ASSESSMENT OF FLORISTIC COMPOSITION, STOCKING AND DISTURBANCE IN MKULAZI CATCHMENT FOREST RESERVE IN MOROGORO DISTRICT, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ECOSYSTEMS SCIENCE AND MANAGEMENT OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

This study attempted to assess floristic composition, stocking and disturbance in MCFR. Specifically, the study aimed to assess plant species richness and diversity, stem density, basal area and volume of the trees, intensity and distribution of disturbance and determine land cover changes for the past 41 years in MCFR. A total of 20 clusters with 100 concentric circular plots with radii 2,5,10 and 15m aligned in four transects across the entire forest of 65710ha were used for the study. Data collection involved recording information on species name, diameter at breast height, tree height with diameter ≥5cm, counts and records species of regenerants and human disturbance in each plot. Landsat MSS, TM and OLI image of the year 1975, 1995 and 2016 were used to quantify land cover changes for the past 41 years. Inventory data were analyzed by using MS excel and PAST while Landsat Image were analyzed using QGIS software version 2.8.1. A total of 57 plant species belonged to 23 families were identified.Shannon-Wiener index and Simpson Diversity Indices were 3.086 and 0.9436 respectively. The mean volume of 88.07±25.61m^3/ha, stem density of 255.9±61.7 stem/ha, basal area 7.6±2.1m^2/ha and volume of stumps 24.5±9.3m^3/ha were obtained. Apart from disturbances frequently that affects forest, this study found that MCFR is disturbed by animal grazing 43.5%, footpath 21.7%, camping site 17.4%, car truck 15.2% and fire damage 2.2%. For the past 41 years land cover changed from closed woodland, bush land and riverine to open woodland and bare land by 44.71%, 37.59% and 1.08% respectively. Generally, MCFR has higher species richness and diversity. There were also consistently negative changes in forest cover, relatively to low stem density, mean tree height, and mean Dbh and basal area which were indications of the presence of human disturbance. Therefore, there is a need of resurvey, JFM, good governance and Management plan to be implemented by the MCFR.

DECLARATION

I, **Christoganus John**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted to any other institution.

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DEDICATION

This work is dedicated to my beloved Parents my father John Vyokuta and my mother the late Catherine Francisco who laid the foundation of my education. The work is dedicated to my lovely wife Senorina Gervas, my children Elisha and Elice who tolerated difficulties while I was away for studies. My mother passed away while I was undertaking this study. May the almighty God rest her soul in eternal peace, Amen!

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LIST OF ABBREVIATIONS AND ACRONMYS

DBH	Diameter at Breast Height
DHA	Danish Hunter Association
EIA	Environmental Impact Assessment
FAO	Food Agricultural Organization of the United Nation
GIS	Geographical Information System
GPS	Global Positioning System
Ha	Hectare
IVI	Importance Value Index
LULC	Land Use Land Cover Changes
MCFR	Mkulazi Catchment Forest Reserve
MSS	Multispectral Scanner
NAFORMA	National Forest Resources Monitoring and Assessment
PAST	Paleontological Statistics Software
REDDC	Reduced Emissions from Deforestation and forest Degradation Change
TaFF	Tanzania Forest Fund
TM	Thematic Mapper
UNFCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
USGS	United States Geological Survey
UTM	Universal Transverse Mercater

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

One of the most significant challenges facing the Earth today are land use and land cover changes caused by human activities (Mustard *et al.*, 2012). Human activities affect the earth's systems such as climate, hydrology, global biodiversity, and the fundamental sustainability of lands. Various estimates indicate that 50 percent of the ice-free land surface has been affected or modified in some way by human activity (Vitousek *et al*., 1997), while 10 to 55 percent of the net primary productivity has been taken by human land use activities (Rojstaczer *et al*., 2001). According to Ayivor and Gordon (2012), in Ghana most of the forest catchment reserves have undergone massive transformation over the last three decades due various land use activities namely, agriculture, urban development, grazing, residential and transportation (Ayivor and Gordon, 2012). Similarly in Uganda grazing, fire and tree-cutting, have been reported to erode the forest edge and prevented regeneration. In addition, human impacts as well as natural gradients had major impacts on species richness patterns (Sassen and Sheil, 2013).

Tanzania has a total of about 48 million hectares of forest and woodlands (NAFORMA, 2015), about 2.8 million hectares are mainly catchment forest reserves (Zahabu *et al*., 2009), while 1.6 million hectares are under water catchment management (FAO, 2010). However, Catchment forest reserves like other forests reserves in the country have a big role such as provision of medicinal plants, fruits and other non-wood products as well as indirect benefits were stabilization of water flows, maintenance of climate and biodiversity conservation (NAFORMA, 2015).

Despite catchment forests offering both direct and indirect benefits such as environmental services, the catchment are still threatened by prevailing high rate of deforestation and general degradation (Malimbwi *et al.*, 2005). Nonetheless, communities over dependency of the forest resources are one of the factors that contribute to deforestation (Kessy *et al.*, 2016). Generally, direct causes of catchment forests degradation includes: encroachment in agricultural activities, illegal timber harvesting, illegal settlement in the forest, grazing and bush fire which resulting from illegal activities such honey harvesting and hunting. Thus the drivers of deforestation and forest degradation entails complex underlying causes which include an interaction of socioeconomic, political, cultural and technological factors. According to Kessy *et al.*, (2016), other factors are population increase, weak law enforcement and governance, lack of awareness and mobilization as well as lack of sustainable means of forest protection. The degradation and deforestation of catchment forests have resulted to loss of reduced catchment values leading to hydrological imbalance which is reflected in reduced water levels in rivers and streams in the dry seasons and floods in rainy season.

However, regardless of the available evidence on the importance of catchment forest reserve, most forests have either outdated or no maps which show clear boundaries (Zahabu *et al*., 2009). In Tanzania, recent forest inventory survey shows that deforestation and degradation is in progress in all forest reserves including in the Mkulazi catchment forest reserve (NAFORMA, 2015).

1.2 Problem Statement and Justification

There is abundant literature on the effects of illegal human activities on biodiversity conservation and water catchment values of many catchment forest reserves in Tanzania (Mati *et al*., 2008; Kashaigili and Majaliwa 2010; Shirima *et al*., 2011;

Mombo *et al.*, 2014). Mkulazi catchment forest reserve (MCFR) is one of the biggest catchment forest reserves in Morogoro, it is found in lowland dry miombo woodland (Lovett and Pocs, 1993). Although the reserve is potential for wildlife habitat, and as a major source of River Ruvu which is a major source of water for Dar es Salaam and parts of the Pwani Region, source of seed for valuable tree species such *Afzelia quanzensis, Dalbergia melanoxylon, Pterocarpus angolensis* (Lovett and Pocs, 1993).

Since its gazettement in 1955 due to its potential in water storage and biodiversity conservation, the reserve has been constantly facing immense pressure from the adjacent communities residing in 14 villages. As the communities struggle to satisfy their needs within the catchment area through expansion of their agricultural activities, illegal timber harvesting, illegal settlement and grazing, these human activities have seriously affected the condition of the forest as well as degrading the catchment values of the forest.

However, according to Lovett and Pocs (1993) to date there is no information showing floristic composition, stocking and disturbance in MCFR.Trying to build an understanding of the current floristic composition, stocking and disturbance of MCFR is critical for the management and conservation strategies of the reserve. This will facilitate preservation of the remaining threatened biodiversity which is potential for climate change mitigation and for adjacent community (Godoy *et al*., 2011). The results from this study will provide baseline information which will be used for management and conservation of the reserve as well as other similar reserves in the country.

1.3 Objectives of the Study

1.3.1 Main research objective

Assessment of floristic composition, stocking and disturbance in MCFR.

1.3.2 Specific objectives

i. To assess the current plant species richness and diversity (floristic composition) in MCFR

ii. To determine stem density, basal area and volume (stocking) of the trees

iii. To assess the intensity and distribution of disturbance in MCFR

iv. To assess land cover changes for the past 41years in MCFR

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Miombo Forest, Coverage and Their Importance

Miombo woodlands, classified as dry forests, are dominated by wood plants, primarily trees, whose canopy cover more than 10% of the ground surface (Munishi *et al.*, 2014). The woodlands are dominated by deciduous trees of the genera *Brachystegia*, *Jurbenadia* and *Isoberlinia* (Mwakalukwa *et al.*, 2014). Covering an area of about 3.6 million km^2, Miombo woodlands play a critical role in the livelihoods of Tanzanian communities because they provide social, economic and environmental benefits such as firewood, timber, medicinal plants, food and catchment protection (Munishi, 2014).

2.2 Species Composition

Species composition is the identity of all the different organisms that make up a community. Munishi (2001) pointed out that species composition is the relative contribution of a particular species as a percentage of the total number of species in a community. It is one of the major components of biological structure (Huang *et al.*, 2003), and can change with time due to variations in moisture levels associated with seasonal rainfall fluctuations, unpredictable disturbance and environmental contrasts (Munishi *et al.*, 2007). Variation in species composition in forests of either similar or different conditions is obvious and has been experienced. For instance, a study in dry montane forests by Mialla (2002) reported a total of 42 trees and shrubs species in Monduli Catchment Forest Reserve. Furthermore, according to Mwakalukwa (2014), there are 88 trees and shrubs species in Gangalamtumba land Forest Reserve.

2.3 Useful stand Parameters

2.3.1 Species diversity

Diversity is the structural and functional variety of plants and animals at genetic, species, population, community and ecosystem levels (McElhinny, 2005). Harrison *et al.* (2007) indicated two components of species diversity: the spread of individuals between species within the community (evenness) and species richness which is the actual number of different species in a community rather than the number of individuals contained therein. However, Huang *et al.* (2003) reported that species diversity in tropical forests varies greatly from place to place mainly due to variation in biogeography, habitat and disturbance causing differences in species composition at all scales. For instance, in the Neotropics, the maximum species richness is 300 tree species per hectare. In Africa, Huang *et al.* (2003) reported a maximum of 60 species per hectare due to lack of data that has restricted most discussion of rarity in the tropics to local scarcity.

Based on the relationship between abundance and diversity, habitats supporting larger numbers of individuals can support more populations and more species than habitats supporting small numbers of individuals (Huang *et al.*, 2003). Huang *et al.* (2003) further explained that occurrence of one or more tree species with high frequency would influence species diversity and that; environmental heterogeneity has strong effects on it. Assigning biodiversity values to specific sites has been widely used to describe community composition and structure or to prioritize conservation policy decisions and the biodiversity value which depends not only on the habitat studied and the species examined, but also on the measurement used (McDolnald *et al.*, 2010). The authors reported that, most methods used for measuring species diversity are those which combine aspects of species richness, diversity and evenness. However, most studies use Shannon-Wiener and Simpson diversity indices (McDolnald *et al.*, 2010).

McElhinny (2005) pointed out that these indices are the measure of structural diversity and are indicative of biological diversity and the diversity of a system with one attribute or element has a diversity of zero. According to Krebs (1989), Shannon-Wiener diversity index increases with the number of species in the community but does not exceed 5.0, while Simpson diversity index ranges between 0 and 1.

In Tanzania and elsewhere, the variation in species diversity is evident even with the same forest type. For instance, Mwakalukwa (2014) reported a H´ of 3.44 and 3.26 for large and small individual, (Nkonoki and Msuya, 2014) reported 4.17, While Zahabu, (2001) reported 3.79 and 3.13 respectively in Miombo woodland of Kitulangalo Forets Reserve.

2.3.2 Stem density and basal area

Stocking include number of stems or basal area per unit area, normally per hectare, and reflects the spatial distribution of individual trees within the forest and the distribution of different species in relation to one another (Rutten *et al.*, 2015; Bouvier *et al.*, 2015). Data on stem density (i.e., stems/ha) and basal area are useful attributes of forest structure since they can advise forest leaders on available vegetation quantities and the regenerating capacity of a forest stand. In most cases, stand parameters including stocking is expressed in terms of diameter size class distribution.

According to Hitimana *et al.* (2004) and Crowther *et al.* (2015), a mixed uneven-aged tropical forest generally represents all age classes with a typical reversed “J” shaped curve. This general model can however be modified by various environmental factors and biotic agents including differences in topography or soils, irregular or seasonal climate events, tree cutting, competition for resources, allellopathy between species or between mother trees and seedlings and regeneration patterns. Stem density distribution across different diameter size classes indicates how well the growing forest is utilizing site resources (Hitimana *et al.,* 2004).

