lands and Forest reserve, in order of the Importance Value Index

Distribution of stem numbers shows that, in public lands there are many stems of *J. globiflora* of smaller sizes compared to fewer stems of larger sizes in reserved forest (Fig. 9). This suggests that the species is regenerating in public lands following charcoal extraction disturbances. *B. boehmii* ranked the second in terms of *Important Value Index* in reserved forest while it is the eleventh in public lands (Appendices 5, 6 & 7). The species is also among the most preferred tree species for charcoal making and although only small sized trees were observed in public lands (Appendix 8), its regeneration potential might be lower than that of *J. globiflora*. *Combretum* and *Acacia* species which are also used for charcoal making seem to be important in all forests, again the species have smaller sizes in public lands compared to reserved forest.

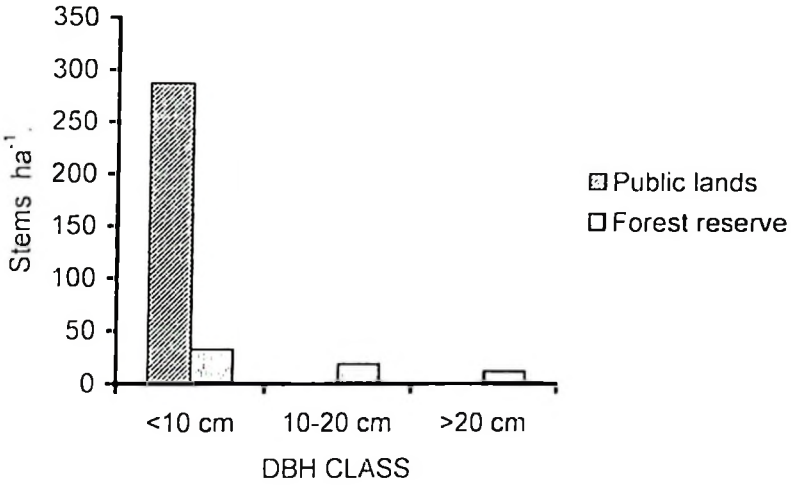

Figure 9. Distribution of *Julbernadia globiflora* stem numbers in Public lands and Forest Reserve at Kitulangalo.

Index of Dominance (ID)

This index measures the distribution of individuals among the species in a community. The greater the value of the ID, the lower the species diversity in the community and vice versa. In this study the ID were 0.092 and 0.065 in public lands and reserved forest respectively (Appendix 5, 6 & 7). This indicates that there is higher species richness in forest reserve compared to the public lands. The difference can be explained by much degradation in public lands due to among other things charcoal making activities. Nduwamungu (1996) reported the ID values of 0.03, 0.04 and 0.06 for diameter class <10, 10-20 and > 20 cm dbh respectively at Kitulangalo SUA training forest reserve. The observed ID value by Nduwamungu (1996) especially for trees >20 cm dbh is comparable to the present study value for the same forest suggesting small difference in species richness for large trees during the period

of 1996 and 1999.

Shannon-Wiener Index of Diversity (H')

This Index is most widely used because it combines species richness and evenness and it is not affected by sample size. The larger the value of H' the greater is the diversity of the community. The H' calculated using natural logarithms were 2.9 and 3.13 respectively in public land and reserved forest (Appendix 6 & 7), also suggesting that there is high species diversity in forest reserve compared to the public lands. Nduwamungu (1996) reported the H' values of 3.79, 3.56 and 3.26 for diameter class <10, 10-20 and > 20 cm dbh respectively at Kitulangalo SUA training forest reserve. Again the observed H' value by Nduwamungu (1996) for trees >20 cm dbh is comparable to the present study value for the same forest also suggesting small difference in species richness for large trees during the period of 1996 and 1999. However as it was with the case of Index of Dominance (ID) the trees in the diameter classes <20 cm dbh were observed to have high species richness in 1996 (Nduwamungu 1996) which could be due to little disturbances to the forest after the period between 1996 and 1999. Chidumayo (1988), observed that tree density in regrowth miombo woodland decreases with time due to moisture and heat stress.

4.2.2 Woodland change with distances from the highway in the public lands.

Distribution of stem numbers, basal area and wood volume at the roadside, 5 km, 10 km and 15 km from the highway are shown in Table 12. Both volume and basal area are increasing with distance from the highway while stem numbers show a reversed trend. This trend suggests that the woodland at roadside have been depleted much mostly for charcoal extraction because of easy accessibility compared to far distance woodlands from the highway. More stem numbers observed at roadside indicate regeneration of the woodland following cutting for various purposes including charcoal making. Miombo species regenerate largely through coppice re-growth and root suckers rather than seeds (Chidumayo & Frost 1996). The forest conditions at about 10 and 15 km away from the highway are comparable to those of forest reserve.

Table 12. Distribution of stocking, basal area and wood volume by distance from the highway in public lands.

Distance from the highway	N	G	V
At road side	2480	5.00	22.00
5 km away	2029	7.47	48.15
10 km	819	6.98	50.56
15 km	365	7.69	61.45

Appendices 8 (a), (b), (c) and (d) show the distribution of N, G and V by species in the public lands according to the distances from the highway. Muwindi (*Acacia polyacantha subsp. campylacantha*) seem to be the most dominant species at the road side of Kitulangalo area. The species is a pioneer and not suitable for charcoal as its

charcoal crumbles into small pieces during transportation, also its thorny stems make it unattractive to handle. Mng'ongo (*Sclerocaria birrea*), Mtogo (*Diplorhynchus condylocarpon*) and Mharaka (*Spirostachys africana*) are also the dominant tree species at 5, 10 and 15 km away from the highway. There are considerable stocks of preferred tree species for charcoal making at 15 km away from the highway and observations shows that by now charcoal extraction activities are concentrated at that area.

4.3 Woodland growth rate

Stem numbers

The mean total number of stems per hectare was 691stems in 1996 (Nduwamungu 1996) and 619 in 1999 (Table 13). All of these stem numbers are in line with those observed by Malaisse (1978) and Rees (1974) for miombo woodlands. The stem numbers have decreased in lower diameter classes and recruited in the higher diameter class. This generally suggests stand growth. Harvesting and wild fire in the woodland open up the forest and give way for regeneration. There has been no harvesting and less frequent fires in this forest since 1996 and hence little newly grown regenerants in < 10 cm dbh class. However the distribution of stem numbers per hectare by plots between 1996 and 1999 (Figure 10) follows a reserved J-shaped trend as expected in natural forest, which is an indication of good regeneration and recruitment (Philip 1983).

Table 13. Comparison of Stocking (number of stems ha^{-1}) by plot between 1996 (Nduwamungu, 1996) and 1999.

	DBH CLASSES							
	<10 cm		20 < 10 cm		> 20 cm		TOTAL	
Plot No.	1996	1999	1996	1999	1996	1999	1996	1999
1	127		64	382	71	70	262	453
2	382	382	64	127	71	85	517	594
3	509	255	159	287	42	42	710	584
4	509	255	159	223	0	70	668	548
5	127	255	96	64	0	28	223	347
6	127	0	32	318	14	42	173	361
7	1146	764	64	287	42	28	1252	1079
8	509	637	0	223	57	99	566	958
9	127	637	96	223	28	99	251	958
10	764	382	127	64	28	28	919	474
11	509	637	0	287	28	56	537	980
12	1783	382	159	96	28	42	1970	520
13	764	0	96	32	71	85	931	116
14	255	764	191	127	14	70	460	962
15	509	127	191	255	71	56	771	439
16	637	510	414	127	71	141	1122	778
17	382	382	64	0	113	56	559	439
18	127	1274	191	32	57	42	375	1348
19	127	510	127	159	14	56	268	725
20	255	510	32	159	57	127	344	796
21	127	382	127	478	42	14	296	874
22	255	764	159	446	141	70	555	1281
23	382	764	127	414	85	70	594	1249
24	127	0	127	127	42	113	296	240
25	255	510	159	127	99	42	513	679
26	382	255	159	64	42	70	583	389
27	509	0	159	127	28	70	696	198
28	127	510	64	0	170	42	361	552
29	127	255	127	127	57	56	311	439
30	2674	127	318	32	28	70	3020	230
31	509	255	287	96	71	85	867	435
32	382	255	127	96	85	127	594	477
33	764	127	127	287	113	127	1004	541
34	764	382	32	32	113	56	909	470
35	891	255	573	64	170	225	1634	544
36	2037	892	64	191	0	28	2101	1111
37	127	255	159	159	14	113	300	527
38	127	127	191	255	42	127	360	509
39	509	1019	64	32	99	14	672	1065
40	509	510	159	191	71	99	739	799
41	382	0	159	223	85	70	626	293
42	0	127	64	127	113	85	177	339
43	509	127	159	159	28	56	696	343
44	127	382	64	32	57	42	248	456
45	255	0	64	127	71	28	390	156
46	127	637	191	127	28	56	346	821
MEAN	493	391	138	165	60.24	71.34	691	619

