IMPACT OF CHARCOAL EXTRACTION TO THE FOREST RESOURCES OF TANZANIA: THA CASE OF KITULANGALO AREA, TANZANIA

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Abstract

Research is being undertaken to expand the knowledge about the biomass potential for supplying charcoal to urban centres and find workable policy tools that will enable sustainable production and use of charcoal in the medium term perspective. The project, CHAPOSA (Charcoal Potential in Southern Africa) focuses on the dynamics of charcoal production in supply areas (mainly woodlands) and its consumption in three major cities: Lusaka, Zambia, Dar es Salaam, Tanzania and Maputo, Mozambique. The three year research project is funded by European Union (EU) and co-ordinated by Stockhom Environmental Institute (SEI). In each of the three partner countries, socio-economic and ecological aspects of charcoal are being studied in the supply areas and charcoal consumption and market forces studies are being undertaken in the cities. Preliminary results on the supply side are presented for Tanzania in this paper.

At Kitulangalo one of the charcoal supplying areas in Tanzania, an average charcoal making household produce 43 bags of charcoal per month, charcoal is sold at kiln site at Tshs. 1,000/= per bag. The household realizes an income of Tshs. 43,000/= per month. This income is above the minimum salary rates paid currently to government workers and hence attracts more people to join the business.

There are 7 trees of about 10 cm dhb for every 22 bags of about 50 kg of charcoal produced from this area. The mean charcoal kiln efficiency of 23.5% was found. Preferred tree species for charcoal includes, *Julbernadia globiflora*, *Brachystegia boehmii, Tamarindus indica, Acacia nigresces, Acacia gerrardii, Acacia nilotica, Combretum adenogonium, Combretum molle, Combretum zeyheri, Boscia salicifolia, Diplorhynchus condylocarpon, Pseudolachnostylis maprouneifolia, Terminanalia mollis, Pteleopsis myrtifolia,Combretum collinum, Diospyros kirkii, Xeroderris stuhrmanii, Mimusops kummel, Albizia harvey, Acacia goetzei subsp. Goetzei, Lonchocarpus capassa* and Mhungilo. Standing wood volume and basal area of these species are lower in public lands compared to forest reserves while stem numbers shows a reversed trend suggesting regeneration of these species in public lands. 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. An average stand growth rate of 2.3 $m^3ha^{-1}year^{-1}$ has been recorded for the re-growth miombo woodland at Kitulangalo.

1 INTRODUCTION

Tanzania has about 33.55 million hectares of forests and woodlands. Out of this total forest area about 90% is covered by Miombo woodlands (URT 1998), the rest being mangrove forests and forests other than mangrove. Such a forest resource contains large values in the form of timber and catchment. They do also have unique environmental and biodiversity values, and also makes available a long 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 57% is forest in public lands. Forest reserves are gazetted forests under the management of central and local governments. And according to the new forestry policy these forests are managed for production and or protection based on forest management plans. Forests on public lands are without any legal protection and in accessible areas their utilization is exploited without any control. Most Miombo woodlands, which constitute the largest forest ecosystem in the country, fall under public lands.

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 & Hakan 1997). Woodlands trees produce a heavier and more concentrated fuel than most fast growing softwood species (Gauslaa 1988) and tropical rain forests. Apart from fuelwood extraction, wildfire, shifting cultivation and selective harvesting of trees for different purposes all affect the dynamics of miombo woodlands.

Miombo is the type of tropical woodland, which is dominated by the genera of *Brachystegia, Julbernadia* and/or *Isoberlinia* the three closely, related genera from the legume family Leguminaceae (White 1983). Woodlands are low-stocked open forests commonly with interlocking tree cover, sparse shrub layer and grass rich field strata. These woodlands cover vast areas of Africa stretching from Angola through Zimbabwe, Zaire to Mozambique, the entire Zambia, Malawi and most of Tanzania. It is the most ecologically widespread woodland in Africa after the tropical rainforests. 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, a fifth of population in sub-saharan Africa (SADC Energy Sector 1993).

High fuelwood consumption in Tanzania is ascribed to low per capita income and limited investment in alternative energy supplies. Households consume about 97% of wood energy in SADC region mostly for cooking, heating and coltage 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 industry and domestic activities which rely upon wood energy provide employment and income for rural people particularly during off-season in agricultural production (Monela & Kihiyo 1998).

The Tanzania energy policy of 1997 still stress development and use of indigenous energy sources such as bio-energy, coal, natural gas and hydropower (URT, 1997). Less than two percent of energy development budget is allocated to wood energy programs, fuelwood being regarded as minor forest product with little market value (TFAP 1989). Yet still the vast majority of woodfuel 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 renders fuelwood more preferable than alternative sources of energy. And according to the present economic forces the majority of urban population in Tanzania will continue to depend on fuelwood for long time to come (URT 1998; Moyo *et al* 1993). 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 raise to a greater extent. This can put strains on natural forests from where the charcoal is obtained, possibly resulting in deforestation of the forest ecosystems.