Diameter size class distribution is ecologically more informative when accompanied with data on spatial distribution of individuals (Gbedomon *et al.*, 2016) and is commonly used to assess disturbance effects in the forests and detect trends in regeneration pattern (Hitimana *et al.,* 2004). A few small to medium sized trees per hectare may imply that the forest land is not being fully utilized by the tree crop (Hitimana *et al.,* 2004). The decline in density of large-diameter size classes often but not always follows a reversed "J" shape since frequency distribution may or may not shift over time. More often undisturbed forests are also found with some diameter size classes missing (Hitimana *et al.,* 2004; Gbedomon *et al.,* 2016). The authors added further that the reverse-J-curve holds in most cases when all tree species are grouped together but differ markedly for individual tree species. The variation in stem density in undisturbed natural forest has been reported to be less than in disturbed forest (Huang *et al.,* 2003).

Studies done in other miombo woodland forest signify variation in stem density for instance (Nkonoki and Msuya, 2014) reported 567± 8.37 stem/ha for undisturbed area and 246±15.69 stem/ha for disturbed area and for basal area reported 11.21± 1.10 m^2/ha, 3.25±0.20 for undisturbed and disturbed area respectively, Mwakalukwa (2014) reported 1521±594 stem/ha for large individuals tree with Dbh ≥5cm, small individual with Dbh<5cm was 14318±6956 stem/ha and for basal area for large trees Dbh ≥ 5cm were 13.55±5.52m^2/ha and small tree individual Dbh < 5cm were 3.05±0.02m^2/ha. According to Asner (2016), the factors which controlling tree density was the effects of natural, anthropogenic disturbance and soil condition.

2.3.3 Stand volume

Stand volume is an important indicator of the forest ecosystem productivity. Its estimation is important for decision making and sustainable management of forest resources (Adekunle *et al.,* 2013). Forest volume dictates the allocation of forest products such as poles and timber while estimation of wood volume enables calculation of the monetary value of commodities and services that forests provide to the society (Adekunle *et al.*, 2013). For forest management and planning purposes at national and stand levels, is vital to know the volume of wood resources and their rates of growth essential for understanding both ecological dynamics and productive capacity for the managers to be able to manage stands within their limits of sustainability due to their defined growth dynamics (Adekunle *et al.,* 2013). Behera *et al.* (2016) further reported that forest volume assessment is of increasing global interest, especially in the context of the Kyoto protocol. Volume measurement of trees requires recording of diameter and height along the bole of each tree, but reducing the number of tree measurements can reduce field cost and increase precision of the estimates.

However, there is variation in the mean stand volume in various miombo woodland forests of Tanzania, for instances (Nkonoki and Msuya, 2014) reported a mean volume of 71.21m^3/ha for undisturbed forest and 17.72m^2/ha for disturbed. Likewise, Mwakalukwa (2014) reported a mean volume of 92.17±39m^3/ha for large trees with a (Dbh≥5cm) and 12.57±6.35m^3/ha for small individual (Dbh< 5cm).

2.3.4 Land use land cover changes (LULC)

Land use/land cover (LULC) changes play a major role in the study of global change. Land use/land cover and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disaster such as flooding (Smith *et al*., 2016; Dwived *et al*., 2005). These environmental problems are often related to LULC changes. Therefore, available data on LULC changes can provide critical input to decision-making of environmental management and planning the future (Prenzel *et al*., 2004). The growing population and increasing socio-economic necessities creates a pressure on land use/land cover. This pressure results in unplanned and uncontrolled changes in LULC (Reddy *et al*., 2016; Meshesha *et al*., 2016; Seto *et al*., 2002). The LULC alterations are generally caused by mismanagement of agricultural, urban, range and forest lands which lead to severe environmental problems such as landslides, floods among other catastrophies (Lal and Kumar, 2017; Reis *et al*., 2008).

2.4 Drivers of Forest Deforestation and Degradation

The deforestation drivers of Africa relates with those of Asia, while degradation drivers are more similar in Latin America and Asia. Commercial agriculture is the most important driver of deforestation, followed by subsistence agriculture. Timber extraction and logging drives most of the degradation, followed by fuel wood collection and charcoal production, uncontrolled fire and livestock grazing. The results reflect the most up to date and comprehensive overview of current national-level data availability on drivers, which is expected to improve over time within the frame of the UNFCCC REDDC process (Tegegne *et al*., 2016; Mbatu, 2015; Tegegne *et al*., 2014; Hosonuma *et al*., 2012).

2.5 Effects of Human Activities on Vegetation Structure

Every forest has its own threat that it faces. Threat of a particular forest might be different from the other due to several factors such as population density around the forest area and invasive alien plant species that are present in the forest .According to Sawe *et al.* (2014) among the conservation challenges of the miombo ecosystem include maintaining the habitat diversity and integrity, the hydrologic systems and species diversity and status. Other challenges includes maintaining the biological and social values of landscapes of biological significance, restoration of degraded areas and those invaded by exotic species and improving livelihoods by sustainable use of natural resources (Chidumuyo and Kwibisa, 2003; Bustamante *et al*., 2017). Activities such as charcoal production, firewood collection a, conversion of woodlands to farmlands as well as seasonal forest fires are the major drivers of deforestation and forest degradation (Sauer and Abdalah, 2007).

2.6 Impact of Forest Degradation and Deforestation

Deforestation and degradation of forests create ecological problems in every part of the world (Johnson, 2015; Bustamante *et al.*, 2017). Deforestation is occurring at a rapid place, especially in tropical regions where millions of acres are clear cut every year. Remaining forests also suffer from pollution and selective logging operations that degrade the integrity of local ecosystems (Johnson, 2015). Destruction of forests also affects the soil and water quality in the immediate area and can have an adverse effect on biodiversity over a range of connected ecosystems (Brandt, 2016).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Location, climate and biodiversity of the study area

3.1.1.1 Location

Mkulazi Catchment Forest Reserve (MCFR) covers an area of 65710ha; it lies north of the River Ruvu (Lovett and Pocs, 1993). In the Northern and Eastern boundaries run along the River Ngerengere, and are marked by various access roads from Ngerengere to Kidunda Village. The forest reserve is located about 180km from Morogoro town. It located latitude 7° 10´ South Longitude 38° 12´ East. MCFR is surrounded by 14 villages in 5 wards. In Mkulazi ward are Mkulazi and Kidunda villages, Mlilingwa, Nyambogo, Dete and Kisanga Stand villages in Tununguo Ward. Matuli, Diguzi and Kwaba in Matuli ward. Kiganila, Bwirajuu, Bwirachini and Kiburumo in Selembala Ward and Ngerengere village found in Ngerengere ward.

3.1.1.2 Climate

Morogoro Region experiences a bimodal rainfall pattern characterized as long and short rains. The short rains are experienced in October to December. While the long rains in March to May. There is usual a dry spell in January and February. The rains vary from year to year in timing, amount, duration and intensity. In MCFR and nearby villages the area receives estimated rainfall 1000-1500 mm/year with some ground water reported by nearest rainfall station: Tununguo, Ngerengere Agriculture central zone, and temperature averages from June to September is 28°C max and min 24°C December (Lovett and Pocs, 1993; Edward, 2013).

3.1.1.3 Biodiversity features

(a) Flora

Mkulazi Catchment Forest reserve is a lowland forest covered by miombo woodland with thicket on termite mounds and taller; the reserve is dominated by *Brachystegia spiciformis with: Afzelia quanzensis, Dalbergia melanoxylon, Hexalobus monopetalus, Hyphaene spp. Pteleopsis myrtifolia, Pterocarpus angolensis, Vitex sp, Xytotheca tettensis, Hyphaene sp and Swartzia madagascariensis* (Carwardine *et al.*, 2012; Egoh *et al.*, 2010; Lovett and pocs, 1993).

(b) Fauna

MCFR is adjacent to Selous GR, the area is a habitat and transit route from Selous Game Reserve. Danish Hunters Area describe 5 major crossing point in MCFR in which large herbivores such as the Elephant, Buffalo, Wildebeest, Hartebeest, Zebra and Giraffe migrate in and out of MCFR, depending on season availability of Forage (URT, 2008). The area is rich in tree species of Miombo woodland and also these tree species are of conservation importance including *Afzelia quanzensis, Dalbergia melanoxylon and Pterocarpus angolensis,* (Lovett and Pocs, 1993).

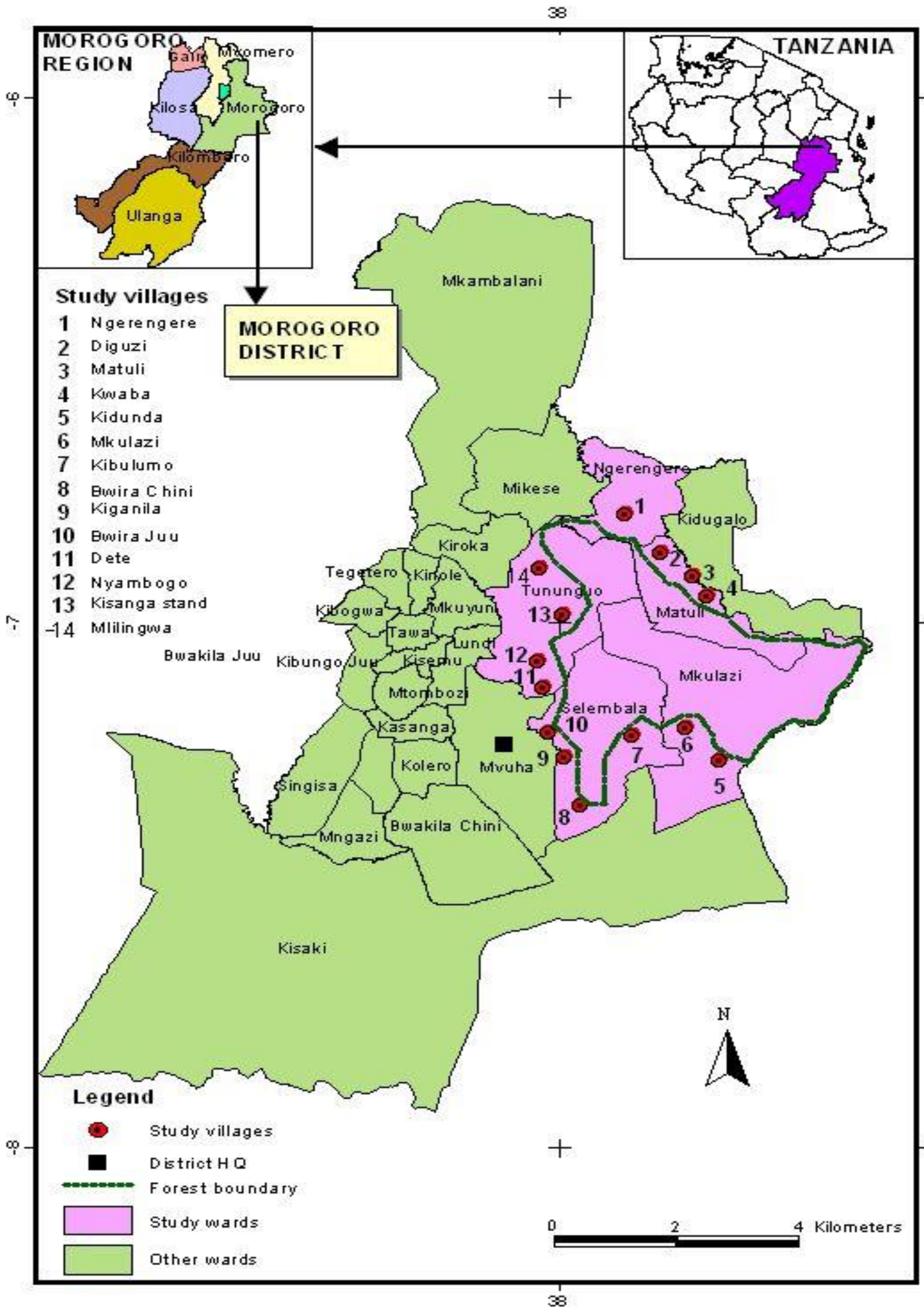

Figure 1: Sketch map of Morogoro District showing the location of MCFR in Tanzania

3.2 Methods

3.2.1 Sampling design and plot shape

Systematic allocation of the cluster along transect line was applied. This was used since it increases the chance of including all vegetation types in the forest and it is easy in allocation of concentric circular plots (Sutherland, 2006). The circular plot was divided into four sub plots with radius of 2m, 5m, 10m and 15m respectively. The sub plot areas in hectares were calculated by $\pi r^2/10\,000$ and the results were as follows. At radius of 2 m the area was 0.001256m^2, 5m was 0.00785m^2, 10m was 0.0314m^2 and in15m radius was 0.07065m^2. This method is appropriate for tropical natural forest inventory since each individual has an equal chance of inclusion in a sample under study (Giliba *et al*., 2011).