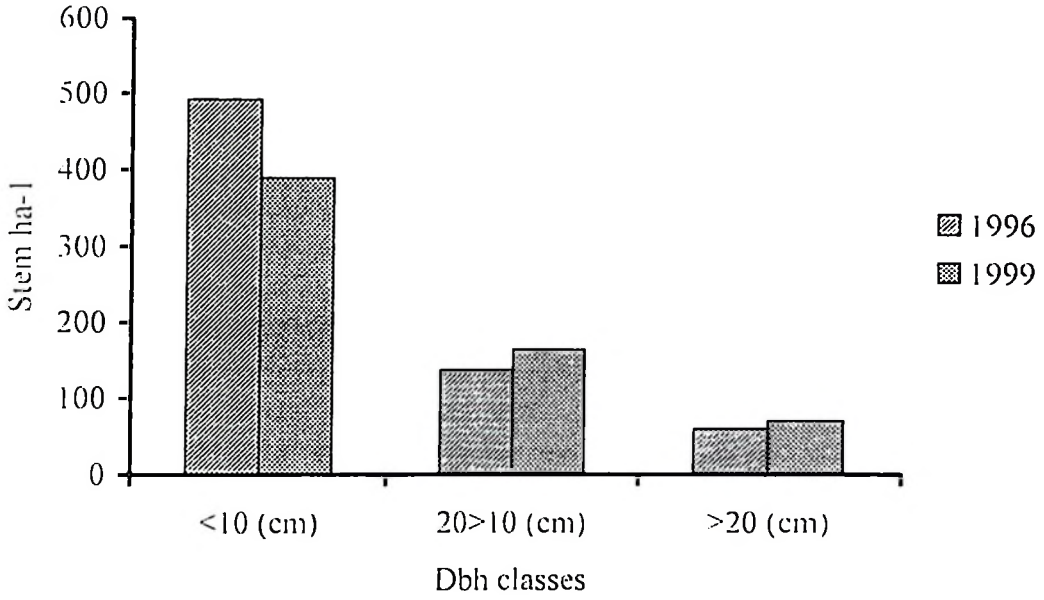

Figure 10. Comparison of the Stocking Distribution by dbh classes between 1996 (Nduwamungu, 1996) and 1999 at Kitulangalo

Figure 10 shows a decrease in stem number between 1996 (Nduwamungu 1996) and 1999 in diameter class <10 cm dbh and subsequent increase in diameter class 20>10 cm dbh and >20 cm dbh. These results suggest recruitment of smaller diameter class trees in preceding high classes and hence stand growth.

Basal area and volume

Basal area and wood volume were observed to increase with diameter class. The mean total basal area was 10.3 and 10.18 m^3ha^{-1} while wood volume was 71.12 and 78.16 m^3ha^{-1} in 1996 (Nduwamungu 1996) and 1999 respectively (Table 14 and 15). This also shows that the forest stand is growing with greater volume and basal area of

large size trees. While there was no opening up of the forest which could encourage regeneration. large trees were growing with little disturbances from wild fires. Since 1995 the Kitulangalo SUA training forest reserve is managed by the Faculty of Forestry and Nature Conservation of Sokoine University of Agriculture for training and research purposes. With these management goals no harvesting for whatever purpose is allowed in the forest and less frequent wild fires were reported.

As it was with the case of stem numbers above both volume and basal area per hectare have decreased in lower diameter classes and recruited in the higher diameter class. These parameters decreased in diameter class <10 cm dbh and 1999 and subsequently increased in diameter class 20>10 cm dbh and >20 cm dbh between 1996. This suggest recruitment of smaller diameter class trees in preceding high classes and thus stand growth with little regeneration due to absence of disturbances.

Table 14. Comparison of Basal area m^2ha^{-1} by plot between 1996 (Nduwamungu, 1996) and 1999.

	DBH CLASSES							
	<10 cm		20 < 10 cm		>20 cm		TOTAL	
Plot No.	1996	1999	1996	1999	1996	1999	1996	1999
1	0.60	0.66	0.70	5.49	6.50	6.13	7.80	12.28
2	1.60	0.72	1.10	2.34	6.80	6.08	9.50	9.13
3	3.60	1	2.40	4.12	8.20	6.94	14.20	12.06
4	3.20	1.17	2.40	3.45	0.00	3.95	5.60	8.57
5	1.00	0	1.90	1.20	0.00	0.98	2.90	2.18
6	0.20	2.63	1.00	5.50	2.90	2.49	4.10	10.62
7	3.00	1.86	0.90	4.21	2.50	0.98	6.40	7.04
8	0.60	1.81	0.00	2.87	9.70	5.70	10.30	10.38
9	0.20	1.25	1.50	3.49	2.50	5.17	4.20	9.91
10	2.90	2.4	2.10	0.94	1.40	3.49	6.40	6.84
11	2.50	2.43	0.00	4.13	2.00	4.18	4.50	10.74
12	5.40	0	3.10	0.86	1.10	2.41	9.60	3.27
13	1.50	3.02	2.20	0.90	5.60	4.79	9.30	8.72
14	1.39	0.49	2.60	2.17	1.20	2.84	5.20	5.51
15	0.90	1.67	4.30	4.04	7.50	3.59	12.70	9.30
16	2.50	0.86	8.50	2.89	5.60	13.05	16.60	16.80
17	1.60	3.46	1.40	0.00	16.20	11.32	19.20	14.78
18	0.60	1.11	4.80	0.36	5.00	3.33	10.40	4.80
19	1.00	1.25	2.70	2.13	3.00	5.03	6.70	8.41
20	0.30	2.11	0.70	1.64	6.10	7.03	7.10	10.77
21	0.40	2.73	2.20	5.94	8.70	1.68	11.30	10.35
22	1.00	2.63	3.00	5.65	13.50	3.23	17.50	11.51
23	1.20	0	2.10	6.22	8.60	7.63	11.90	13.85
24	1.00	1.46	3.20	2.41	2.80	12.34	7.00	16.21
25	1.40	1.62	3.50	2.92	5.10	3.19	10.00	7.72
26	2.00	0	2.00	1.47	6.40	10.25	10.40	11.72
27	1.90	2.13	3.30	2.67	1.70	6.96	6.90	11.77
28	0.20	1.13	1.30	0.00	13.80	5.05	15.30	6.18
29	1.00	0.25	2.30	2.21	6.40	3.18	9.70	5.64
30	11.30	0.61	5.80	0.30	3.60	5.98	20.70	6.89
31	3.80	1.45	5.50	0.91	5.40	5.67	14.70	8.04
32	2.20	0.64	2.10	0.97	5.10	11.16	9.40	12.77
33	4.70	1.38	1.70	4.78	10.10	7.36	16.50	13.51
34	2.60	0.41	0.40	0.56	12.20	2.38	15.20	3.35
35	4.60	3.01	9.30	1.45	25.90	24.57	39.80	29.03
36	5.60	0.72	1.30	2.64	0.00	2.06	6.90	5.41
37	0.60	0.49	2.50	1.87	0.60	10.11	3.70	12.47
38	0.60	2.91	2.50	5.14	2.70	11.59	5.80	19.64
39	0.80	1.87	1.20	0.42	8.50	1.51	10.50	3.81
40	2.30	0	3.20	2.90	3.50	9.18	9.00	12.08
41	0.60	0.36	2.90	3.70	4.20	11.49	7.70	15.55
42	0.00	0.36	1.80	2.60	9.10	7.34	10.90	10.30
43	3.00	0.97	2.70	2.65	6.00	3.16	11.70	6.78
44	0.20	0	1.50	0.72	6.10	2.12	7.80	2.84
45	0.30	2.66	1.40	2.60	4.30	3.64	6.00	8.90
46	1.00	12.47	4.10	1.78	6.90	5.67	12.00	19.93
MEAN	1.93	1.57	2.55	2.57	5.98	6.04	10.30	10.18

Table 15. Comparison of Wood volume m^3ha^{-1} by plot between 1996 (Nduwamungu, 1996) and 1999.