Commercial fuelwood extraction such as charcoal production requires large volume of wood, which in turn depletes tree stocks resulting to various forms of soil erosion. 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 intervene in the charcoal sectors. Rational decisions in management of natural forest depend on information available on their growing stock. Acquisition of forest growth information is prerequisite to any forest management system and sustainable land use (Mgeni & Malimbwi, 1990)

This report is based on a study carried out at Kitulangalo area with the major objective of determining the ecological and socio-economic impact of charcoal making activities and the potential of the forest to supply charcoal.

2 MATERIALS AND METHODS

Both socio-economic and ecological surveys were done at Kitulangalo Area. The ecological survey was conducted in Kitulangalo SUA Training Forest Reserve as well as in the public lands of the bordering villages of Maseyu and Gwata. The socio-economic survey was also done in these two villages.

2.1 The study area

Kitulangalo area is located about 50 km east of Morogoro municipality towards Dar es Salaam on the sides of Zambia - Tanzania Highway. Dar es Salaam is about 200 km from Morogoro municipality. The predominant feature in this area is the Kitulangalo hill which is about 800 m above sea level situated at $06^0$41'S and $37^0$57'E. Kitulangalo SUA Training Forest Reserve is under management of Sokoine University of Agriculture since 1995. Formally the forest was part of the Kitulangalo Forest Reserve and was also highly encroached through charcoal extraction, pitsawing, and building pole collection.

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 24.3^0C while the annual minimum and maximum temperature are 18^0C and 30^0C respectively (Ernest in Mugasha 1996). January is the hottest month while June is the coldest. 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 bottom (Msanya *et al*, 1995). 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).

Most of the reserve and public lands are covered with regrowth open Miombo woodlands with some scattered *Julbenadia globiflora*, *Brachystegia spp*. and *Pterocarpus rotundifolius* 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.

2.2 Methodology

Both ecological and socio-economic data were collected.

2.2.1 Socio-economic survey

This survey was aimed at collecting information concerned with socio-economic status of the people involved with charcoaling, 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 closed-ended questions was used. Pre-testing of the questionnaire was done in order to see if questions are understood and address questions under investigation. The questionnaire is attached as Appendix 3. 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 business selected at random. About 50% of the charcoal makers in each village were selected and interviewed.

The questionnaire was 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 are the stakeholders. These involved: regional, district, division and village forest officers; long-lived people in the village and religious leaders. Appendix 4 shows the checklists.

(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 activities from views. 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. 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.

2.2.2 Ecological Survey

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

Data collection

Forest growth rate data

Inventory procedures used by Nduwamungu (1996) studying the same forest were employed in order to calculate current stand parameters and derive 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, approximately 500 ha. A total of 46 sample plots were laid at an interval of 320 m apart. For better layout of both transect and sample plots, the first of each was laid at half distance i.e. 160 m from the boundary.

Charcoal extraction dynamics data

Stratified random sampling was applied. Parameter used to stratify the forest was distance from roads and highway in public lands. A total of 30 plots were laid out in public lands of the two villages bordering the Kitulangalo SUA training forest.

One access road shared by both villages was selected. Three transects were laidout perpendicular to the access road at 5 km, 10 km and 15 km interval away from the highway. Perpendicular to the highway two transects were also established each in opposite sides of the highway. In each of the laidout transects three clusters of two plots each were laid at an interval of 500 m apart. A total of 30 plots were therefore sampled.

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

Plot shape and size

The shape of the sample plots used in both public lands and forest reserve was circular with radius depending on the dbh of the trees 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

Species name and dbh of all measured trees were recorded in each plot. Local botanists elderly people who were familiar with tree species were used to identify tree species for later translation into botanical names using checklists of the area. The number of stems were determined from the dbh tally. The total height of the closest tree ("sample tree") to the plot centre was also measured and recorded. A count of tree number below 4 cm dbh in inner plot of 1m radius was also made to quantify regeneration.

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 was calculated using the formula provided by Malimbwi *et al.* (1994), the equation was:

$$Vi = 0.0001di^{2.032}\ hi^{0.66}$$

Where; Vi = the volume of tree i (m3)

di = the diameter at breast height (1.3m) for tree i (m) and

hi = the total height of tree i (m)

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

The computed parameters were also separated into three diameter classes i.e. <10 cm dbh, 10-20cm dbh and >20cm dbh for diameter classes 1, 2, and 3 respectively.

The following parameters was 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**

2.2.3 Charcoal kilns efficiency data

Tree species and biomass to make up fifteen kilns were determined and compared to biomass of charcoal obtained from such kilns. To facilitate this a record of tree dbh, height and local name was done for all trees felled to constitute a kiln. Log sections from each tree were also measured for mid diameter and length. The number of bags from each kiln was counted and weighed.

From the collected data, Huber's formula was used to estimate volume of individual log sections and hence volume for each tree. Tree biomass was calculated as 0.85% of the total tree volume (Malimbwi *et al*. 1994).

3 RESULTS AND DISCUSSION

3.1 Socio-economics of charcoal production at Kitulangalo

3.1.1 Charcoal extraction activities at Kitulangalo

The charcoal makers

The mainstay of the 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 all of the two activities essentially in their effort to subsidize income from agriculture. Charcoal production in Tanzania is known to contribute substantially to the economy of rural people in Eastern Tanzania (Monela *et al* 1993). 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. Both cash and food crops were grown while nowdays only food crops such as maize, wheat and legumes for their own use are grown. Difficult in cash crops marketing associated with unstable prices has discouraged cultivation of cash crops such as simsim and cotton in these villages.