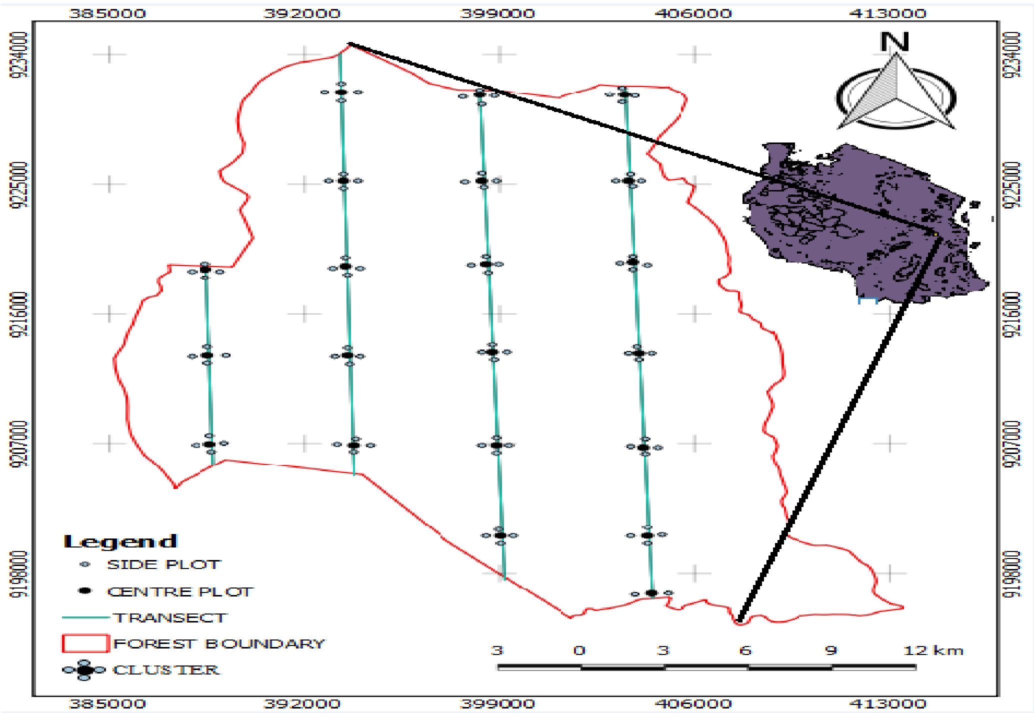

Figure 2: Location and layout of cluster and plots in MCFR

3.2.2 Data collection

3.2.2.1 Forest inventory data

Data collection was done in each circular plot established along the four transect lines in the forestry. These transects were established from the forest boundary with its long axis running through the entire forest reserve as guided by compass and Global positioning System (GPS). The starting and ending points of cluster were Georeferenced by the use of (GPS) for mapping purpose. Each cluster contained 5 plots as shown in Figure 1. Concentric circular plots of 2 m, 5 m, 10 m and 15m were used as adopted by NAFORMA (2015) with small modifications. Hence, data collection and assessment in each sub plot was done as follows as shown in Figure 2.

i) Within 2-m ; all trees and shrubs with DBH<5 cm were identified and counted at species level,

ii) Within 5-m**;** all trees and shrubs with DBH ≥ 5 - <10 cm were identified and measured for DBH at species level ,

iii) Within 10-m**;** all trees and shrubs with DBH ≥ 10 - <20 cm were identified and measured for DBH at species level

iv) Within 15-m main radius; all trees and shrubs with DBH ≥ 20 cm were identified and measured for DBH at species level. In each plot, three tree heights (highest, medium and smallest) were measured using Sunto hypsometer. Identification was by both vernacular and scientific names carried out by experienced local person and a botanist but when proved difficult to identify in the field, voucher specimens were collected for proper identification in the Herbarium at Department of Botany in TAFORI at Lushoto-Tanga. In order to cover the whole area of the forest, the number of transects and the distance between them was determined as:

Distance between transects= Total road distance /Number of transects

=24.8 km/4 which was equal to 6.2km

Distance between clusters= Total transect length /Number of clusters

= 104km/20 equal to 5.2km

Hence, a total of 4 transects were laid parallel to one another at a distance of 6.2km apart. A total of 100 sample plots were established to cover the whole forest area in which the distance between clusters were 5.2km and the distance between plots within the cluster was 250m.

However, the number of sampling plots was determined based on a sampling intensity of 0.01% used by Malimbwi *et al.* (2005). Among other things, financial and time constraints were the main reasons for the adoption of the particular intensity. According to Synnott (1979), a sampling intensity of 0.5% to 0.7% is recommended for tropical natural forest inventories. However, according to Malimbwi and Mugasha (2002) and Malimbwi *et al.* (2005), financial and time constraints and purpose of the forest inventory may dictate the sampling unit to be as low as 0.01%. This study adopted a sampling intensity of 0.01% which is equivalent of 100 plots reasons behind was due to financial limitation, size of the forest, time constraints and the purpose of the forest inventory. Thus, the numbers of sampling plots were determined by using the following formula:

N= (TA*Si)/ (Ps*100) (Munishi, 2005); Where;

N= Number of sample plots,

TA=Total area of the forest (65710ha),

Si=sampling intensity (0.01%),

Ps=Plot size (0.071ha).

Therefore, a total of 20 clusters were established and each cluster consisted of 5 concentric circular plots

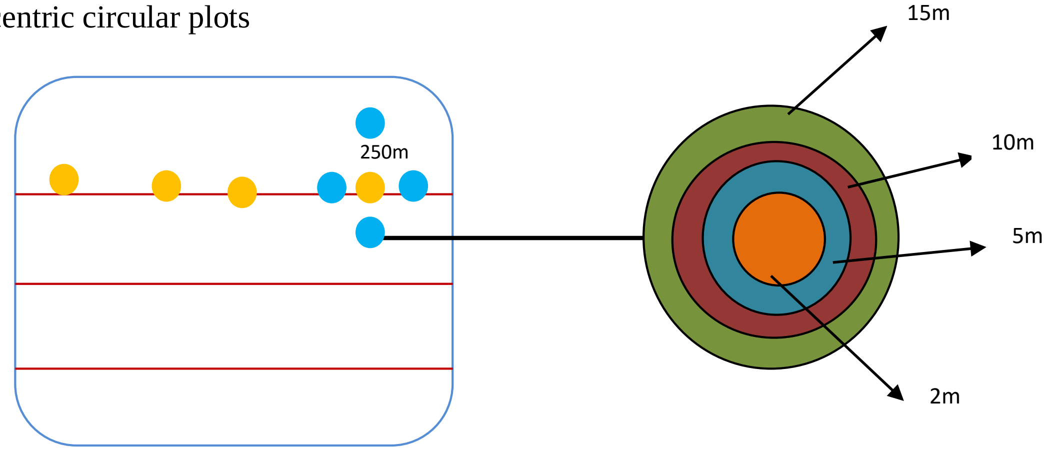

Figure 3: Plot design within transect and cluster

Plate 1: Alignment for inventory data collection

3.2.2.2 Intensity and distribution of human disturbance data

The amount and spreading human disturbance was recorded according to Doggart, (2006). In each plot, all stumps at a height of 10cm from the ground were identified through smell, colour and measured for stump diameter to species level. Cut trees and poles were described as old cut if there was any sign of blackening up of the stump and otherwise as fresh cut. Other indicator of human disturbances that were considered were the areas observed by the presence of burnt trees and ground vegetation as shown by the fire burnt area caused by fire damage, livestock signs as an indicator of grazing, all human used footpath and car used pathways were describe as footpath and car truck respectively. These disturbances once they were encountered in each cluster were counted and recorded.

3.2.2.3 Spatial data

Includes satellite images downloaded from USGS – GLOVIS (www.glovis.usgs.gov) and ground truthing land cover verification data collected by using Global positioning system (GPS).

3.3 Data Analysis

3.3.1 Forestry inventory data analysis

Plant species composition was a list of different plant species identified in Mkulazi Catchment Forest Reserve (MCFR). Shannon-Wiener and Simpson indices were computed using Microsoft excel and Paleontological Statistics Software (PAST).

3.3.1.1 Height estimation /diameter equation

Two models based on height (Ht) and diameter (D) were fitted using regression to obtain a better fit model for estimation of height for unmeasured trees. The better fit model was selected based on the standard error (E) and coefficient of Determination (R^2).Equation (2) was used for height estimation as it has higher value of r^2 and low standard error as shown Table 1.

Table 1: Selecting the best Model for height/Diameter equation for trees species with dbh≥5cm (MCFR)

S/No.	Model	A	B	R^2	MSE
1	Ht=a+b(Dbh)	3.0375	-11.526	0.57	289
2	Ln(Ht)= a+bLn(Dbh)	1.4858	-0.6829	0.6524	0.2983

$$\mathrm{Ln}\,(Ht) = a+b\mathrm{Ln}\,(Dbh)$$

Where:

H= Estimation of tree height

a and *b* are constants with 1.4858 and 0.6829 values respectively

Dbh (Cm) = Diameter at breast height

3.3.1.2 Stocking parameter

For the purpose of this study stocking parameter includes: stem density (N), Basal area (G) and volume of the Forest. Computation of stocking parameters procedures were as follows:

3.3.1.3 Species richness

Species richness was done by counting the total number of different species which were identified at MCFR while Species diversity was computed by Shannon’s Wiener Index of Diversity (H’) and Index of Dominance (ID) (Simpson’s Index).

3.3.1.4 Shannon-Wiener Index of diversity (H')

Shannon-Wiener Index of diversity (H') was calculated by using the following equation

$H' = -\sum_{i=1}^{S}(\text{Pi Log}_{a}\text{ Pi})$……………………………………..………………… (1)

Whereby-Σ is the summation symbol, S Is the number of species, Pi Is the proportional of individuals or the abundance of species 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 variable in order to make the H' positive. The larger the value of H' the greater the uncertainty the index increases with the number of species in the community.

3.3.1.6 Simpsons Diversity Index

The Simpsons diversity index of species dominance was calculated using

IndexC= $\Sigma(pi)^2$

Pi= n/N …………………………………..……………………..……………… (2)

Where: C= Dominance Index,

n= number of Individual of one plant species and

N=Total number of all species identified in a sample area. The greater the value of dominance index, the lower is the species diversity in the community and vice versa.

Stem density= n/N;

Where n= number of stems for particular species per plot and

N= Total number of stems of all tree species per plot.

3.3.1.7 IVI = Importance Value Index of a particular species (%)

IVI=rA+ rF+ rD/3……………………………………………………………………..(3)

IVI = Importance Value Index of a particular species (%)

rD = Relative Density (number of individuals of a species)/ (total number of individuals of all species) x 100,

rF = Relative Frequency (frequency of one species)/ (sum of all frequencies) x 100,

rA = Relative Abundance (combined basal area of single species)/ (total basal area of all species) x 100,

r = Relative

3.3.1.8 Volume

Volume was calculated by using equation developed by (Mauya *et al.*, 2014)

Volume (i) = 0.00011(DBHi)$^{2.133}$ (Hti)$^{0.5758}$……………………..…………………..…. (4)

Whereby; DBHi= Diameter at Breast Height (cm)

Hti= Tree height (m).

3.3.1.9 Stem density and basal area were determined by equations 5 and 6, respectively

$$N = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{n_i}{a}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where;

N= Density (Number of stems ha^{-1})

n_i = Number of stems in i th plot

a = Sample plot area

n = Number of plots

$$G = \frac{1}{n * a} \sum_{i=1}^{n} \left(\frac{\pi d^2}{40\ 000} \right) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (6)$$

Where; G = Basal area in (m^2ha^{-1})

n_i = Basal area of i th trees in a plot

n = Number of sample plots

d = Tree diameter at 1.3 m height measured in cm.

a = Sample plot area in (ha).

3.3.1.10 Volume lost (m^3/ha) can be estimated from the stump volume.

In which the stump volume is used as the parameter for the determination of how much volume has been removed from the forest. Malimbwi (1994), stump volume was calculated by using the following model; $V=0.000047\times\text{Stump diameter (cm)}^{2.56}$.