	DBH CLASSES								
	<10 cm		20 < 10 cm		> 20 cm		TOTAL		
Plot No.	1996	1999	1996	1999	1996	1999	1996	1999	
1	3.70	0.00	3.30	33.56	62.00	56.16	69.00	89.72	
2	6.00	2.54	6.90	15.08	57.70	52.58	70.60	70.20	
3	15.40	3.07	13.70	25.17	68.30	74.04	97.40	102.28	
4	13.50	4.61	14.30	21.40	0.00	33.63	27.80	59.65	
5	4.70	5.63	11.00	7.68	0.00	7.08	15.70	20.39	
6	0.50	0.00	6.60	34.93	21.40	20.32	28.50	55.25	
7	10.70	11.89	5.10	25.65	20.70	7.11	36.50	44.65	
8	2.10	8.11	0.00	17.22	102.20	46.60	104.30	71.93	
9	0.50	7.95	7.80	22.21	20.20	41.72	28.50	71.89	
10	11.50	5.60	9.80	5.80	10.90	33.52	32.20	44.92	
11	8.80	11.07	0.00	25.42	17.20	36.02	26.00	72.51	
12	25.30	12.30	14.00	4.66	7.90	19.94	47.20	36.89	
13	4.50	0.00	13.20	6.28	42.50	39.50	60.20	45.78	
14	6.30	14.00	16.30	14.00	9.80	21.40	32.40	49.40	
15	3.20	2.23	28.30	25.22	67.40	31.14	98.90	58.59	
16	10.00	7.60	55.60	19.41	50.70	119.07	116.30	146.08	
17	5.60	3.50	8.50	0.00	143.30	132.42	157.40	135.92	
18	2.80	14.81	32.00	2.06	37.50	29.34	72.30	46.21	
19	3.70	4.49	13.90	12.70	29.40	45.19	47.00	62.38	
20	0.90	5.40	3.60	9.22	52.40	57.16	56.90	71.78	
21	1.70	10.42	11.00	35.22	78.80	15.89	91.50	61.53	
22	3.40	12.68	18.10	33.85	105.50	25.37	127.00	71.90	
23	4.20	11.89	13.00	38.19	69.50	78.74	86.70	128.81	
24	5.20	0.00	19.90	15.41	21.70	121.45	46.80	136.85	
25	5.90	6.28	21.10	19.73	35.70	28.14	62.70	54.15	
26	8.40	8.20	10.70	9.82	55.80	102.49	74.90	120.50	
27	7.60	0.00	19.20	17.54	11.80	66.11	38.60	83.65	
28	0.80	9.92	7.70	0.00	103.20	49.55	111.70	59.47	
29	4.20	5.31	12.80	13.98	50.50	25.87	67.50	45.16	
30	49.90	0.98	33.80	1.67	25.00	53.43	108.70	56.08	
31	17.00	2.52	30.00	5.05	43.80	49.12	90.80	56.69	
32	9.70	7.18	12.30	5.44	37.90	102.17	59.90	114.78	
33	18.30	3.08	10.20	29.91	72.00	60.08	100.50	93.07	
34	11.40	6.29	1.60	3.54	93.50	18.21	106.50	28.04	
35	21.80	1.56	51.30	9.64	258.20	239.27	331.30	250.48	
36	22.10	13.59	7.30	16.04	0.00	17.51	29.40	47.14	
37	2.50	3.07	12.10	10.84	3.50	92.84	18.10	106.74	
38	3.10	2.23	13.30	33.56	19.40	109.93	35.80	145.71	
39	2.40	12.77	6.60	2.50	60.50	13.99	69.50	29.26	
40	9.50	8.52	19.20	17.72	24.40	91.29	53.10	117.54	
41	1.90	0.00	14.30	23.33	30.80	122.07	47.00	145.40	
42	0.00	1.53	9.50	16.94	65.40	66.30	74.90	84.77	
43	14.20	1.53	13.00	16.65	50.40	25.86	77.60	44.04	
44	0.50	4.05	6.80	4.79	51.60	16.78	58.90	25.63	
45	0.90	0.00	8.30	16.95	31.70	37.41	40.90	54.35	
46	4.90	12.47	24.30	10.76	6.90	53.82	36.10	77.05	MAI
MEAN	8.07	5.89	14.59	16.02	48.46	56.25	71.12	78.16	2.35

The distribution of both basal area and wood volume show a J-shaped trend as expected due to the influence of large trees on basal area and volume.

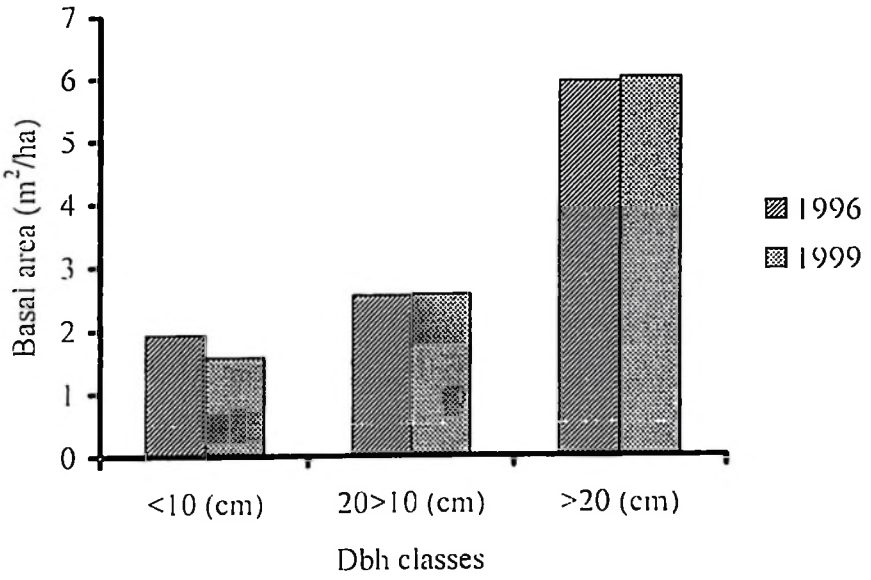

Figure 11. Comparison of the Distribution of basal area by dbh Classes between 1996 and 1999 at Kitulangalo

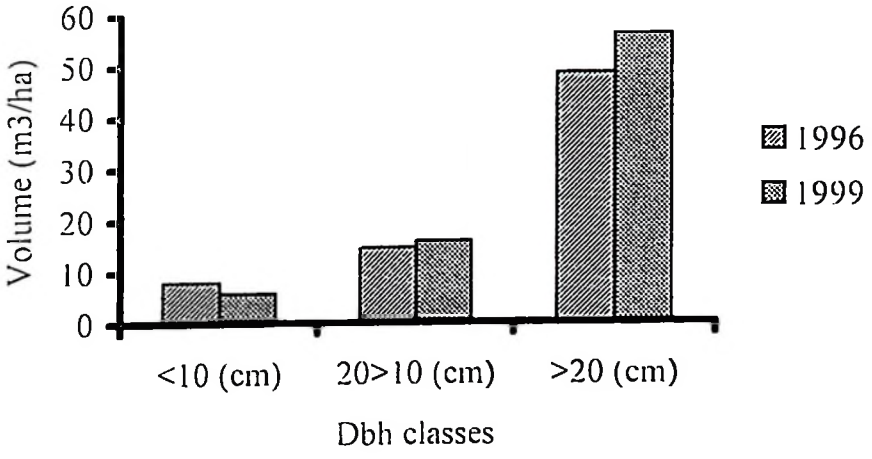

Figure 12 Comparison of the Distribution of wood volume between 1996 and 1999 at Kitulangalo

Table 15 also shows that the Mean Annual Increment (MAI) for the period of three years (1996-1999) is 2.35 $m^3ha^{-1}year^{-1}$. This rate is in line with that of Nilsson (1986) and Temu (1980) who estimated an annual growth rate of 1-2 $m^3ha^{-1}year^{-1}$ for disturbed woodlands in Tanzania. Chidumayo (1988) reported a mean annual fuelwood increment of 1.96 $m^3ha^{-1}year^{-1}$ in dry miombo. However the rate is contrary to that provided by Malimbwi *et al* (1994) of 0.54 $m^3ha^{-1}year^{-1}$ for regrowth miombo woodland and 7.4 $m^3ha^{-1}year^{-1}$ together with 7.3 $m^3ha^{-1}year^{-1}$ in the old growth miombo and semi-evergreen miombo respectively. Small coverage of the study by Malimbwi *et al.* (1994) may have been the source of the discrepancy, but also the results caution against applying existing growth rate data in new locations due to the high variation that may exist between different miombo ecosystems.