Almost all of the people involved in charcoal making were males and belong to the ethnic tribes of Waguru, Wakwere, Wadoe, Wazaramo, Wazigua and Wakami. These are the main tribes present in studied villages. However 60% interviewed people were not born in their respective village, which implies that most of them have their origin outside the area. The marital status of these people are shown in Tables 1. In terms of education level, 40% of the interviewed people have no formal education while the rest have either four or standard seven years of primary 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

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**

3.1.2 Suitable tree species for charcoal making

As stated above charcoal is usually extracted form the public lands owned by local governments. It was found that 84% of the interviewed charcoal makers do select suitable tree species for charcoal. Those who have no species preference (16% of the respondents) are those clearing the woodland for agriculture. This second category of charcoal makers generate income not only from the charcoal they make but also from the farm preparation work they are doing. They are usually hired by farmers from outside the area. This group of charcoal makers includes also retrenched workers from towns.

Most of the woodland tree species are suitable for fuelwood with few exceptions. The un-preferred tree species such as muwindi (*Acacia polyacantha subsp. Campylacantha)*, mmoze (*Sterculia africana*) and mbuyu (*Adansonia digitata*) are either with thorn stem and producing lighter charcoal or produce charcoal which breakdown easily into smaller fragments during transportation. The most preferred tree species for charcoal in this area are listed in Table 2. These results are in line with those of Monela *et al* (in press) and Nduwamungu (1996) with addition of some few tree species.

Table 2 Mostly preferred tree species for charcoal making at Kitulangalo area

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

A. nigrescens seem to be the most used tree species in terms of frequency and has second highest volume to *L. schimperi.* However Mhungilo also contribute higher to use volume. The most commonly known tree species for charcoal making, *B. boehmii and J. globiflora* appear to be less conspicuous in both volume contribution and use frequencies. Other tree species mentioned to be used but not found at the site are *Tamarindus indica, Combretum collinum,* and *Diospyros kirkii.*

4 The charcoal making process.

Charcoal in this area is made by covering a pile of logs (rectangular pile) with earth blocks (Fig. 1). The source of labour for charcoal making activities is mainly household labour with some few cases of hired and communal labour (Table 3).

Figure 1 Typical charcoal kiln under preparation at Kitulangalo area.

Table 3 Source of labour for charcoal making

Labour source	Gwata village	Maseyu village	Total respondents	Percent
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 preparation, carbonization and finally unloading charcoal from the kiln. The average number of days spent for each activity are shown in Table 4. The average working days per month are 18 days with 5 average working hours per day. About 80% of the respondents said there are no special months for charcoal production.

There is an average of 43 bags of charcoal per month produced for each household for sale in the studied villages. No charcoal is produced intentionally for home use.

Table 4 Number of man days spent for different steps in charcoal making process.

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

4.1 Charcoal pricing at production site

The average prices for charcoal are given in Table 5. Table 5 also shows that the main charcoal market place is at charcoal making site and little charcoal is sold at the roadside (Fig. 2)

Figure 2 Selling charcoal at roadside in Kitulangalo area

Table 5 Average charcoal prices at Kitulangalo area.

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

Charcoal transaction at the road side is influenced by the licensing system. Interview of the forest officials, revenue collectors and charcoal dealers in Morogoro region showed that no licences are usually offered for charcoal dealers and instead just formal registration of dealers is made. However charcoal makers do neither be registered no pay any levi for 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 bulky buyers are from outside the area (Table 6.)

Table 6 Charcoal buyers at Kitulangalo area.

Buyers	Gwata	Maseyu	Percentage
Other villagers (respondents)	1	2	12
From outside the village (respondents)	7	8	60
Both (respondents)	3	4	28
Total (respondents)	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.

4.1.1 Licensing and other payable fees

As mentioned above the bulky charcoal buyers bother to be registered as charcoal dealers from which revenue goes to the government. In both old and new forest ordinances, there is no licence for charcoal dealers. Only Registration form is issued, the registration fee is Tshs. 50,000/= paid to the government through regional catchment forest office for the case of Morogoro region.

Apart from the registration fees, other levies collected from charcoal dealers amounts to Tshs. 600/= and Tshs. 500/= per bag for the Morogoro urban district and Morogoro rural district respectively. The revenues differ from one district to another due to differences in district council by-laws. In both cases the revenues are distributed equally to both central and local government.

From the above results, an average charcoal making 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 (tax free). This income is above the minimum salary rates paid currently to government workers. Given the low education level of these charcoal makers, the income may be attractive enough even to other people to join the business, and hence more deforestation of the woodland.

4.2 Impact of charcoal making to the woodlands

The general trend is that, people are extracting charcoal in an increasing trend. They seem to progress from where they are today in search of preferred tree species. Eighty percent of the interviewed respondents said that the distance from where they were doing charcoaling has increased, and about the same proportion of the respondents said they move to the next kiln site due to scarcity of preferred tree species for charcoal. These results were supported by the ecological survey. The remaining proportion of respondents (20%) might be staying to browse whatever tree of preferred species that attain exploitable size for charcoal making. Almost all the respondents in the studied area said tree cover is worse than 10 years ago due to charcoal making activities at the area.