3.3.1.11 Human induced disturbance

The extent of disturbance was determined through analysis the drivers of disturbance which are Grazing, fire damage, campsite, foot path and car truck. The number of occurance of each driver was recorded, counted and analysed in terms of percentage.

3.3.2 Cover change detection analysis

The land cover change detection analysis was conducted based on the following steps:

3.3.2.1 Image selection and acquisition

Satellite imagery acquisition was done by considering cloud cover, the seasonality and phenological effect (Kashaigili, 2006). Data from the same seasons gives uniform spectral and radiometric characteristics and minimize the seasonal to give uniform variation, in spectral reflectance of land cover type with the interval not less than twenty years from 1975 to 2016 (Table 2) were used in assessing temporal and spatial dynamics of land cover in the study area.

Table 2: Landsat images used in analysis of land-cover change

Year	Satellite	Sensor	Path/Raw	Acquisition date	Season	Spatial resolution
1975	Landsat 2	MSS	167/65	27-07-1975	Dry	60 m
1995	Landsat 5	TM	167/65	02-07-1995	Dry	30 m
2016	Landsat 8	OLI	167/65	08-05-2016	Dry	30 m

3.3.2.2 Image pre-processing

Pre-processing procedures were adopted as an initial stage of refining and rectifying digital image flaws and deficiencies. These include geo-correction and image rectification conducted to rectify precisely matching of images and to correct distortions resulting from the image acquisition process. Followed by Band stacking and Images enhancement using different color composite band combination to reinforce the visual interpretability of images. Lastly images were reprojected to the UTM map coordinate system, Zone 37 South, Datum Arc 1960 in which Mkulazi Catchment Forest Reserve is located.

3.3.2.3 Image classification and ground truthing

Supervised classification using Maximum Likelihood classifier using QGIS 2.8.1 was chosen to classify the images. The method group together features in specified classes based on the likelihood of the spectral signature of each feature to the sample set representing a specified class. The process involved selection of training sites in the Area of interests on the image, which represent specific land classes to be mapped out. The training sites were generated by on-screen digitization of selected areas for each land cover classes identified on color composite (Kashaigili and Majaliwa, 2010). Essentially it is a visual tool that gives an overview of where the classes will be assigned in the image and whether additional classes are required. The objective was to produce thematic classes that resemble to actual land cover types on the earth’s surface (Kashaigili and

Majaliwa, 2010). Data from ground truth were used to formulate and confirm different cover classes existing in the study area.During Supervised Classification, maximum of five distinct land cover classes were identified which are; Closed woodland (CW), Open woodland (OW), Bushland (BL), Bareland (BRL) and Riverine vegetation (RV).

3.3.3 Accuracy assessment

Kappa coefficient statistics was used to assess the accuracy of final image classification. Accuracy assessment's objective was to detect and refine bias of thematic classified maps (Congalton, 1991). The classification procedure shows good agreement with the real world as indicated by overall classification accuracies of 99.7%, 98.4% and 99.5% respectively, for 1975, 1995 and 2016 with their corresponding Kappa statistics of 0.99, 0.98 and 0.99 respectively.

3.3.4 Land use and vegetation cover change detection analysis

In the context of this study, post-classification change detection method was used to assess extent of land cover changes over the period 1975 and 2016. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different time (Mas, 1999). The approach identifies changes by comparing independently classified multi-date images on pixel by pixel basis using a change detection matrix (Kashaigili, 2006). The estimation for the rate of change for the different covers was computed based on the following formulae (Kashaigili, 2006).

$$\%\text{ Cover change} = \frac{\text{Area}_{\boldsymbol{i}\text{ year }\boldsymbol{x}} - \text{Area}_{\boldsymbol{i}\text{ year }\boldsymbol{x+1}}}{\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \text{Area}_{\boldsymbol{i}\text{ year }\boldsymbol{x}}} \text{ x } 100\% \quad (1)$$

$$\text{Annual rate of change} = \frac{\text{Area}_{\boldsymbol{i}\text{ year }\boldsymbol{x}} - \text{Area}_{\boldsymbol{i}\text{ year }\boldsymbol{x+1}}}{\boldsymbol{t}_{\text{years}}} \quad (2)$$

$$\%\text{ Annual rate of change} = \frac{\text{Area}_{\boldsymbol{i}\text{ year }\boldsymbol{x}} - \text{Area}_{\boldsymbol{i}\text{year}\boldsymbol{x+1}}}{\text{Area}_{\boldsymbol{i}\text{ year }\boldsymbol{x}}\boldsymbol{xt}_{\text{years}}} \text{x}100\% \quad (3)$$

Where;

Area i year x = area of cover i at the first date,

Area i year x+1 = area of cover i at the second date,

$\sum_{i=1}^{n} Area_{i\,year\;x}$ = the total cover area at the first date and

T years = period in years between the first and second scene acquisition dates.

CHAPTER FOUR

4.0 RESULTS

4.1 Species Richness and Diversity

4.1.1 Species Richness

This study identified a total of 57 species belonging to 22 plant families based only for standing trees and shrubs in MCFR as shown in Appendix 1and Table 3. However, out of these, trees species were 71.4% from 15families and shrubs were 28.6% from7 families. For stumps a total of 11 Species from5 families of trees were identified.

Plant species from the family *Mimosoideae* were 23.76% of the total number of species, followed by those from by the families *Phyllanthaceae* which were 19.7%, *Caesalpinioideae* was 13.79%, P*apilionoideae* were 12.24%, *Combretaceae* were 9.01% and were *Leguminosae* 4.8%. For shrubs species from the family *Euphorbiaceae* were most dominant and contributed to 2.7% followed by those from *Celastraceae* (1.4%), *Rutaceae* (1.3%) and *Ebenacea*e (0.1%) of the total number of species as indicated in (Table 3).

The species accumulation curve is shown Figure 4. This shows that at plot 1 the graph starts to increase at a high increasing rate and as the number of plots increases the rate of increase becomes progressively smaller. At 84 plots, the graph has remained constant with 57 plant species indicating that any further increase of sample size will not affect the number of identified species.

Table 3: Distribution percentage of families identified and recorded in MCFR

Family	T-tree/S-Shrubs	Frequency %	Total species
Mimosoideae	T	23.76	35534
Phyllanthaceae	T	19.70	29465
Caesalpinioideae	T	13.79	20620
Papilionoideae	T	12.24	18309
Combretaceae	T	9.01	13479
Leguminosae	T	4.80	7182
Meliaceae	T	4.04	6042
Apocynoideae	T	3.40	5085
Euphorbiaceae	S	2.78	4155
Capparaceae	T	2.19	3282
Celastraceae	S	1.44	2155
Rutaceae	S	1.36	2028
Ochnaceae	T	0.76	1141
Anacardiaceae	T	0.17	253
Ebenaceae	S	0.17	253
Burseraceae	S	0.09	141
Lamiaceae	S	0.08	113
Rubiaceae	S	0.07	112
Dipterocarpaceae	T	0.06	85
Sapindaceae	T	0.05	70
Malvaceae	T	0.02	28
Sapotaceae	T	0.02	28
		100	149560

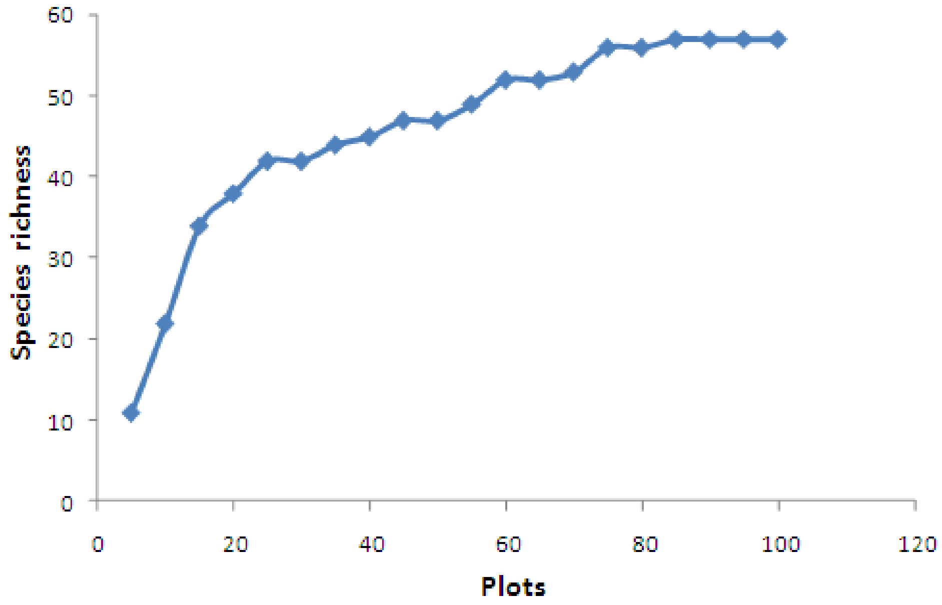

Figure 4: Species accumulation curve of trees/ shrubs sampled in MCFR.

4.1.2 Species Diversity

Species diversity as per Shannon-wiener and Simpson indices in MCFR were 3.086 and 0.946 respectively, the species that contributed to high species diversity based on IVI were *Brachytegia boehmii* (20.59) followed by *Combretum molle* (10.82), *Pseudolachnostylis glauca* (10.01) and *Piliostigma thonningii* (0.041) as shown by species diversity IVI values in Figure 5 and Appendix 2.

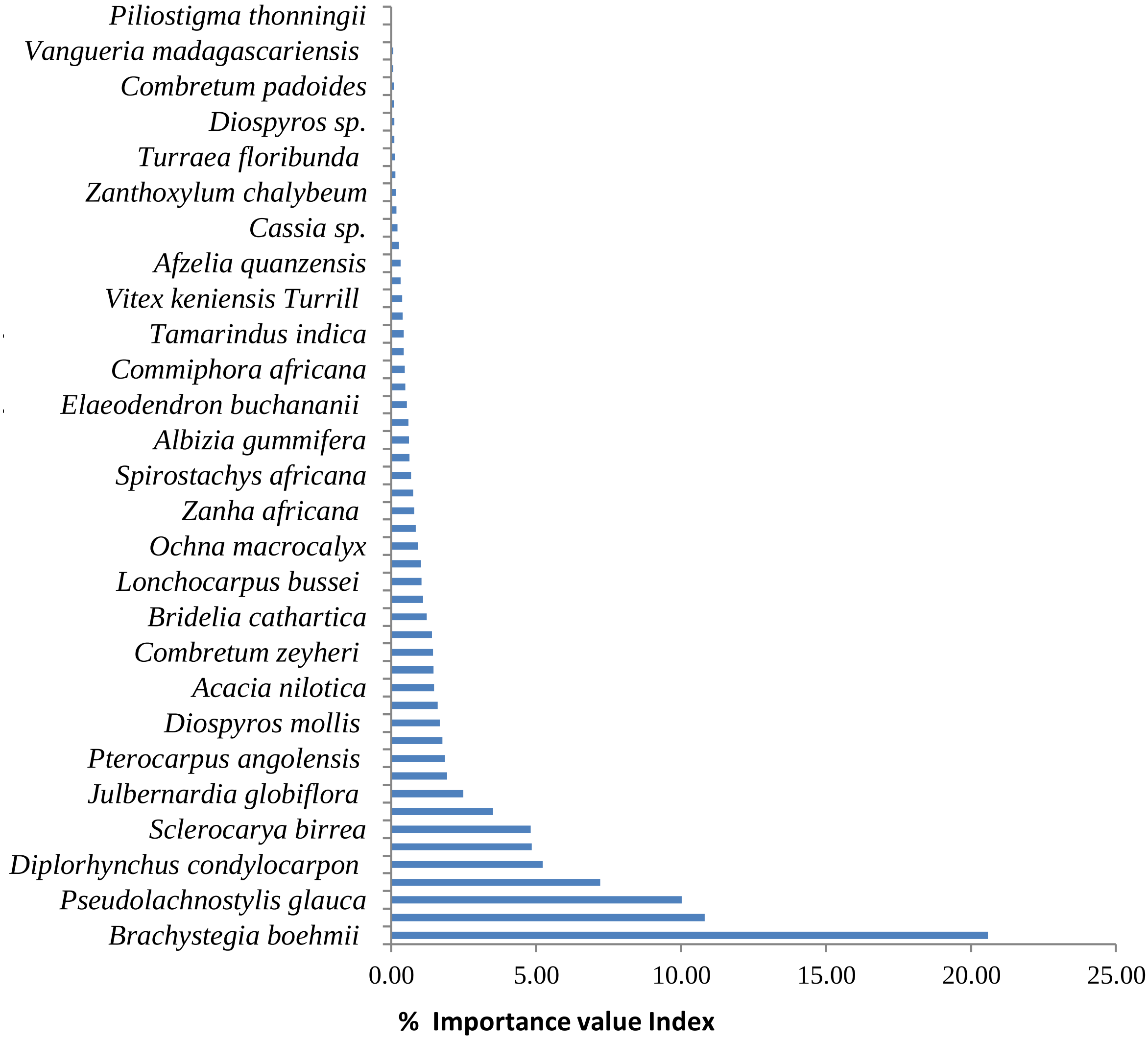

Figure 5: Species composition according to Importance Value Index (IVI) in MCFR

4.2 Stem Density, Basal Area and Volume

4.2.1 Stem density

The mean stem density in MCFR was 255.9±61.7 stem/ha for trees and shrubs with a Dbh ≥ 5cm, 1495±324 Stem/ha for All trees, shrub and regenerants, where the stem density of regenerants were 1400± 304 stem/ha. More stems were observed in lower DBH class (> 20cm) as shown in (Figure 6 and Figure 7). However, in all trees, shrubs and regenerants the most abundant tree by percentage was *Acacia nilotica* 11.58%, *Brachystegia boehmii* 9.5%, *Pseudolachnostylis glauca* 7.5%, *Albizia petersiana* 6.02% and *Dalbergia melanoxylon 5.4*% as shown in (Figure 6, Appendix 3 and 4).