4.4 Potential of the woodland to produce charcoal

The distribution of volume, basal area and number of stems per hectare for the preferred tree species and sizes for charcoal making in the public land is shown in Table 16. As with the case of total volume, basal area and number of stems per hectare for all species, there is generally increase of these stand parameters with distance from the highway for the preferred tree species for charcoal making. However, although the total volume, basal area and number of stems per hectare for all species at 15 km from the roadside is higher than at 10 km (Table 12), these parameters are greater for preferred tree species at 10 km away from the highway

(Table 16). This suggests that cutting at 10 km distance may be for other uses apart from charcoal. This area is close to a sub-village and more tree cutting may be for building poles and firewood rather than charcoal making.

Table 16. Distribution of tree species of suitable size for charcoal making in the public lands.

	DBH CLASSES						TOTAL			Bags ha^{-1}
	10 – 20 cm			>20 cm						
Distance	N	G	V	N	G	V	N	G	V	
Road side	5	0.05	0.29				5	0.05	0.29	1
5 km	106	1.68	11.06	12	0.50	4.20	119	2.18	15.27	54
10 km	90	1.64	11.23	35	2.48	23.96	125	4.13	35.19	125
15 km	59	0.97	6.5	45	3.00	28.01	103	4.00	34.55	125

About 0.29, 15.27, 35.19 and 34.55 m^3ha^{-1} of exploitable trees are available at road side, 5 km, 10 km and 15 km from the highway respectively (Table 16). Considering a conversion factor of fresh wood volume to wood biomass of 0.85 (see section 3.2.2) and kiln efficiency of 23% (Table 4), the weight of charcoal that can be extracted from the woodland at the roadside is "0.29 m^3ha^{-1} (fresh wood) x 0.85 x 0.23 = 0.056 tons per hectare" or 56 kgs of charcoal, equivalent to only one bag of charcoal per hectare. Similarly 54 bags may be expected at 5 km distance while 125 bags may be extracted from beyond 10 km from the highway (Table 16).

It is clearly shown that the public lands from 5 km away from the highway and the reserved forest have progressively high potential of producing charcoal compared to the woodland in the public land at road side. Given that the woodland growth potential is 2.35 $m^3ha^{-1}year^{-1}$ and assuming the desirable forest condition for charcoal

making is that of the forest reserve which has 53.43 m^3ha^{-1}, the public forest lands management can plan charcoal extraction and sustain woodland status at a desired state. The number of years (n) it will take for the 'Z' forest to attain 'Y' forest situation is given by:

$$n = \frac{(Y\ m^3ha^{-1} - Z\ m^3ha^{-1})}{2.35\ m^3ha^{-1}year^{-1}}$$

where n is the number of are years for the forest to grow before harvesting
'Y' is the desired forest situation with $Y\ m^3ha^{-1}$
'Z' is the forest with $Z\ m^3ha^{-1}$ needed to attain a desired situation and
2.35 ($m^3ha^{-1}year^{-1}$) is the volume mean annual increment

Based on the above assumptions. the time needed for the degraded woodland to attain harvestable status is shown in Table 17. It will take about 23 and 16 years for the woodland at roadside and at 5 km away from the highway respectively to attain the forest conditions of the forest reserve with 53.43 m^3ha^{-1} of preferred tree species for charcoal making. This suggests that for the woodland at roadside to recover for sustainable charcoal production. a rotation age ranging between 16 and 23 years should be considered. However charcoal production could also be sustained at the levels observed at beyond 10 km away from the highway within shorter rotation age range of 8 to 15 years for degraded forest at 5 km away from the highway and at roadside.

For this mechanism to be practiced the public forest land where charcoal is now

being produced could be divided into annual Coupes of desirable sizes to be harvested in 8 years felling cycles. During harvesting it should be ensured that only trees > 10 cm dbh are felled. Mean while research should be carried out in the annual coupes felling system to monitor regeneration and succession.

Table 17. Time lapse for degraded woodland to recover for charcoal production.

Distance / Location	Present exploitable volume (m^3/ha)	Years to attain forest reserve situation	Volume to be attained (m^3/ha)	Years to attain situation at 10 and 15 km in public land	Volume to be attained (m^3/ha)
Forest reserve	53.44				
Road side	0.29	23	53.44	15	35
5 km	15.27	16	53.44	8	35
10 km	35.19	8	53.44		
15 km	34.55	8	53.44		

These proposed rotation ages may be useful especially during this period of forest policy reform in Tanzania where communities may be involved in forest management. Involvement of village communities in forest management among other things requires them to benefit from the forest they manage. At Kitulangalo where charcoal is the main product extracted from the woodlands, allocation annual coupes to village communities could be done by responsible forest officers who will also ensure that the minimum sizes for harvesting are observed.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATIONS

Charcoal extraction provides substantial income to charcoal making households of the Kitulangalo area. For the specialized charcoal making households their monthly income from sales of charcoal is comparable to the minimum salary rate paid currently to the government workers. Given the high un-employment status in the country, people may be attracted to migrate from other areas. The charcoal making households from this area are not depending entirely on charcoal extraction, but rather complement their income from other economic activities such as farming. To them farming is meant for food provision only and during the time of food shortage they buy food from other people in the village and even from outside.

However, there are obvious signs of depletion of the woodland resources due to charcoal extraction activities in this area. The situation may be alarming in the future if the rate of in-migration of people from other parts of the country will be high. The current wood-charcoal conversion efficiencies are in the range of 17.5% and 30% with the possibility of their maximization at 30%. There is thus a need to explore efficient traditional harvesting and conversion techniques that will help to minimize the rate of deforestation at the area.

It is also clear that the commonly used tree species for charcoal such as *Brachystegia,*

Julbernardia and *Combretum* have little volume stocks in the public lands where charcoal making takes place. People have now opted for other tree species that are of large sizes which when mixed with small size trees of the above named species produce suitable charcoal. However, all of the suitable tree species for charcoal making were observed to regenerate fairly.

At Kitulangalo charcoal production was found to concentrate in the public lands and none is done in Kitulangalo SUA Training Forest Reserve. The Kitulangalo SUA Training Forest Reserve is under management of Faculty of Forestry and Nature Conservation of the Sokoine University of Agriculture since 1995. The forest is managed for research and training purposes through two forest guards in collaboration with surrounding communities. No harvesting of whatever way is allowed in this forest reserve. On the other hand there is no harvesting control measures in public lands.

Wood volume stocks of exploitable size and species for charcoal were observed to increase with increasing distance from the highway in the public lands. Public lands from 10 km from the highway were observed to have far better wood volume stocks of exploitable trees for charcoal due to inaccessibility to these places especially during the rainy season. The woodlands in this area have high potential to quickly regenerate under controlled access. Given the fact that the surrounding public lands are having similar soil and climatic conditions to the reserved forest, it is obvious that

controlled harvesting may result to better forest conditions in the public lands. Good infrastructure development and harvesting control by provision of harvesting coupes based on stand growth rate could provide sustainable charcoal harvesting in this area.

However there is a need to assist charcoal makers with training for greater efficiency of charcoal making process. Charcoal makers should also be trained on the sustainable charcoal supply potential of the woodland in this area.

For sustainable management of these woodland especially in the public land management should consider the rotation ages suggested by this study in order to give time for the depleted woodland at roadsides to regenerate. However this should go hand in hand with strict laying down of some bylaws that will regulate charcoal business at the area.