4.2.1 Ecological Impacts of Charcoal Production

Charcoal kiln efficiency

Data from three kilns reveal the mean kiln efficiency of 23.5% (Table 6). This value is in the higher extreme to those by Chidumayo (1991), Kaale (1998) and Sawe & Meena, (1994). These previous studies provided charcoal kiln efficiency values ranging from 13-19%. However species involved in these studies were not mentioned which could be the source of differences. Miombo tree species are said to produce denser charcoal compared to trees of other vegetation. The shape of the earth mould kilns involved in this study was termed by charcoal makers as "rocket" shape. The dimensions of these kilns were measured but later realised that their volume were difficult to compute.

Table 7 Charcoal kiln efficiency at Kitulangalo area.

Kiln No.	No of Trees/kiln	Tree size range (cm) dbh	Average dbh (cm)	Measured kiln Vol. (m3)	Measured Biomass (kg)	No. of Bags/kiln	Average bag Weight (kg)	Charcoal weight (kg)	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	6	17.3-44.7	31	9.84	8364.00	28	69	1944.0	23.2
Mean	7		32	5.85	4973.63	22	50	1198.5	23.52

Table 7 also shows that, mostly trees of about 10 cm are used for charcoal production. On average, 7 trees are used for every 22 bags of about 50 kg of charcoal produced from this area. Nduwamungu (1996) estimated about 12 stems per ha 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.

4.2.2 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 forest reserves, diversity indices have been employed. Three diversity indices used for this purpose were *Important Value Index* (IVI*)*, *Index of Dominance (*ID) and *Shannon-Wiener Index of Diversity* (H’). Also standard stand parameters such as stem numbers, basal area and standing wood volume were used.

Important Value Index (IVI)

Julbernardia globiflora appear to be the most important tree species in both public lands and reserved forest (Fig. 3 a & b). The 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 tree species for charcoal making in the area.

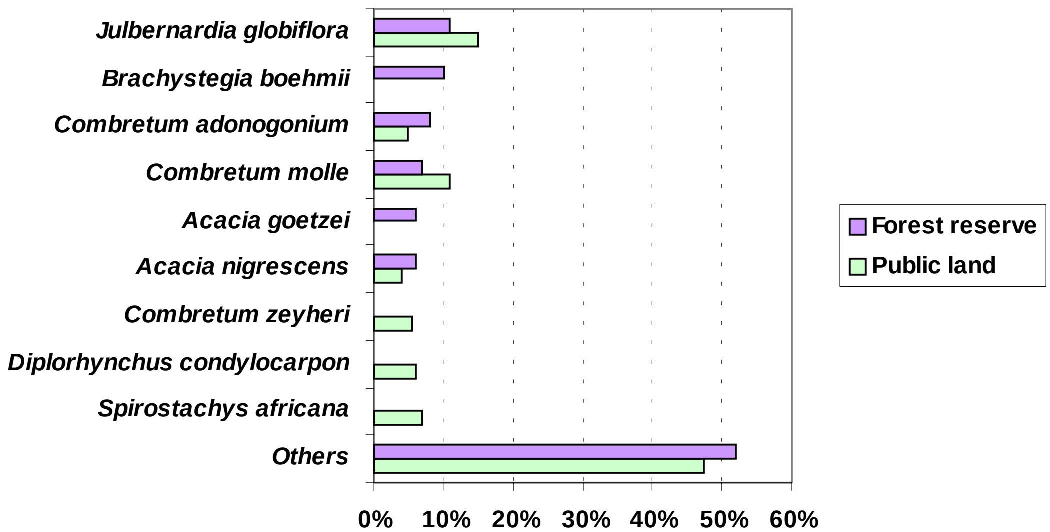

Figure 3 Distribution of tree species in Public lands and Forest reserve, in order of the Importance Value Index

Distribution of stem numbers shows that, in public lands there are many stem numbers of *J. globiflora* of smaller sizes compared to fewer stems of larger sizes in reserved forest (Fig. 4). This suggests that the species is regenerating in public lands. *B. boehmii* ranked the second in terms of Important Value Index in reserved forest while it is the eleventh in public lands (Appendices 1 & 2). The species is also among the most preferred for charcoal making and although only small sizes trees were also observed (Appendix 3), its regeneration potential is lower than that of *J. globiflora*. *Combretum* and *Acacia* species which are also used for charcoal making seem to be important in all forests with smaller sizes in public lands compared to large sizes in reserved forest.