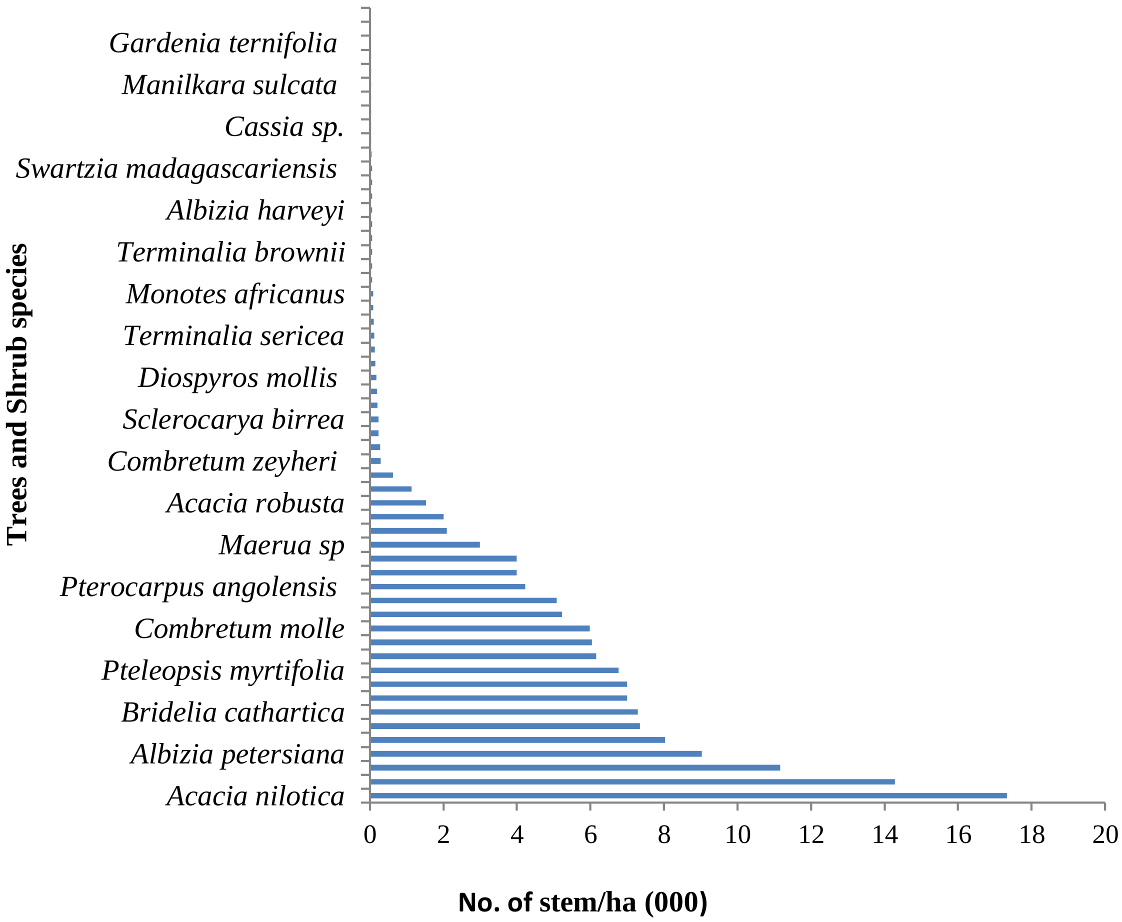

Figure 6: Distribution of stem/ha for all trees, shrubs and regenerants species

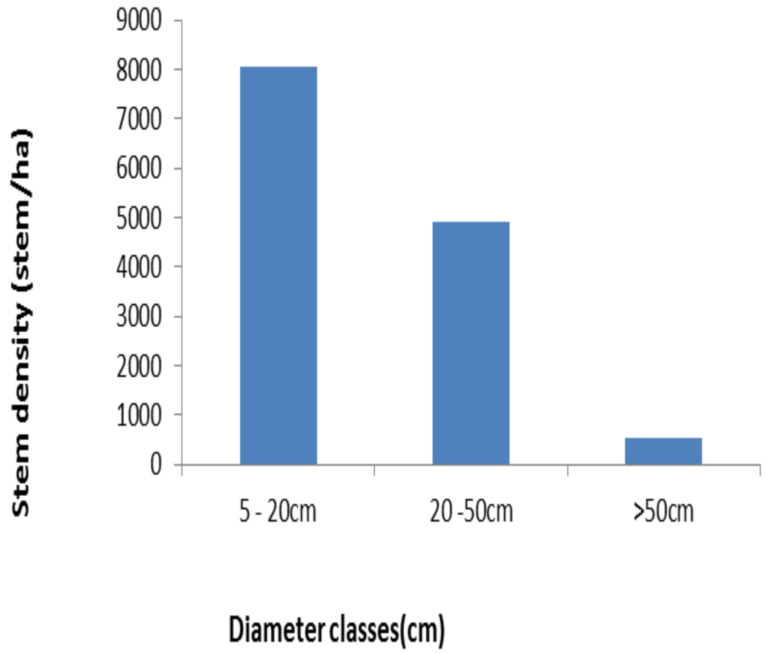

Figure 7: Stem density (stem/ha) distribution in Diameter class (cm)

4.2.2 Basal Area Distribution

The mean average basal area was 7.6±2.1 m²/ha for species with Dbh≥ 5cm as shown in Appendix 5 in Mkulazi catchment forest reserve.The species *Brachystegia boehmii* (21.7%) contributing most to the basal area followed by *Pseudolachnostylis glauca* (10.7%), *Combretum molle* (9.8%), *Xeroderris stuhlmannii* (8%) and *Sclerocarya birrea* (5.8%). Comparison between diameter class and basal area show that there was higher basal area per hectare in mid diameter class having (20-50cm), followed by the trees having the diameter of 5-20cm and least were the trees having the Dbh > 50cm (Figure 8, Appendix 5).

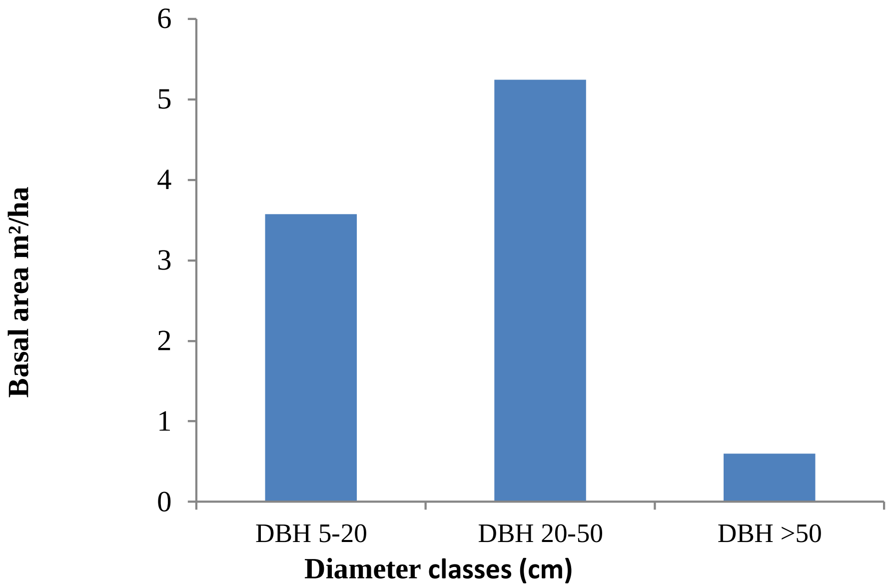

Figure 8: Basal area of woody plant species in MCFR

4.2.3 Volume

The mean standing volumes for all trees with a Dbh ≥ 5cm were 88.07±25.61m³/ha as shown in Appendix 6. The volume having diameter 5-20cm were 39.8±21.9 m³/ha and those with diameter 20-50cm were 39.8±14.19 m³/ha and those with diameter > 50cm were 8.5 ±4.6 m³/ha as shown in Figure 9. In terms of volume for species the most frequent species were *Brachystegia boehmii* which had 2043.9 m³/ha followed by *Pseudolachnostylis glauca* 944.8 m³/ha *Xeroderris stuhlmannii* 786.6m³/ha, *Combretum molle* 702.5 m³/ha *Sclerocarya birrea* 601m³/ha and the least were *Vangueria madagascariensis* 0.9 m³/ha, *Gardenia ternifolia Schumac* 0.8m³/ha and *Piliostigma thonningii* 0.6 m³ /ha as indicated in (Figure 10, Appendix 6).