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APPENDICES

Appendix 1 Household Questionnaire

Date:.....

1. General information

1.1 Village name: .....

1.2 Ward name: .....

1.3 Division name: .....

1.4 District name: .....

1.5 Enumerator name: .....

1.6 Household identification No. .....

2. Classification questions:

2.1 Name of respondent:

2.2 Sex 1. Male ☐

2. Female ☐

2.3 Age ..... years

2.4 Ethnic group

2.5 Marital status

1. Single ☐
2. Married ☐ ..... No. of wives.....
3. Separated ☐
4. Divorced ☐
5. Widowed ☐

2.6 Highest Education level reached

2.7 Household composition

Age	Number		
	Males	**Females**	**Total**
1. Up to 15 years			
2. 15 – 60 years			
3. 60 – 75 years			
4. Above 75 years			

2.8 Were you born in this village? YES/NO. What is your occupation now?

3. **Charcoal making activities:-**

3.1 Is there any natural forest around your village? YES/NO

If YES, who owns or manages it?

Forest type	**ownership**
Government	
Community (village)	
Public land	
Both	

3.2 What is the present state of the forest near the village

Good ☐

Bad ☐

If bad, why? .....

3.3 Is charcoal making an important activity in the village?

YES/NO

3.4 If charcoal maker

1. When did you start the charcoal business? .....
2. What forces made you engage in this business?

.....

.....

.....

3 Are you working under contract production? **No/Yes**

If yes who owns the business .....

And where does she/he stays .....

4 Average working days in a month .....

5 Average working hours in a day .....

			Which activities	No. of people
6	Source of labour:	Household	☐	☐
		Hired	☐	☐
		Communal	☐	☐

3.5 Quantity of charcoal produced for household use ..... bags.

3.6 Quantity of charcoal produced for sale ..... bags.

3.7 Species preferred for charcoal production

.....

.....

.....

.....

3.8 Are they easily accessible? YES/NO

If NO why? .....

3.9 Charcoal making sites:

Site No.	1970's			1980's			1990's		
	Distance from village	Availability of trees	Types of species	Distance from village	Availability of trees	Types of species	Distance from village	Availability of trees	Types of species
1.									
2.									
3.									
4.									
5.									

3.10 When you make charcoal do you select trees or clear the area completely? YES/NO

If YES, what tree species and average sizes are cut?

Species	Average size cut

3.10 Estimate the number of trees cut per kiln for different kiln types and specify the dimensions of these kilns.

Type of kiln	No. of trees per kiln	Kiln dimensions

3.12 Estimate number of bags per kiln ..... bags.

3.13 Estimate number of persondays to operate a kiln

3.14 Is soil erosion a problem in charcoal burning sites? YES/NO

3.15 Is there any regeneration in charcoal making sites? YES/NO

If Yes what types of tree do regenerate?

(i) Those used for charcoal ☐

(ii) Those not used for charcoal ☐

(iii) Both types ☐

3.16 How long does it take a kiln to produce charcoal?

.....Days for wood cutting.

..... Days for kiln preparation.

..... Days for combustion.

....Days for unloading.

3.17 What are the charcoal market places for this area

Name of market place	Distance from charcoal making site
(i) Charcoal making site (ii) Road side (iii) Village (ii) Urban Centre (iii) Dar es Salaam city	

3.18 Specify charcoal prices in these market places

Name of market place	Price (Tshs/bag, tin or can))
(i) Charcoal making site	
(ii) Road side	
(iii) Village	
(iv) Urban Centre	
(v) Dar es Salaam city	

3.19 Specify charcoal transport cost per unit

Transport means	Cost from charcoal making site to: (Tshs)
(i) Head load	Road side Village Urban centres DSM city
(ii) Cart	Road side Village Urban centres DSM city
(iii) Vehicle	Road side Village Urban centres DSM city
(IV) Bicycle	Road side Village Urban centres DSM city

3.20 How long does it take to sale an average kiln ..... days

3.21 Specify the customers:-

(i) Other villagers

(ii) People from outside the village . Specify.....

3.22 What makes you move to the next charcoal making site?

3.23 Has the distance increased over the last ten years. YES/NO

If Yes why?..... .....

3.24 Are there some special months during which you cut trees and make charcoal? YES/NO

If YES, specify the months .....

3.25 Specify the amount of labour over the year for charcoal making (Persondays/Months)

Months	J	F	M	A	M	J	J	A	S	O	N	D
P/days												

3.27 Production, sale, purchase and consumption of charcoal during the past year.

Item	Amount per year (bags)	Value (Tshs)
Production		
Sale		
Purchase		
Consumption		

3.28 Is charcoal scarce today than 10 years ago? YES/NO

3.29 Is the tree cover generally better/worse than 10 years ago? YES/NO. If yes, why .....

3.30 What rules are used to regulate exploitation of woodlands for charcoal making and who makes them

Regulation/rules	Who make them

3.31 Are there any conflicts? YES /NO

If YES of what nature?

.....

.....

.....

Appendix 2. Checklists

Village Checklist

1. General information

1.1 Village name

1.2 Division

1.3 District

2. Demographic data

2.1 Total village population

2.2 Actively working adults (male……: Female…..)

2.3 Children (<16 yrs)

2.4 Elders (>60 yrs)

2.5 Number of households

2.6 Average family size

2.7 In and out migration

3. Land use, social and economic activities

3.1 Social services in the village

3.2 Main economic activities in the village

3.3 Average earnings from each activity

3.4 Land acquisition and expansion

4. Forest activities

4.1 Benefits villagers get from the forests

4.2 Sources of forest products and condition of the forests

4.3 Consumption of charcoal in the village ……..bags/yr

4.4 Sale of charcoal …….bags/yr

4.5 People's involvement in woodland management.

Regional, district, division, ward and or village forest officers Checklist

1. Types and extent of forests and woodlands in your area
2. Threats to forests in the area
3. Extraction activities for forest products and availability
4. Actors in charcoal business and their trends
5. Dependency on forest s and reason for dependency
6. Pricing and levies on forest products
7. Trends in charcoal prices
8. Type of licenses for forest products
9. Attitude towards participatory forest management
10. Rate of deforestation and indicators of forest disturbances

Appendix 3 Sample Plot Field Form

Date ....

CODE	LOCAL NAME	DBH (cm)	Height (m)

Code	Local Name	Ns	Dbh (cm)	Code	Local Name	Ns	Dbh (cm)

Appendix 4 (a). **Charcoal Tree Measurement Form**

Village .... Sub-village ....
Kiln No .... Kiln type ....
Tree No. .... Species ....
DBH .... (cm) Total Ht ....(m)

Section No.	Mid diam. cm	Length m	Section No.	Mid diam. cm	Length m

Appendix 4 (b). Charcoal Kiln Measurement Form

Village ..... Sub-village .....
Kiln No ..... Kiln type .....
Diam./width ..... (m) Length .....(m)

	Tree cutting	Kiln loading	Kiln prep.	Unloading kiln
Women				
Men				
Total				

Days for carbonization ..... days

Total number of bags of charcoal ..... bags.

Bag of charcoal	Weight (kgs)

Appendix 5. List of tree species found at Kitukangalo area.