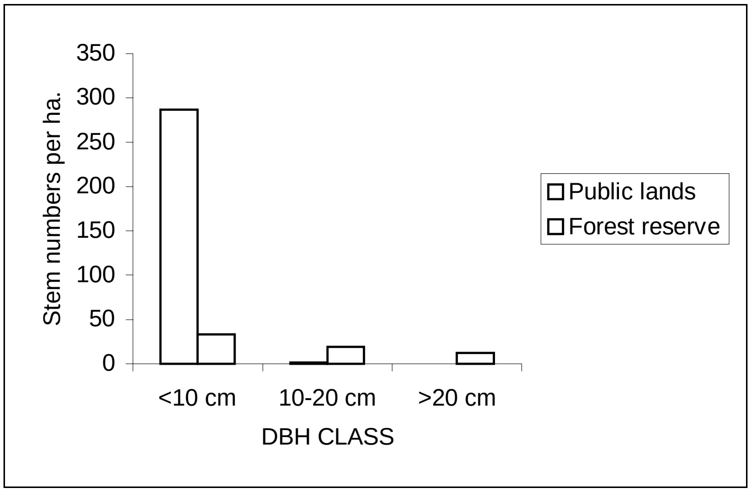

Figure 4 Distribution of J. globiflora stem numbers in Public lands and Forest Reserve at Kitulangalo.

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 forests respectively (Appendix 1 & 2). This indicates that there is high species richness in forest reserve compared to the public lands. The difference can be explained by the much the degradation in public lands due to among others charcoal making activities. Nduwamungu (1996) reported got the ID values of 0.03, 0.04 and 0.06 for diameter class 1, 2 and 3 respectively at Kitulangalo forest reserve.

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 1 & 2), 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 1, 2 and 3 respectively.

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 8. Both volume and basal area, are increasing with distance from the highway while stem numbers show a reversed trend. This trend suggests that forests at roadside have been depleted much because of easy accessibility compared to far distance forests from the highway. More stem numbers observed at roadside indicate regeneration of the forest 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 15 km away from the highway are comparable to those of forest reserve.

Table 8 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
Mean	**1423**	**6.81**	**45.61**
STD	**995**	**1.11**	**16.59**
N	**4**	**4.00**	**4.00**
STE	**497**	**0.56**	**8.30**
TSx	**975**	**1.09**	**16.26**
lower limit	**448**	**5.72**	**29.35**
upper limit	**2398**	**7.90**	**61.87**
Precision	**68**	**16.04**	**35.65**

Appendices 3 (a), (b), (c) and (d) show the distribution of N, G and V by species in the public land 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 breakdown into smaller 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. All of these species are not preferred for charcoal making. But there are considerable stocks of preferred tree species at 15 km away from the highway and observations shows that by now charcoal extraction activities are concentrated at that area.

Table 9 Distribution of tree species of suitable sized preferred for charcoal making in the public lands of Kitulangalo area

	DBH CLASSES								
	10 - 20 cm			>20 cm			TOTAL		
Distance	**N**	**G**	**V**	**N**	**G**	**V**	**N**	**G**	**V**
Road side	5	0.05	0.29				5	0.05	0.29
5 km	106	1.68	11.06	12	0.50	4.20	119	2.18	15.27
10 km	90	1.64	11.23	35	2.48	23.96	125	4.13	35.19
15 km	53	0.90	6.10	31	2.00	18.25	84	5.90	34.34

About 5, 119, 125 and 84 exploitable trees are available at road side, 5 km, 10 km and 15 km from the highway respectively (Table 9). This implies that about 1.4 hectares of the woodland at road side are needed for the preparation of a single average kiln while other locations have the potential of provide wood for more than 10 kilns per hectare

Although the total volume at 15 km from the road side is higher than at 10 km (Table 8), the volume of preferred tree sizes and species is similar at both distances (Table 9). This suggests that cutting at 10 km distance may be for other uses apart from charcoal.

4.3 Woodland growth rate

Stem numbers

Distribution of stem numbers per hectare by plots between 1996 and 1999 is shown in Figure 5. This distribution follow a reserved J-shaped trend as expected in natural forest, which is an indication of regeneration (Philip 1983).

Figure 5. shows a decrease in stem number in diameter class 1 and subsequent increase in diameter class 2 and 3. These results suggest recruitment of smaller diameter class trees in preceding high classes and hence stand growth.

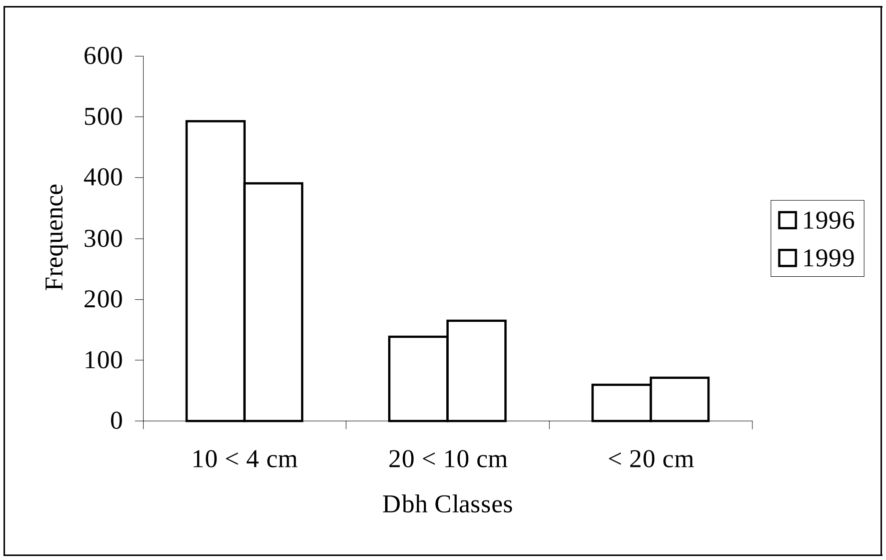

Figure 5 Comparison of the Stocking Distribution by dbh classes between 1996 and 1999 at Kitulangalo

Basal area and volume

Basal area and wood volume were also observed to increase with diameter class. (Fig 6 & 7). This also shows that the stand is growing with considerable greater stocking of large size trees.