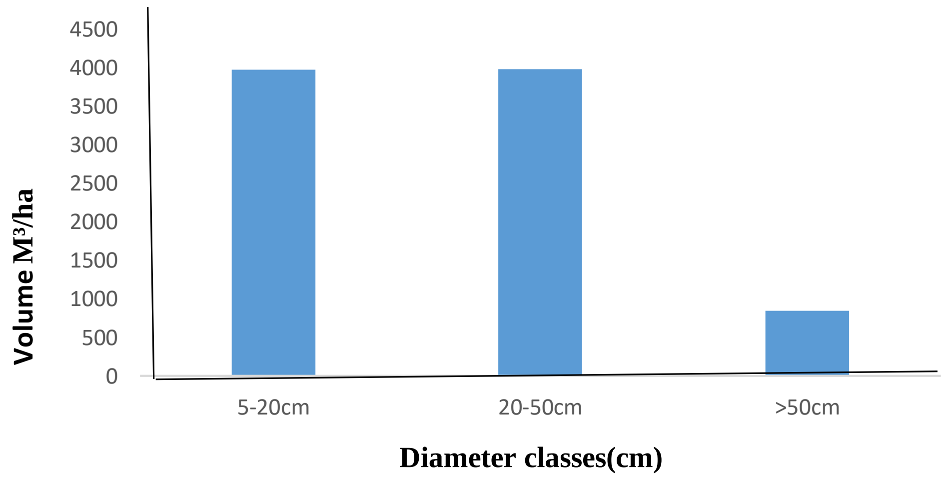

Figure 9: Volume (m^3/ha) per diameter classes

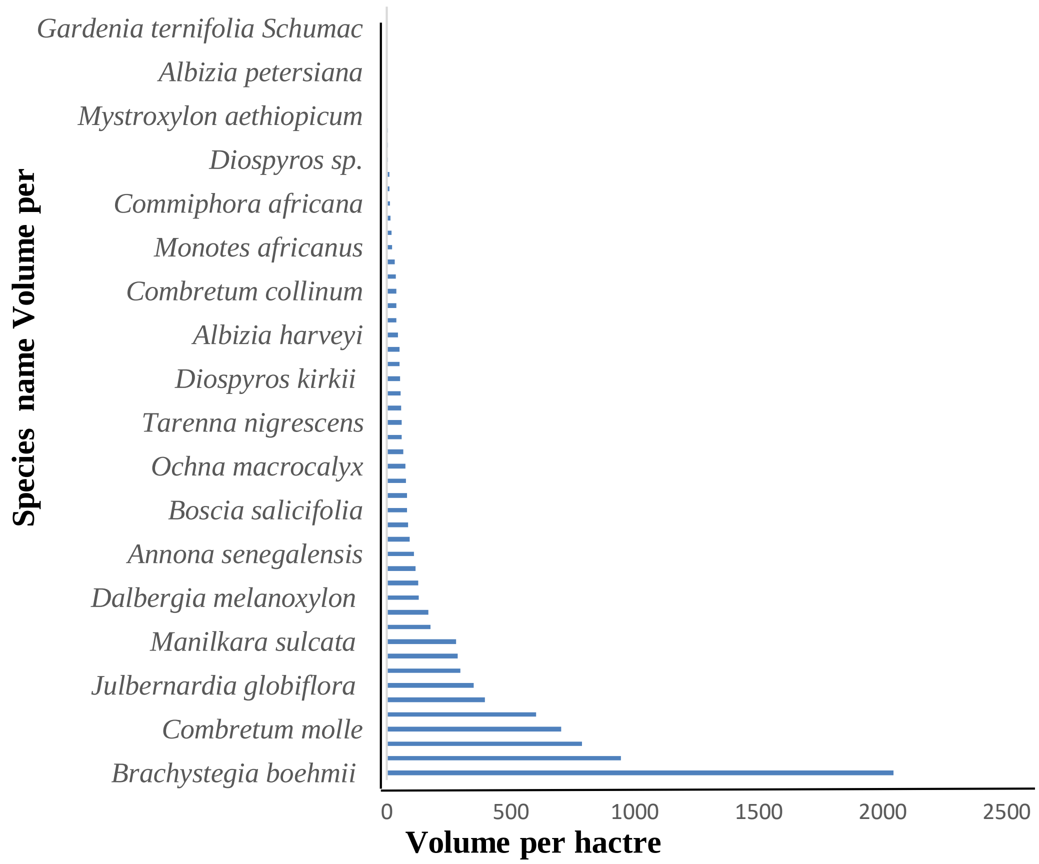

Figure 10: Total volume for each species m^3/ha

Table 4: Stand characteristics in MCFR

Parameter	Value
Sample size	100
Species richness	57
Stand density(stem/ha)	255.9±61.7 stem/ha
Basal area	7.6±2.1 m^2/ha
Standing volume(m^3/ha)	88.07±25.61m^3/ha
Simpson_1-D	0.9436
Shannon_H	3.086

4.3 Intensity and Distribution of Human Disturbance

4.3.1 Disturbance due to illegal harvesting

The mean volume of all stumps recorded and calculated was 24.5±9.3m^3/ha in MCFR reserve with a total volume of 2450 m^3 as indicated in Appendix 7.

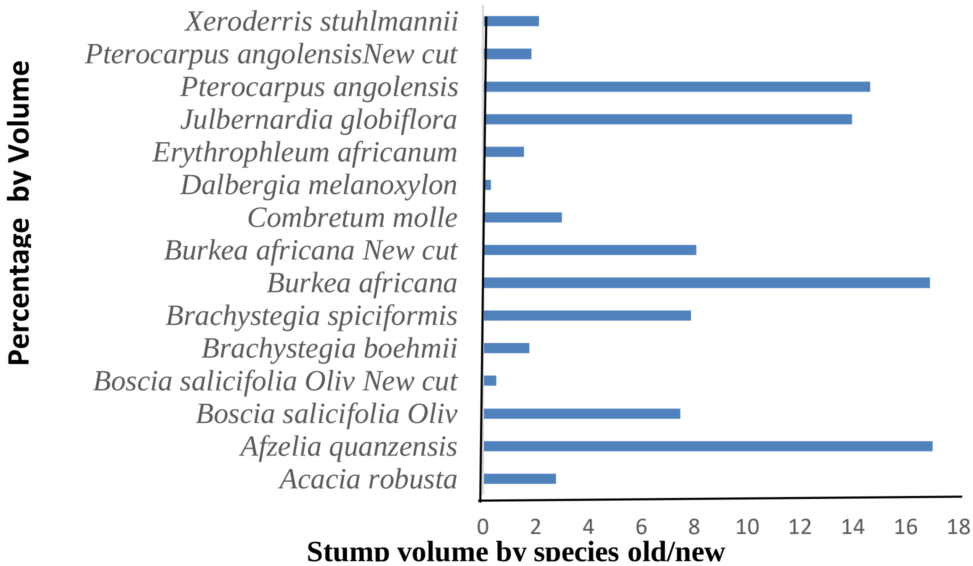

Figure 11: Intensity and distribution of human disturbance

The volume of old cut were 2193m^3 (89.55%) *and 256m^3 (10.45%)* for new cut. For all species the highest volume were for *Afzelia quanzensis17.3%, Burkea Africana 16.9%* and *Pterocarpus angolensis* 14.7% while for new cut the highest was *Burkea Africana 8.08%* followed by *Pterocarpus angolensis* 1.84% and 0.515% *Boscia salicifolia* (Figure 11).

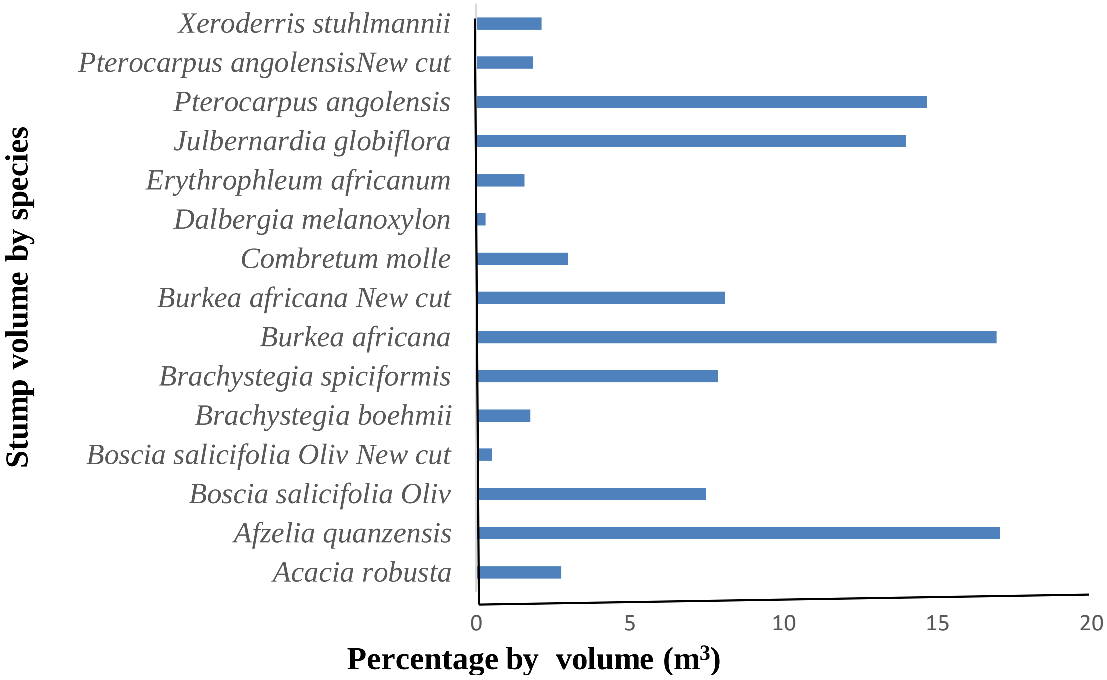

Figure 12: Quantity of old cut and fresh cut stump volume for each species recorded in MCFR

Plate 2: Stump measurement in the field

4.3.2 Other Disturbance Observed in Each Cluster

All forms of anthropogenic disturbance within clusters were observed in this study, where 43.5% were grazing, 21.7% were foot path, 17.4% camping site, 15.2% car truck and 2.2% was fire damage. (Figure13, Appendix 8).

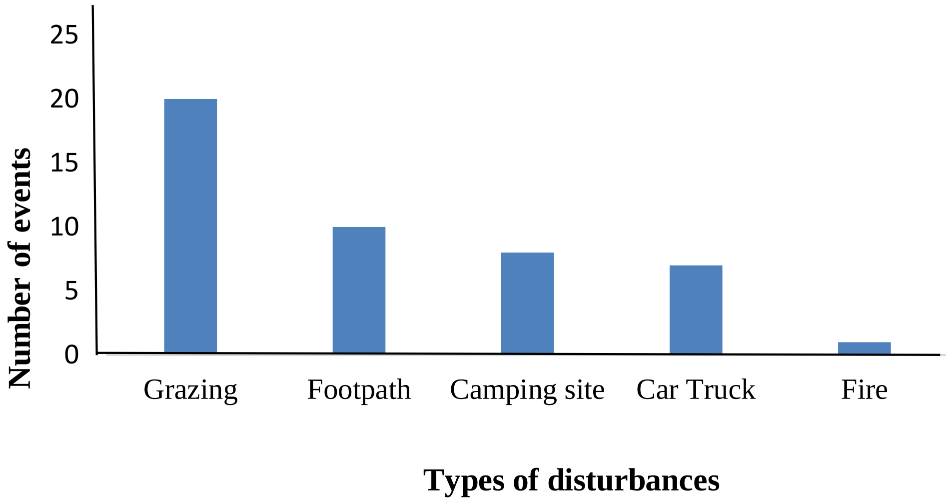

Figure 13: Types of disturbance observed in MCFR counts by number in each cluster

Plate 3: Disturbance based on Grazing in MCFR

Plate 4: Disturbance based on fire damage

4.4 Land Cover Changes during the Period of 1975-2016

The land cover changes data and maps for 1975, 1995 and 2016 are presented in Table 5, Figure 14, 15 and 16) respectively.

Table 5: Land cover 1975, 1995 and 2016 in MCFR

YEAR	1975		1995		2016	
	Ha	(%)	Ha	(%)	Ha	(%)
Closed woodland	42897.22	65.28	28301.55	43.07	14696.6	22.37
Open woodland	5751.74	8.75	22221.16	33.82	31741.77	48.31
Bushland	12479.427	18.99	9260.947	14.09	1033.887	1.57
Bareland	1860.76	2.83	3251.55	4.95	16228.94	24.70
Riverine	2720.88	4.14	2674.82	4.07	2008.83	3.06
Total	65710.027	100	65710.027	100	65710.027	100

Generally, the maps show variation in cover changes between three time periods under consideration. The analysis shows the land use/ land cover maps of the study area for the years 1975, 1995 and 2016 respectively. Five land cover classes namely CW-Closed wood land, OP-Open woodland, BSL-Bush land, BRL- Bare land and RV-Riverine were recognized. The land use/land cover categories delineate in the study area revealed the

Changes in land use /land cover statistics (in hectare and percentages) that have taken place during the period between 1975 and 2016.

Results in (Table 5 and Figure. 14, 15 and 16) indicate difference in land cover classes in the period of 41 years ago (1975, 1995 and 2016). In 1975 the area cover was 42 897.22 ha (62.28%) for CW- closed woodland, 5751.74 ha (8.75 %) for OP- open woodland, 12479.427 ha (18.99 %) for bush land, 1860.76 ha (2.83 %) for BRL-Bare land and 2720.88ha (4.14 %) for RV-Riverine vegetation.

In 1995 the area covered by CW- closed woodland, BSL-Bush land and RV-riverine vegetation was decreased to 28301.55 ha (43.07%), 9260.947 ha (14.09 %) and 2674.84ha (4.07) respectively while OP- open woodland and BRL-Bare land increased to 22221.16 ha (33.82 %) and 3251.55 (4.95%) respectively. In 2016 the area covered by CW-closed woodland, BSL-Bush land and RV-Riverine vegetation was in progressive decrease to 14696.6ha (22.37%), 16228.94 (24.70%) and 2008.83ha (3.06%) respectively while OP- open woodland and BRL-Bare land increased to 31741.77 ha (48.31 %) and 16228ha (24.70%) respectively.