Code	Local Name	Botanical name
1	Mtogo	*Diplorhynchus condylocarpon*
2	Myombo	*Brachystegia boehmii*
3	Kisasamwege	*Acacia goetzei subsp. Microphylla*
4	Mnhondolo	*Julbernardia globiflora*
5	Mhingi	*Ximenia caffra*
6	Mlama-mtitu / Mlama -mweusi	*Combretum molle*
7	Mnhindipori	*Lannea schimperi (a)*
8	Mfumbili	*Lonchocarpus Sp.*
10	Kifunganyumbu	*Acacia nilotica*
11	Kikulagembe	*Dichrostachys cinerea*
12	Mng'ongo	*Sclerocarya birrea subsp. caffra*
13	Mmoze	*Sterculia africana*
17	Msosoana	*Dombeya rotundifolia*
18	Msinzira	*Bridelia cathartica*
19	Mkambala	*Acacia nigrescens*
20	Mharaka	*Spirostachys africana*
21	Mgama	*Mimusops kummel*
22	Mpingo	*Dalbergia Melanoxylon*
23	Mkulwi	*Diospyros kirkii*
24	Mdaula	*Zanha africana*
25	Mninga	*Pterocarpus angolensis*
26	Mnyenye	*Xeroderris stuhrmannii*
27	Mlama-ng'ombe	*Combretum adonogonium*
28	Mtanga	*Terminalia mollis*
29	Mkwaju	*Tamarindus indica*
30	Msisimizi	*Albizia harveyi*
32	Msolo	*Pseudolachnostylis maprouneifolia*
33	Mtutuma	*Catunaregam spinosa*
34	Mtomokwe	*Annona senegalensis*
39	Mguluka	*Boscia salicifolia*
42	Mgovu	*Pteleopsis myrtifolia*
44	Kilemelantembo	*Gardenia ternifolia subsp. jovis-tonantis*
45	Kisakulanhwale	*Margaritaria discoidea*
48	Mtwintwi	*Commiphora pteleifolia*
55	Mnzenzegele	*Dalbergia nitidula*
57	Mtwintwi	*Commiphora africana*
61	Mkusu	*Harissonnia abyssinica*
67	Muwindi	*Acacia polyacantha subsp. campylacantha*

Appendix 5. Contn.

74 Mhembeti	*Sterculia quinqueloba*
75 Msegese	*bauhinia petersiana*
79 Mbwewe	*Lecaniodiscus flaxinifolius*
85 Mlamamdunku / Mlama-mwekundu	*Combretum zeyheri*
87 Kilumbulumbu	*Ormocarpum kirkii*
88 Mkole	*Grewia sp.*
90 Mkongowe	*Acacia gerrardii*
91 Mfuru	*Vitex ferruginea*
92 Mkumbi	*Ochna holstii*
94 Mgwejameno	*Antidesma venosum*
106 Mseni	*Brachystegia microphylla*
107 Mnenekenda	*Elaedendron schlechterianum*
117 Kisasa	*Acacia goetzei subsp. goetzei*
130 Mkomanguku	*Stereospermum kanthianum*
133 Mufleta	*Albizia anthelmintica*
150 Msezi	*Manilkara sulcata*
151 Mhungilo	*Lannea schimperi (b)*
152 Myuyu	*Makhamia sp.*
153 Mlama - dori	*Combretum collinum*

Appendix 6. Distribution of Tree species in the public land of Kitulangalo Forest in order of their *Importance Value Index* (IVI)

Code	Local Name	Botanical Name	N	G	V	Frq.	Rel. Freq	Rel. Dom.	Rel. Den	IVI	H'	(n/N)^2
4	Mnhondolo	*Julbernardia globiflora*	288	0.556	2 321	55	16 176	7.855	20.487	44.518	0.325	0 041970
6	Mlama-mtitu / Mlama - mweusi	*Combretum molle*	239	0.559	3 111	26	7 647	7.894	17.027	32.569	0.301	0.028993
20	Mharaka	*Spirostachys africana*	70	0 563	3 660	27	7 941	7 959	4.984	20.884	0.149	0.002484
1	Mtogo	*Diplorhynchus condylocarpon*	67	0.531	3 858	20	5 882	7 506	4.741	18 129	0.145	0 002247
85	Mlamamdunku / Mlama-mwekundu	*Combretum zeyheri*	103	0 201	0 824	20	5 882	2 836	7.317	16.036	0.191	0.005354
27	Mlama-ng'ombe	*Combretum adonogonium*	53	0 386	2.323	17	5 000	5.452	3.778	14 230	0.124	0 001427
19	Mkambala	*Acacia nigrescens*	41	0.322	2 531	15	4 412	4 543	2.947	11.902	0.104	0.000868
17	Msosoana	*Dombeya rotundifolia*	28	0.300	1.980	15	4 412	4 242	2.003	10 657	0.078	0 000401
90	Mkongowe	*Acacia gerrardii*	9	0 440	4.147	11	3.235	6.211	0.607	10.053	0.031	0.000037
107	Mnenekenda	*Elaedendron schlechterianum*	41	0.253	1.585	12	3.529	3.572	2.916	10.017	0.103	0.000850
2	Myombo	*Brachystegia boehmii*	32	0.287	1 952	11	3.235	4.061	2 298	9.594	0.087	0.000528
25	Mninga	*Pterocarpus angolensis*	44	0 111	0.502	13	3.824	1 569	3.163	8.556	0 109	0 001001
67	Muwindi	*Acacia polyacantha subsp. campylacantha*	16	0.244	2.075	12	3.529	3.440	1.117	8.086	0.050	0.000125
12	Mng'ongo	*Sclerocarya birrea subsp. Caffra*	5	0.391	4.110	7	2.059	5 519	0.345	7.923	0.020	0.000012
28	Mtanga	*Terminalia mollis*	56	0.107	0.454	6	1.765	1.518	3.965	7.248	0.128	0.001572
106	Mseni	*Brachystegia microphylla*	45	0.100	0 451	4	1.176	1.414	3.209	5.800	0.110	0.001030
55	Mnzenzegele	*Dalbergia nitidula*	2	0.273	0 406	5	1.471	3.863	0 112	5.445	0.008	0.000001
44	Kilemelantembo	*Gardenia ternifolia subsp. jovis-tonantis*	38	0.057	0 215	2	0.588	0.800	2.737	4.125	0.098	0.000749
11	Kikulagembe	*Dichrostachys cinerea*	38	0.052	0.192	2	0.588	0.735	2.737	4.061	0.098	0.000749
18	Msinzira	*Bridelia cathartica*	11	0.103	0.619	6	1.765	1.454	0.756	3.974	0.037	0.000057
22	Mpingo	*Dalbergia Melanoxylon*	8	0.094	0.632	5	1.471	1.334	0.603	3.408	0.031	0.000036
26	Mnyenye	*Xeroderris stuhrmanni*	6	0.119	1.082	4	1 176	1.687	0.461	3.324	0.025	0.000021
57	Mtwintwi	*Commiphora africana*	33	0.042	0.150	1	0.294	0.588	2.359	3.242	0.088	0.000557
138=153	Mlama - dori	*Combretum collinum*	33	0.042	0.150	1	0.294	0.588	2.359	3 242	0.088	0.000557

Appendix 6. Continued

Code	Local Name	Botanical Name	N	G	V	Frq.	Rel. Freq	Rel. Dom.	Rel. Den	IVI	H'	(n/N)^2
32	Msolo	*Pseudolachnostylis maprouneifolia*	9	0.100	0 784	4	1 176	1.418	0.608	3.203	0.031	0.000037
130	Mkomanguku	*Stereospermum kanthianum*	6	0.102	0 810	3	0.882	1.437	0.461	2.780	0.025	0 000021
33	Mtutuma	*Catunaregam spinosa*	13	0 036	0.158	4	1.176	0.509	0.945	2.630	0.044	0.000089
133	Mufleta	*Albizia anthelmintica*	3	0.097	0.737	3	0.882	1.363	0 231	2 476	0.014	0.000005
74	Mhembeti	*Sterculia quinqueloba*	6	0.081	0.626	2	0.588	1.143	0.420	2.151	0.023	0.000018
10	Kifunganyumbu	*Acacia nilotica*	4	0.069	0.469	3	0 882	0.980	0.283	2.146	0.017	0.000008
94	Mgwejameno	*Antidesma venosum*	3	0.068	0 516	3	0.882	0.955	0.178	2 016	0.011	0 000003
23	Mkulwi	*Diospyros kirkii*	7	0 053	0.345	2	0.588	0 743	0.472	1.804	0 025	0.000022
21	Mgama	*Mimusops kummel*	1	0.075	0.674	2	0.588	1.057	0.084	1.729	0.006	0.000001
5	Mhingi	*Ximenia caffra*	17	0 012	0.037	1	0.294	0.165	1 180	1.639	0.052	0.000139
3	Kisasamwege	*Acacia goetzei subsp. Microphylla*	2	0.057	0.433	2	0.588	0.800	0 136	1.525	0.009	0.000002
34	Mtomokwe	*Annona senegalensis*	3	0.032	0.197	3	0 882	0 451	0.189	1.522	0.012	0.000004
151	Mhungilo		8	0.025	0.113	2	0.588	0.356	0.567	1.511	0.029	0 000032
8	Mfumbili	*Lonchocarpus Sp.*	2	0.052	0.400	2	0.588	0.728	0.136	1.453	0.009	0.000002
30	Msisimizi	*Albizia harveyi*	4	0 034	0.216	2	0.588	0.483	0.283	1.354	0.017	0.000008
79	Mbwewe	*Lecaniodiscus flaxinfolius*	1	0.027	0.220	1	0.294	0.375	0.042	0.711	0.003	0.000000
45	Kisakulanhwale	*Margaritaria discoidea*	3	0.010	0.048	1	0.294	0.144	0 189	0.627	0 012	0.000004
24	Mdaula	*Zanha africana*	3	0.008	0.033	1	0.294	0.106	0.189	0.589	0.012	0.000004
92	Mkumbi	*Ochna holstii*	3	0 005	0.021	1	0.294	0.074	0.189	0.557	0.012	0.000004
152	Myuyu		3	0.005	0.021	1	0.294	0.074	0.189	0.557	0.012	0 000004
		Total	1405	7.079	46.191	340	100	100	100	300	2.904	0.092033

Appendix 7. Distribution of Tree Species Found in Kitulangalo SUA Training Forest Reserve in order of IVI.