Table 8 shows that the Mean Annual Increment (MAI) for the period of three years (1996-1999) is 2.35 m^3/ha/year. This rate is in line with that of Nilsson (1986) who estimated an annual growth rate of 1-2 m^3/ha/year for disturbed woodlands in Tanzania. Chidumayo (1988) reported a mean annual fuelwood increment of 1.96 m^3/ha in dry miombo. However the rate is contrary to that provided by Malimbwi *et al* (1994) of 0.54 m^3/ha/year for regrowth Miombo woodland and 7.4 m^3/ha/year together with 7.3 m^3/ha/year in the oldgrowth miombo and semi-evergreen miombo respectively. Smaller coverage of the study by Malimbwi *et al* (1994) may have been the source of the discrepancy.

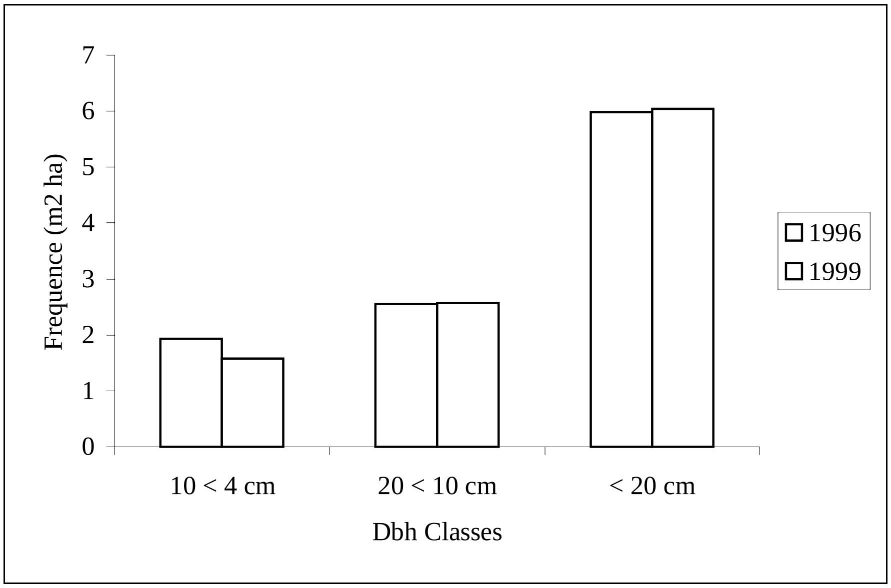

Figure 6 Comparison of the Distribution of basal area by dbh Classes between 1996 and 1999 at Kitulangalo

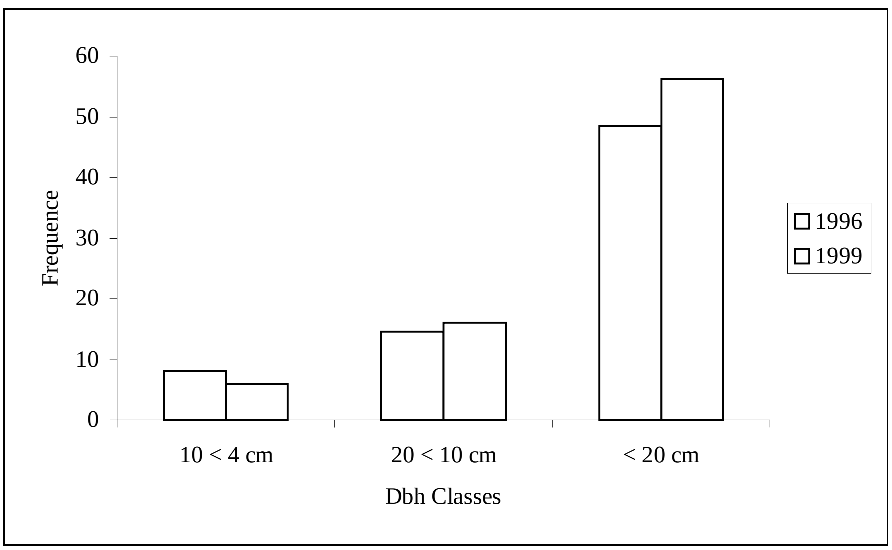

Figure 7 Comparison of the Distribution of wood volume between 1996 and 1999 at Kitulangalo

The observed stand growth rate by this study may be useful especially during this period of forestry policy reform in Tanzania where communities are involved in forest management. Involvement of village communities among other things requires them to benefit from the forest they manage. Allocation of harvesting quarters needs proper information on stand growth.