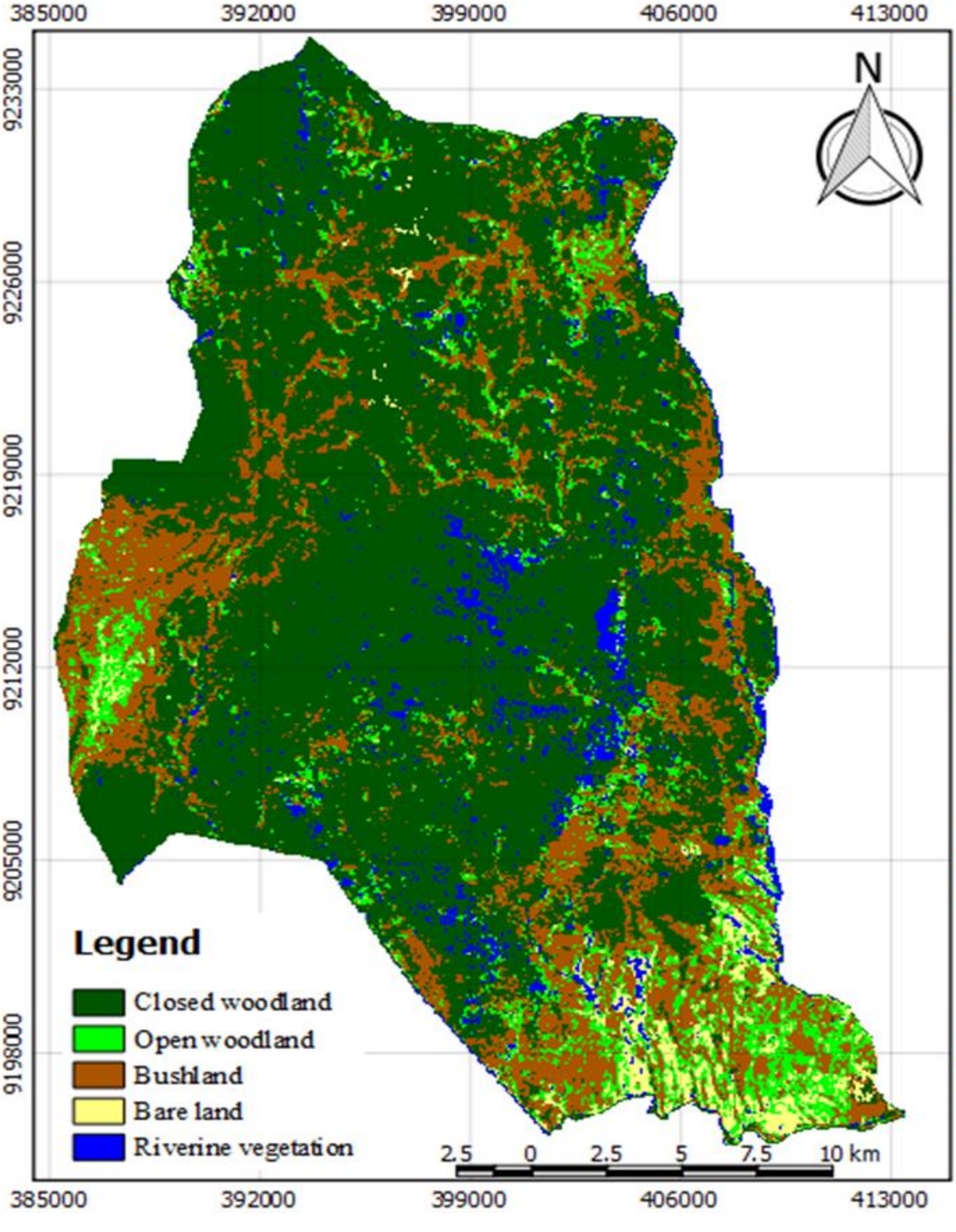

Figure 14: Land cover/ use map for MCFR 1975

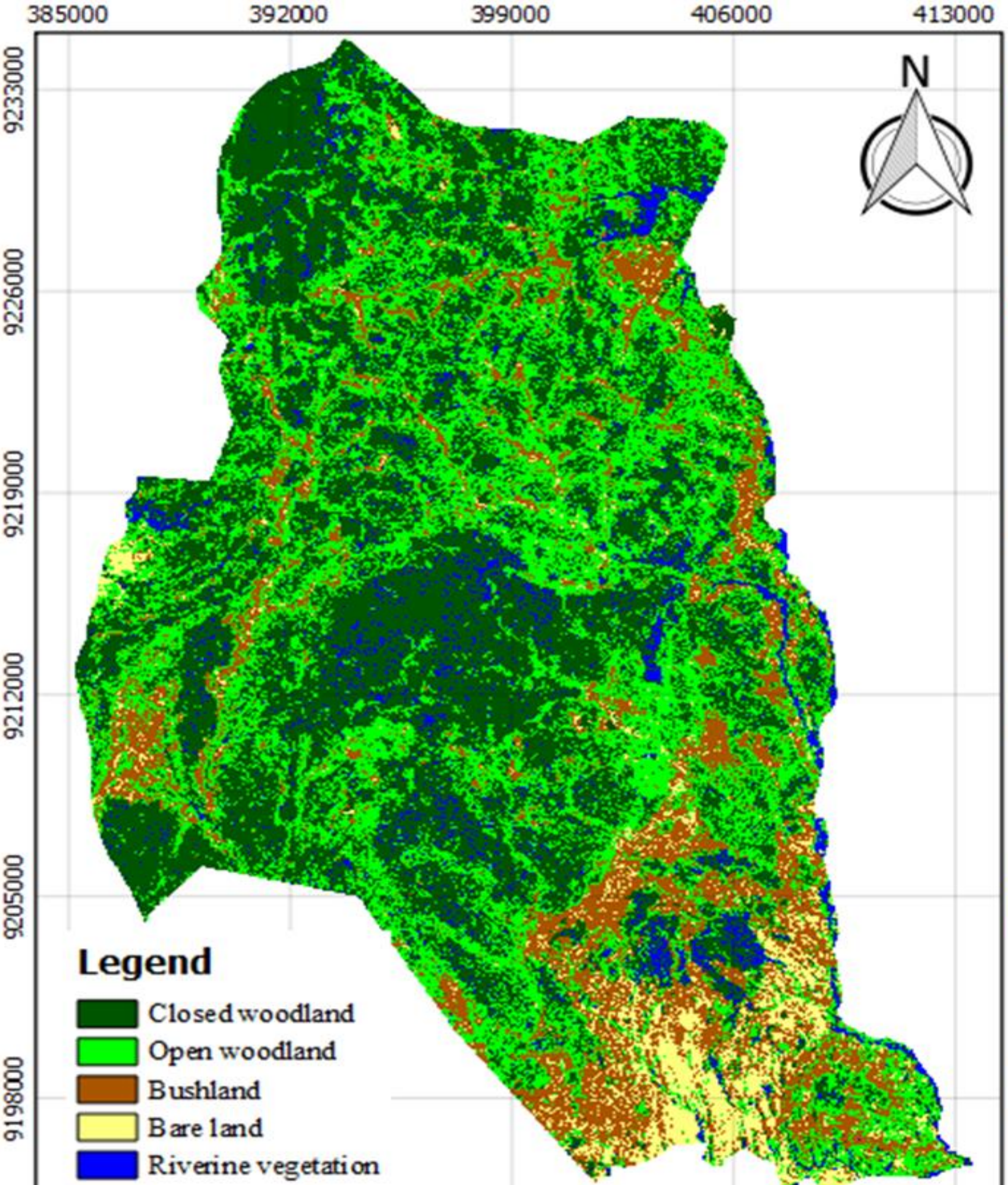

Figure 15: Land cover/ use map for MCFR 1995

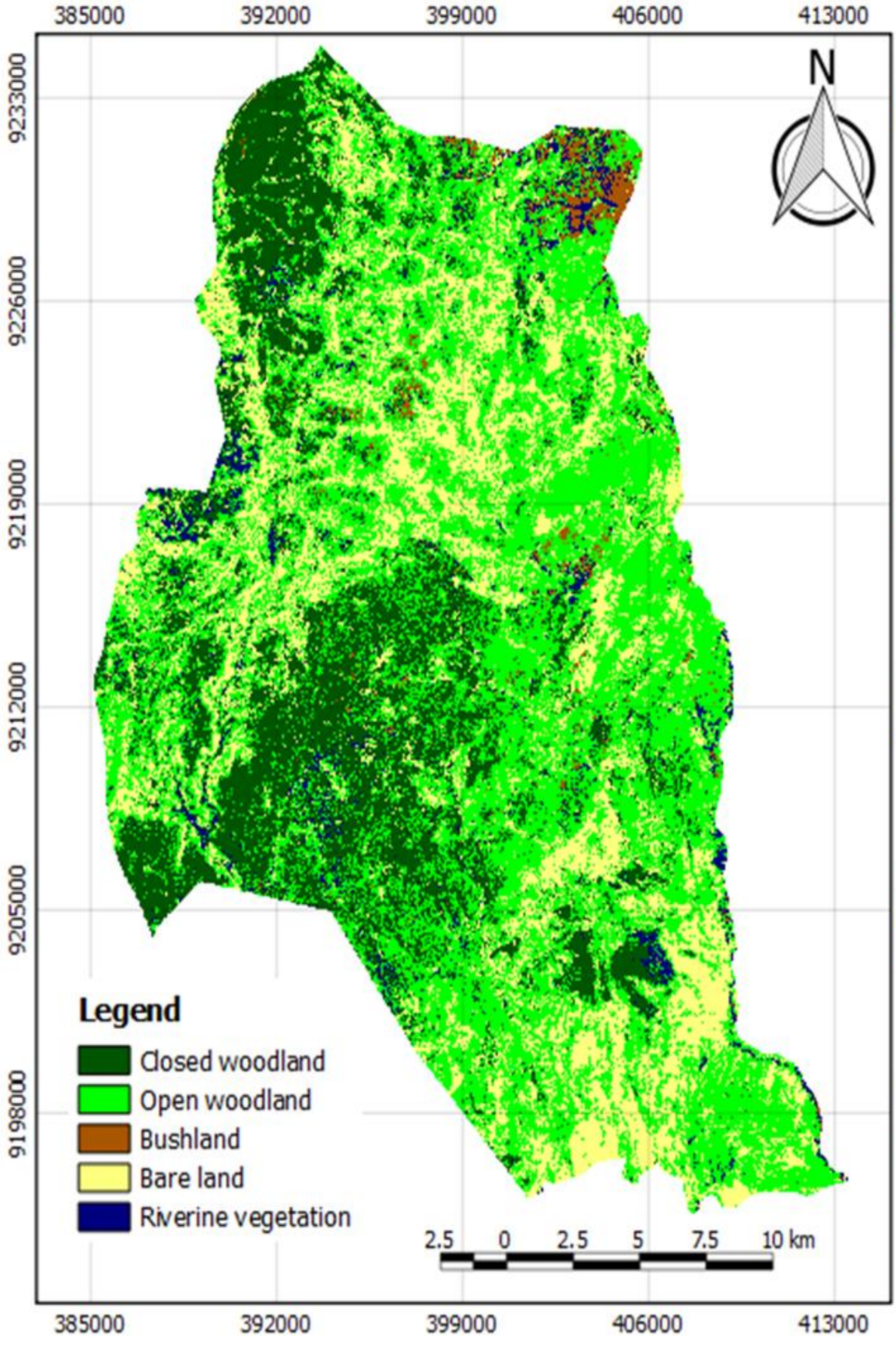

Figure 16: Land cover/ use map for MCFR 2016

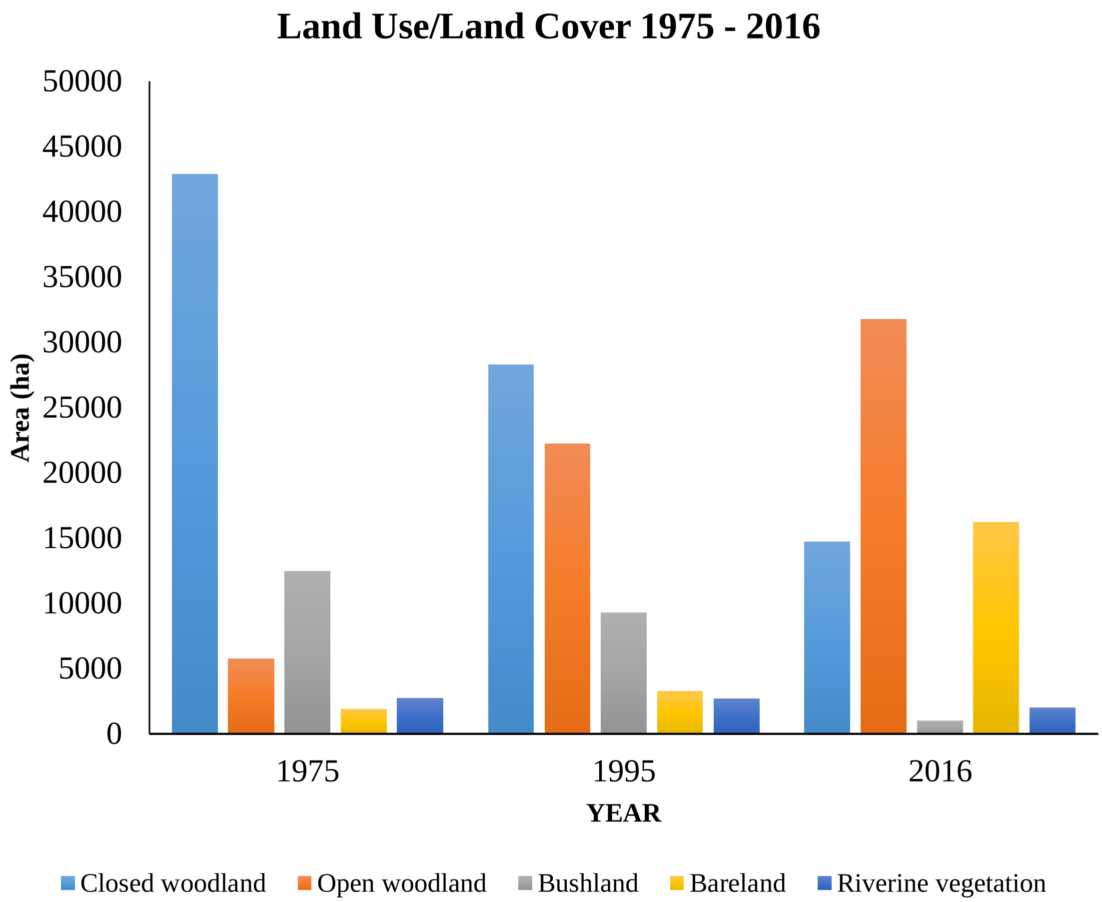

Figure 17: Land use/ cover distribution for MCFR 1975, 1995 and 2016

4.4.1 Cover area, changed area and the rate of change between 1975 and 1995

Results of cover area and rate of change between 1975 and 1995, between 1995 and 2016 are presented in Tables 6. From 1975 to 1995 there was tremendous decrease of CW- Closed woodland, BSL-Bush land area and RV-Riverine vegetation in MCFR from 42897.22ha to 28301.55ha (-22.21%), 12479.43ha to 9260.95ha (-4.90%) and 2720.88ha to2674.82ha (-46.06%) respectively. OP-open woodland, BRL-Bare land increased from5751.74ha to 22221.16ha (25.07%) and 1860.76ha to3251.55ha (2.12%) respectively as shown in Table 6.

Table 6: Land cover change between 1975, 1995 and 2016

YEAR	1975		1995		2016		1975 - 1995				1995 - 2016			
LULC	Ha	%	Ha	%	Ha	%	Area change (Ha)	Area change (%)	Annual rate of change (Ha/year)	%Annual rate of change (%/year)	Area change (Ha)	Area change (%)	Annual rate of change (Ha/year)	%Annual rate of change (%/year)
CW	42897.22	65.28	28301.55	43.07	14696.6	22.37	-14595.67	-22.21	-729.78	-1.11	-13604.95	-20.70	-647.85	-0.99
OW	5751.74	8.75	22221.16	33.82	31741.77	48.31	16469.42	25.07	823.47	1.25	9520.61	14.49	453.36	0.69
BSL	12479.43	18.99	9260.95	14.09	1033.887	1.57	-3218.48	-4.90	-160.92	-0.25	-8227.06	-12.52	-391.76	-0.60
BRL	1860.76	2.83	3251.55	4.95	16228.94	24.70	1390.79	2.12	69.54	0.11	12977.39	19.75	617.97	0.94
RV	2720.88	4.14	2674.82	4.07	2008.83	3.06	-46.06	-0.07	-2.30	0.00	-665.99	-1.01	-31.71	-0.05
TOTAL	**65710.027**	**100**	**65710.027**	**100**	**65710.027**	**100**								

Between 1975 to 2016 persisted enormous decreases CW- Closed woodland, BSL-Bush land and RV-Riverine vegetation areas in MCFR from 42897.22ha to 14696.6ha (-22.21%), 12479.43ha to 1033.887ha (-17.42%) and 2720.88ha to 2008.83ha (-1.08%) respectively. Still OP-open woodland, BRL- Bare land increased from 1860.76ha to 16228.94ha (21.87%) and 5751.74ha to 31741.77ha (39.56%) respectively (Table 6)

4.4.2 Change detection matrix of different land cover/use 1975-2016

Table 7 present the land cover changes detection matrix Landsat satellite imagery during the period of 1975 to 1995. The results show that there were fluctuations of land cover classes in the study area as follows. For instance, closed woodland changed into open woodland, bush land, bare land and riverine vegetation by 29.34%, 3.96%, 32.90%, and 1.03% respectively. Also 32.77% of closed woodland remained unchanged. Nonetheless, about 0.07% changed into closed woodland, 18.26% bush land, 48.45% into bare land, 9.18% riverine vegetation, but 24.05% of open woodland remained unaffected.

Table 7: Changes matrix detection from 1975-1995

	LULC 1995 (ha)					
LULC 1975 (ha)	CW	OW	BSL	BRL	RV	Total
CW	12754.92	11421.74	1539.94	12803.59	402.3	38922.488
%	32.77	29.34	3.96	32.90	1.03	100
OW	5.832	1909.387	1449.607	3846.8	728.514	7940.14
%	0.07	24.05	18.26	48.45	9.18	100
BSL	33.05	2688.07	3755.65	4115.21	1110.92	11702.88
%	0.28	22.97	32.09	35.16	9.49	100
BRL	6.89	189.62	433.35	2173.79	540.11	3343.755
%	0.21	5.67	12.96	65.01	16.15	100
RV	171.32	375.17	186.71	191.97	2875.60	3800.764
%	4.51	9.87	4.91	5.05	75.66	100
Total	12972.001	16583.982	7365.248	23131.355	5657.441	65710.027

Key: CW= closed woodland, OW = open woodland, BSL= bush land, BRL Bare land and RV= riverine vegetation

However, closed woodland, open woodland, bare land and riverine vegetation changed by 0.28%, 22.97%, 35.16% and 9.49% respectively, but 32.09% of bush land remained unchanged. Bare land was converted to closed woodland; open woodland, bush land bare land and riverine vegetation by 0.21%, 5.67%, 12.96% and 16.15% respectively and 65.01% of the bush land remained unchanged. Moreover, 4.51% of the riverine vegetation changed to closed woodland, 9.87% to open woodland, 4.91% to bush land and 5.05% to bare land and 75.66% remained unchanged as shown in Table 8.

The result suggests that, closed woodland, bush land and riverine vegetation were almost depleted compared to other land cover classes.

4.4.3 Land cover changes during 1995 and 2016.

The period consists of land cover changes detected from landsat imagery. Based on the changed detection matrix for different land use cover between 1995-2016 the results from Table 8 revealed that, about 1.85% of closed woodland were converted to open woodland, 3.67% bushland, 44.54% bare land and 8.6% were converted to riverine vegetation while 41.17% of closed woodland remained unchanged.Bush land changed to closed woodland, open woodland land and riverine vegetation by 0.00%, 12.02%, 54.68% and 3.46% respectively while 29.84% of bush land remained unchanged. Riverine vegetation changed to closed woodland, open woodland, bush land and bare land by 0.00%, 1.38%, 0.09% and 0.51% respectively.