Code	Local Name	Botanical name	N	G	V	Freq.	Rel. Freq	Rel. Dom.	Rel. Den	IVI	H'	(n/N)^2
4	Mnhondolo	*Julbernardia globiflora*	64	1.356	11.020	25	8.532	13.188	10.396	32.116	0.235	0.010808
2	Myombo	*Brachystegia boehmii*	47	1.605	14.314	24	8.191	15.616	7.557	31.363	0.195	0.005710
27	Mlama-ng'ombe	*Combretum adonogonium*	81	0.597	3.536	16	5.461	5.806	13.130	24.397	0.267	0.017239
6	Mlama-mtitu / Mlama –mweusi	*Combretum molle*	69	0.457	2.613	15	5.119	4.445	11.176	20.740	0.245	0.012491
117	Kisasa	*Acacia goetzei subsp. goetzei*	37	0.524	3.402	23	7.850	5.102	6.034	18.986	0.169	0.003641
19	Mkambala	*Acacia nigrescens*	17	0.969	9.767	16	5.461	9.424	2.734	17.619	0.098	0.000747
1	Mtogo	*Diplorhynchus condylocarpon*	37	0.535	1.262	9	3.072	5.200	5.937	14.209	0.168	0.003525
26	Mnyenye	*Xeroderris stuhrmanni*	8	0.554	5.148	15	5.119	5.386	1.241	11.746	0.054	0.000154
8	Mfumbili	*Lonchocarpus Sp*	32	0.151	0.851	10	3.413	1.466	5.252	10.131	0.155	0.002758
18	Msinzira	*Bridelia cathartica*	27	0.109	0.559	10	3.413	1.059	4.418	8.890	0.138	0.001952
17	Msososana	*Dombeya rotundifolia*	31	0.104	0.472	5	1.706	1.014	5.041	7.761	0.151	0.002541
12	Mng'ongo	*Sclerocarya birrea subsp. Caffra*	5	0.390	3.533	9	3.072	3.791	0.868	7.730	0.041	0.000075
10	Kifunganyumbu	*Acacia nilotica*	11	0.186	1.258	12	4.096	1.809	1.704	7.609	0.069	0.000290
90	Mkongowe	*Acacia gerrardii*	8	0.243	2.046	7	2.389	2.363	1.305	6.058	0.057	0.000170
23	Mkulwi	*Diospyros kirkii*	9	0.180	1.373	8	2.730	1.747	1.529	6.007	0.064	0.000234
22	Mpingo	*Dalbergia Melanoxylon*	7	0.119	0.827	8	2.730	1.155	1.144	5.029	0.051	0.000131
150	Msezi	*Manilkara sulcata*	10	0.117	0.711	5	1.706	1.138	1.618	4.463	0.067	0.000262
28	Mtanga	*Terminalia mollis*	6	0.098	0.671	7	2.389	0.954	1.045	4.388	0.048	0.000109
7	Mnhindipori	*Lannea schimperi*	5	0.152	1.114	6	2.048	1.480	0.831	4.360	0.040	0.000069
20	Mharaka	*Spirostachys africana*	6	0.267	2.350	2	0.683	2.593	0.894	4.170	0.042	0.000080
32	Msolo	*Pseudolachnostylis maprouneifolia*	5	0.124	0.915	6	2.048	1.209	0.857	4.115	0.041	0.000074
11	Kikulagembe	*Dichrostachys cinerea*	14	0.065	0.340	3	1.024	0.637	2.240	3.901	0.085	0.000502
30	Msisimizi	*Albizia harveyi*	2	0.170	1.607	5	1.706	1.658	0.360	3.724	0.020	0.000013
85	Mlamamdunku / Mlama-mwekundu	*Combretum zeyheri*	7	0.086	0.565	5	1.706	0.834	1.058	3.599	0.048	0.000112

Appendix 7. Continued.

Code	Local Name	Botanical Name	N	G	V	Frq.	Rel. Freq	Rel. Dom.	Rel. Den	IVI	H'	(n/N)^2
67	Muwindi	*Acacia polyacantha subsp. campylacantha*	3	0.149	1.197	4	1.365	1.452	0.508	3.325	0.027	0.000026
75	Msegese	*bauhinia petersiana*	14	0.050	0.229	1	0.341	0.484	2.240	3.066	0.085	0.000502
25	Mninga	*Pterocarpus angolensis*	3	0.069	0.471	4	1.365	0.674	0.498	2.537	0.026	0.000025
74	Mbembeti	*Sterculia quinqueloba*	2	0.119	1.098	3	1.024	1.155	0.261	2.440	0.016	0.000007
29	Mkwaju	*Tamarindus indica*	4	0.129	1.151	1	0.341	1.256	0.709	2.306	0.035	0.000050
44	Kilemelantembo	*Gardenia ternifolia subsp. jovis-tonantis*	8	0.026	0.115	2	0.683	0.256	1.344	2.283	0.058	0.000181
24	Mdaula	*Zanha africana*	1	0.070	0.597	3	1.024	0.677	0.211	1.912	0.013	0.000004
33	Mtutuma	*Catunaregam spinosa*	2	0.042	0.291	3	1.024	0.404	0.323	1.751	0.019	0.000010
42	Mgovu	*Pteleopsis myrtifolia*	1	0.083	0.717	2	0.683	0.812	0.198	1.693	0.012	0.000004
94	Mgwejameno	*Antidesma venosum*	6	0.011	0.046	2	0.683	0.110	0.896	1.689	0.042	0.000080
34	Mtomokwe	*Annona senegalensis*	4	0.035	0.224	2	0.683	0.342	0.610	1.634	0.031	0.000037
13	Mmoze	*Sterculia africana*	6	0.018	0.082	1	0.341	0.180	0.896	1.417	0.042	0.000080
88	Mkole	*Grewia sp.*	4	0.030	0.156	1	0.341	0.288	0.672	1.301	0.034	0.000045
106	Mseni	*Brachystegia microphylla*	1	0.082	0.802	1	0.341	0.793	0.099	1.234	0.007	0.000001
153	Mlama - dori	*Combretum collinum*	2	0.049	0.339	1	0.341	0.472	0.386	1.199	0.021	0.000015
55	Mazenzegele	*Dalbergia nitidula*	1	0.025	0.164	2	0.683	0.247	0.224	1.154	0.014	0.000005
39	Mguluka	*Boscia salicifolia*	1	0.020	0.122	2	0.683	0.195	0.224	1.102	0.014	0.000005
61	Mkusu	*Harissonnia abyssinica*	3	0.018	0.089	1	0.341	0.171	0.448	0.961	0.024	0.000020
91	Mfuru	*Vitex ferruginea*	1	0.028	0.185	1	0.341	0.275	0.224	0.840	0.014	0.000005
21	Mgama	*Mimusops kummel*	1	0.025	0.186	1	0.341	0.247	0.162	0.749	0.010	0.000003
107	Mnenekenda	*Elaedendron schlechterianum*	1	0.014	0.106	1	0.341	0.135	0.162	0.638	0.010	0.000003
87	Kilumbulumbu	*Ormocarpum kirkii*	1	0.018	0.120	1	0.341	0.171	0.112	0.625	0.008	0.000001
133	Mufleta	*Albizia anthelmintica*	1	0.008	0.045	1	0.341	0.076	0.112	0.529	0.008	0.000001
48	Mtwintwi	*Commiphora pteleifolia*	1	0.005	0.029	1	0.341	0.053	0.112	0.506	0.008	0.000001
		Total	**618**	**10.27**	**78.81**	**293**	**100**	**100**	**100**	**300**	**3.125**	**0.064800**