Table 10. Comparison of Wood volume m^3ha^{-1} by plot between 1996 and 1999.

	DBH CLASSES							
	10 < 4 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
MEAN	8.07	5.89	14.59	16.02	48.46	56.25	71.12	78.16
SDV	8.91	4.61	11.44	10.60	45.14	43.89	50.84	43.40

5 CONCLUSION

Charcoal extraction provides substantial income to households of Kitulangalo area. However, there are obvious signs of depletion of the woodland resources. Increased distances from homesteads to kiln sites and reduction of tree diversity in public lands where charcoal making is intensified provides evidences for this situation. Conclusive results await data on extent of the woodland and urban consumption survey.

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Appendix 1. Distribution of Tree species in the public land of Kitulangalo Forest inorder 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 stuhrmannii*	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
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

Code	Local Name	Botanical Name	N	G	V	Frq.	Rel. Freq	Rel. Dom.	Rel. Den	IVI	H'	(n/N)^2
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 flaxinifolius*	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	2,904382	0,092033

Appendix 2. Distribution of Tree Species Found in Kitulangalo SUA Taining Forest Reserve in order if 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*	64,25203	1,355599	11,02023	25	8,532	13,188	10,396	32,116	0,235	1,08E-02
2	Myombo	*Brachystegia boehmii*	46,70393	1,605163	14,31351	24	8,191	15,616	7,557	31,363	0,195	5,71E-03
27	Mlama-ng'ombe	*Combretum adonogonium*	81,14876	0,596848	3,535698	16	5,461	5,806	13,130	24,397	0,267	1,72E-02
6	Mlama-mtitu / Mlama -mweusi	*Combretum molle*	69,07447	0,456881	2,612589	15	5,119	4,445	11,176	20,740	0,245	1,25E-02
117	Kisasa	*Acacia goetzei subsp. goetzei*	37,29216	0,524429	3,401583	23	7,850	5,102	6,034	18,986	0,169	3,64E-03
19	Mkambala	*Acacia nigrescens*	16,89478	0,968766	9,766623	16	5,461	9,424	2,734	17,619	0,098	7,47E-04
1	Mtogo	*Diplorhynchus condylocarpon*	36,69498	0,534555	1,262288	9	3,072	5,200	5,937	14,209	0,168	3,53E-03
26	Mnyenye	*Xeroderris stuhrmannii*	7,668275	0,553596	5,148309	15	5,119	5,386	1,241	11,746	0,054	1,54E-04
8	Mfumbili	*Lonchocarpus Sp.*	32,4595	0,150729	0,851236	10	3,413	1,466	5,252	10,131	0,155	2,76E-03
18	Msinzira	*Bridelia cathartica*	27,30702	0,108861	0,558767	10	3,413	1,059	4,418	8,890	0,138	1,95E-03
17	Msosoana	*Dombeya rotundifolia*	31,1548	0,104185	0,471532	5	1,706	1,014	5,041	7,761	0,151	2,54E-03
12	Mng'ongo	*Sclerocarya birrea subsp. Caffra*	5,365062	0,389641	3,532751	9	3,072	3,791	0,868	7,730	0,041	7,54E-05
10	Kifunganyumbu	*Acacia nilotica*	10,5312	0,185959	1,25761	12	4,096	1,809	1,704	7,609	0,069	2,90E-04
90	Mkongowe	*Acacia gerrardii*	8,068071	0,242914	2,045717	7	2,389	2,363	1,305	6,058	0,057	1,70E-04
23	Mkulwi	*Diospyros kirkii*	9,452729	0,179622	1,37285	8	2,730	1,747	1,529	6,007	0,064	2,34E-04
22	Mpingo	*Dalbergia Melanoxylon*	7,069557	0,118675	0,82668	8	2,730	1,155	1,144	5,029	0,051	1,31E-04
150	Msezi	*Manilkara sulcata*	9,998791	0,117006	0,711105	5	1,706	1,138	1,618	4,463	0,067	2,62E-04
28	Mtanga	*Terminalia mollis*	6,457187	0,0981	0,67052	7	2,389	0,954	1,045	4,388	0,048	1,09E-04
7	Mnhindipori	*Lannea schimperi*	5,138836	0,152177	1,113751	6	2,048	1,480	0,831	4,360	0,040	6,91E-05
20	Mharaka	*Spirostachys africana*	5,52498	0,26655	2,349573	2	0,683	2,593	0,894	4,170	0,042	7,99E-05
32	Msolo	*Pseudolachnostylis maprouneifolia*	5,298755	0,124323	0,915277	6	2,048	1,209	0,857	4,115	0,041	7,35E-05
11	Kikulagembe	*Dichrostachys cinerea*	13,84658	0,065489	0,340057	3	1,024	0,637	2,240	3,901	0,085	5,02E-04
30	Msisimizi	*Albizia harveyi*	2,223254	0,170394	1,606602	5	1,706	1,658	0,360	3,724	0,020	1,29E-05
85	Mlamamdunku / Mlama-mwekundu	*Combretum zeyheri*	6,538632	0,085757	0,564676	5	1,706	0,834	1,058	3,599	0,048	1,12E-04
67	Muwindi	*Acacia polyacantha subsp. campylacantha*	3,141808	0,149231	1,197112	4	1,365	1,452	0,508	3,325	0,027	2,58E-05
75	Msegese	*bauhinia petersiana*	13,84658	0,049783	0,228767	1	0,341	0,484	2,240	3,066	0,085	5,02E-04
25	Mninga	*Pterocarpus angolensis*	3,075501	0,069291	0,470837	4	1,365	0,674	0,498	2,537	0,026	2,48E-05
74	Mhembeti	*Sterculia quinqueloba*	1,610884	0,118739	1,097899	3	1,024	1,155	0,261	2,440	0,016	6,79E-06

Code	Local Name	Botanical name	N	G	V	Freq.	Rel. Freq	Rel. Dom.	Rel. Den	IVI	H'	(n/N)^2
29	Mkwaju	*Tamarindus indica*	4,3802	0,129103	1,150575	1	0,341	1,256	0,709	2,306	0,035	5,02E-05
44	Kilemelantembo	*Gardenia ternifolia subsp. jovis-tonantis*	8,307948	0,026304	0,115061	2	0,683	0,256	1,344	2,283	0,058	1,81E-04
24	Mdaula	*Zanha africana*	1,304699	0,069587	0,597197	3	1,024	0,677	0,211	1,912	0,013	4,46E-06
33	Mtutuma	*Catunaregam spinosa*	1,997028	0,041538	0,290928	3	1,024	0,404	0,323	1,751	0,019	1,04E-05
42	Mgovu	*Pteleopsis myrtifolia*	1,22474	0,083475	0,717079	2	0,683	0,812	0,198	1,693	0,012	3,93E-06
94	Mgwejameno	*Antidesma venosum*	5,538632	0,011304	0,045776	2	0,683	0,110	0,896	1,689	0,042	8,03E-05
34	Mtomokwe	*Annona senegalensis*	3,76783	0,035166	0,223657	2	0,683	0,342	0,610	1,634	0,031	3,72E-05
13	Mmoze	*Sterculia africana*	5,538632	0,018478	0,081744	1	0,341	0,180	0,896	1,417	0,042	8,03E-05
88	Mkole	*Grewia sp.*	4,153974	0,029565	0,156476	1	0,341	0,288	0,672	1,301	0,034	4,52E-05
106	Mseni	*Brachystegia microphylla*	0,61237	0,081553	0,802039	1	0,341	0,793	0,099	1,234	0,007	9,82E-07
153	Mlama - dori	*Combretum collinum*	2,383172	0,048529	0,3391	1	0,341	0,472	0,386	1,199	0,021	1,49E-05
55	Mnzenzegele	*Dalbergia nitidula*	1,384658	0,025435	0,164462	2	0,683	0,247	0,224	1,154	0,014	5,02E-06
39	Mguluka	*Boscia salicifolia*	1,384658	0,020054	0,121675	2	0,683	0,195	0,224	1,102	0,014	5,02E-06
61	Mkusu	*Harissonnia abyssinica*	2,769316	0,017609	0,089097	1	0,341	0,171	0,448	0,961	0,024	2,01E-05
91	Mfuru	*Vitex ferruginea*	1,384658	0,028261	0,184761	1	0,341	0,275	0,224	0,840	0,014	5,02E-06
21	Mgama	*Mimusops kummel*	0,998514	0,025348	0,186329	1	0,341	0,247	0,162	0,749	0,010	2,61E-06
107	Mnenekenda	*Elaedendron schlechterianum*	1	0,013844	0,106382	1	0,341	0,135	0,162	0,638	0,010	2,62E-06
87	Kilumbulumbu	*Ormocarpum kirkii*	0,692329	0,017609	0,119701	1	0,341	0,171	0,112	0,625	0,008	1,25E-06
133	Mufleta	*Albizia anthelmintica*	0,692329	0,007826	0,044761	1	0,341	0,076	0,112	0,529	0,008	1,25E-06
48	Mtwintwi	*Commiphora pteleifolia*	0,692329	0,005435	0,028762	1	0,341	0,053	0,112	0,506	0,008	1,25E-06
		Total	**618,0471**	**10,27929**	**78,80971**	**293**	**100**	**100**	**100**	**300**	**3,125**	**6,48E-02**

Appendix 3(a). Distribution of N, G & V in order of wood stocking in Transect 1 & 2 of the public land of Kitulangalo Forest

	DBH CLASSES											
	1			2			3			TOTAL		
Code	**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
45	11	0,041	0,191							11	0,041	0,191
Mhungilo	11	0,041	0,191							11	0,041	0,191
5	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
92	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 3(b). Distribution of N, G & V in order of wood stocking in Transect 3 of the public land of Kitulangalo Forest

	DBH CLASSES											
	1			2			3			TOTAL		
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 3(c). Distribution of N, G & V in order of wood stocking in Transect 4 of the public land of Kitulangalo Forest

	DBH CLASSES											
	1			2			3			TOTAL		
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 3(d). Distribution of N, G & V in order of wood stocking in Transect 5 of the public land of Kitulangalo Forest

	DBH CLASSES											
	1			2			3			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**