Appendix 8 (a). Distribution of N, G & V in order of wood stocking in Transect 1 & 2 of the public land of Kitulangalo Forest

	DBH CLASSES											
	<10 cm			20<10 cm			>20 cm			TOTAL		
Species name	N	G	V	N	G	V	N	G	V	N	G	V
Julbernardia globiflora	1141	2.124	8.701							1141	2.124	8.701
Combretum Zeyheri	369	0.680	2.747							369	0.680	2.747
Pterocarpus angolensis	172	0.389	1.683	5	0.055	0.326				178	0.444	2.009
Acacia polyacantha subsp. Campylacantha	42	0.145	0.671	13	0.159	0.987				56	0.304	1.658
Combretum molle	183	0.340	1.359							183	0.340	1.359
Accacia nigrescens	119	0.243	1.036	3	0.025	0.146				122	0.268	1.182
Pseudolachnostylis maprouneifolia	32	0.176	0.901							32	0.176	0.901
Dalbergia nitidula	98	0.186	0.766							98	0.186	0.766
Acacia goetzei subsp. Goetzei	66	0.083	0.300	3	0.025	0.146				69	0.108	0.446
Xeroderris stuhrmannii	21	0.062	0.274							21	0.062	0.274
Combretum adonogonium	11	0.053	0.266							11	0.053	0.266
Annona senegalensis				5	0.046	0.261				5	0.046	0.261
Catunaregam spinosa	32	0.063	0.250							32	0.063	0.250
Margaritaria discoidea	11	0.041	0.191							11	0.041	0.191
Lannea schimperi	11	0.041	0.191							11	0.041	0.191
Ximenia caffra	66	0.047	0.148							66	0.047	0.148
Diplorhynchus condylocarpon	11	0.030	0.131							11	0.030	0.131
Brachystegia boehmii	11	0.030	0.131							11	0.030	0.131
Zanha africana	11	0.030	0.131							11	0.030	0.131
Albizia harveyi	11	0.030	0.131							11	0.030	0.131
Acacia gerrardii	11	0.030	0.131							11	0.030	0.131
Dalbergia melanoxylon				3	0.021	0.115				3	0.021	0.115
Ochna holstii	11	0.021	0.083							11	0.021	0.083
Myuyu	11	0.021	0.083							11	0.021	0.083
Total	**2449**	**4.863**	**20.305**	**32**	**0.332**	**1.980**	**0**	**0.000**	**0.000**	**2480**	**5.195**	**22.286**

Appendix 8 (b). Distribution of N, G & V in order of wood stocking in Transect 3 of the public land of Kitulangalo Forest

	DBH CLASSES											
	<10			20>10			>20			TOTAL		
Spp.Code	N	G	V	N	G	V	N	G	V	N	G	V
12							7	1.054	12.140	7	1.054	12.140
27	106	0.422	2.026	37	0.543	3.577				143	0.965	5.602
1	175	0.383	1.693	16	0.282	1.887				191	0.665	3.580
6	573	0.768	2.831				5	0.107	0.734	578	0.874	3.564
18	42	0.242	1.241	21	0.305	1.945				64	0.547	3.186
19	21	0.042	0.167	11	0.167	1.094	5	0.216	1.813	37	0.424	3.074
28	218	0.370	1.457	5	0.060	0.361				223	0.430	1.818
26							2	0.177	1.657	2	0.177	1.657
94							5	0.189	1.537	5	0.189	1.537
23	21	0.060	0.261	5	0.150	1.121				27	0.210	1.382
106	133	0.167	0.601	5	0.070	0.440				138	0.237	1.040
44	154	0.227	0.862							154	0.227	0.862
11	154	0.208	0.767							154	0.208	0.767
2				5	0.107	0.734				5	0.107	0.734
10				5	0.107	0.734				5	0.107	0.734
117				5	0.107	0.734				5	0.107	0.734
74	21	0.135	0.710							21	0.135	0.710
17							2	0.081	0.634	2	0.081	0.634
55				5	0.094	0.626				5	0.094	0.626
57	133	0.167	0.601							133	0.167	0.601
138	133	0.167	0.601							133	0.167	0.601
Total	1883	3.355	13.817	122	1.991	13.250	26	1.824	18.515	2032	7.170	45.582

Appendix 8 (c). Distribution of N, G & V in order of wood stocking in Transect 4 of the public land of Kitulangalo Forest

	DBH CLASSES									TOTAL		
	<10 cm			20>10 cm			>20 cm					
Spp.Code	N	G	V	N	G	V	N	G	V	N	G	V
1	21	0.082	0.382	21	0.338	2.239	14	0.856	8.055	57	1.275	10.676
90							7	0.561	5.521	7	0.561	5.521
117	64	0.205	0.931	21	0.428	2.955	5	0.163	1.274	90	0.796	5.160
19							2	0.325	3.503	2	0.325	3.503
27	21	0.082	0.382	16	0.383	2.769				37	0.464	3.151
20	149	0.563	2.669	5	0.050	0.291				154	0.614	2.960
6	154	0.273	1.132	11	0.217	1.509				164	0.490	2.640
22	21	0.107	0.531	5	0.070	0.440	5	0.180	1.444	31	0.357	2.415
26							2	0.239	2.396	2	0.239	2.396
2	21	0.060	0.261	16	0.171	1.022	2	0.115	0.975	40	0.346	2.258
32							2	0.226	2.235	2	0.226	2.235
74							2	0.189	1.792	2	0.189	1.792
17	64	0.223	1.026	5	0.070	0.440				69	0.294	1.465
106	42	0.163	0.764							42	0.163	0.764
30				5	0.107	0.734				5	0.107	0.734
12							2	0.081	0.634	2	0.081	0.634
85	42	0.123	0.549							42	0.123	0.549
130	21	0.107	0.531							21	0.107	0.531
34				5	0.082	0.528				5	0.082	0.528
33	21	0.082	0.382							21	0.082	0.382
151	21	0.060	0.261							21	0.060	0.261
Total	663	2.130	9.803	111	1.916	12.926	45	2.934	27.829	819	6.980	50.56

Appendix 8 (d). Distribution of N, G & V in order of wood stocking in Transect 5 of the public land of Kitulangalo Forest

	DBH CLASSES											
	<10 cm			20>10 cm			>20 cm			TOTAL		
Code	N	G	V	N	G	V	N	G	V	N	G	V
20	42	0.217	1.092	74	0.821	4.984	9	0.602	5.603	126	1.640	11.679
90							16	1.168	10.938	16	1.168	10.938
67							7	0.670	6.644	7	0.670	6.644
17				32	0.493	3.196	9	0.334	2.625	41	0.826	5.820
12				5	0.120	0.852	5	0.307	2.815	10	0.427	3.667
133				11	0.271	1.972	2	0.115	0.975	13	0.386	2.947
130							5	0.300	2.707	5	0.300	2.707
21							5	0.299	2.695	5	0.299	2.695
19							5	0.269	2.363	5	0.269	2.363
6	21	0.042	0.167	11	0.152	0.967	2	0.134	1.179	34	0.328	2.313
2	42	0.083	0.333	11	0.221	1.560				53	0.304	1.894
3				5	0.120	0.852	2	0.106	0.882	8	0.227	1.733
1				11	0.229	1.606				11	0.229	1.606
8				5	0.082	0.528	2	0.125	1.074	8	0.206	1.602
10				11	0.171	1.143				11	0.171	1.143
79							2	0.106	0.882	2	0.106	0.882
94				5	0.082	0.528				5	0.082	0.528
4				5	0.050	0.291				5	0.050	0.291
Total	106	0.342	1.593	186	2.811	18.479	73	4.536	41.379	365	7.689	61.451