Table 8: Changes matrix detectionfrom 1995-2016

	LULC 2016 (ha)					
LULC 1995 (ha)	CW	OW	BSL	BRL	RV	Total
CW	12354	555.75	1102.23	13365.18	2629.89	30007.05
(%)	41.17	1.85	3.67	44.54	8.76	100
OW	3.137	1313.2	1033.3	5056.14	4441.59	11847.367
(%)	0.03	11.08	8.72	42.68	37.49	100
BSL	0	881.91	2189.72	4012.14	254.07	7337.84
(%)	0.	12.02	29.84	54.68	3.46	100
BRL	0	2817.09	261.18	5524.43	5598.88	14201.58
(%)	0	19.84	1.84	38.90	39.42	100
RV	0	31.95	1.98	11.7	2270.56	2316.19
(%)	0	1.38	0.09	0.51	98.03	100
Total	12357.137	5599.9	4588.41	27969.59	15194.99	65710.027

Key: CW= closed woodland, OW = open woodland, BSL= bush land, BRL Bare land and RV= riverine vegetation

However, 98.03% of riverine vegetation remained unchanged. Open woodland was converted to closed woodland, bush land, bare land, and riverine vegetation by 0.03%, 8.72%, 42.68% and 37.49% respectively and 11.08% of open woodland did not change.

Bareland were converted to closed woodland, open woodland, bush land and riverine vegetation by 0.00%, 19.84%, 1.84% and 39.42% respectively while 38.90% of bare land remained unchanged as shown in Table 9.

4.4.4 Variation on detected changes and interpretation

Assessment of the detected changes during 1975, 1995 and 2016 which was an average period of 20years that mainly between 1975 and 1995 as indicated in Table 6 show that three cover classes of CW, BSL and RV decreased at a rate of -22.21%, -4.90% and -0.07 respectively. On the other hand, OW and BRL for 20years increased at a rate of 25.07% and 2.12% respectively. Apparently, decrease in forest cover in CW, BSL and RV change to OW and BRL were contributed due to human activities such as illegal timber harvesting, grazing, camping sites, global warming and increase of natural disaster including flooding and fire (smith *et al.,* 2016; Dwived *et al.,* 20015). Since 1995 to 2016 as shown in Table 8 the CW, BSL and RV forest cover changed to OW and BRL where by CW, BSL and RV decrease at a rate of -20.70%, -12.52% and 1.01% respectively. In addition, OW and BRL increased by 14.49% and 19.75% respectively for 21years.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Species Richness and diversity

5.1.1 Species Richness

The results reported in this study show the composition of the vegetation types found in MCFR, particularly the dominance of species from the family *Combretacea, Papilionoideae, Caesalpinioidea, Phyllanthaceae* and *Mimosoideae* agreed well with previous description and classification of plant communities commonly found in miombo woodlands (Mwakalukwa, 2014; Mugasha *et al*., 2013). Generally, the observed dominance based on IVI is as shown in Appendix 6 and Figure 10. *Brachytegia boehmii* was the dominant species followed by *Combretum molle, Pseudolachnostylis glauca, Xeroderris stuhlmannii, Diplorhynchus condylocarpon and Pteleopsis myrtifolia* this implies the common patterns usually considered as miombo woodland. The frequency of species observed in the MCFR as shown in Appendix 6 show similar deviations exist between the results obtained by Mwakalukwa (2014) in Gangalamtumba Village Land Forest Reserve where he reported that *Combretum molle* and *Brachytegia* were species which had high IVI.

The species richness observed in the MCFR compares well with miombo community studies in other areas of dry Miombo in Tanzania for instance (Malimbwi, 1998; Mayes *et al.,* 2015; Jew *et al*., 2016) and thus the high species richness in the study area is attributed probably due to the presence of the riverine forest along MCFR which favour the growth of many species (Burgess *et al.,* 2010).

5.1.2 Species Diversity

The values of the Shannon-Wiener Index of diversity (H') tells about species richness and evenness,whereby the larger the value H' the greater the species diversity and vice versa (Rands *et al.,* 2010). Usually, an ecosystem with H' value greater than 2 has been regarded as medium to high diverse in terms of species (Rands *et al.,* 2010). Krebs (1989) suggested that the value of the index usually lies between 1.5 to 3.5 as a principle that, Shannon diversity increases with increase in number of species, in this study species index Shannon and Simpson were 3.09 and 0.9437 respectively (Table 4) as compared to those found in Gangalamtumba Village land Forest Reserve by Mwakalukwa (2014) and Mbwambo *et al.* (2012) which were 3.44, also Kitulangalo Miombo Forest, Tanzania by Nduwamungu (1996) which were 3.79, 3.56 and 3.26 for all diameter classes respectively, Also other studies by Nkokoni and Msuya (2014) in Chenene Forest Reserve reported the species index of 4.17. Moreover, according to Zahabu (2001) Shanon- index in miombo woodland of Kitulangalo Forest Reserve, Morogoro Tanzania was 3.79 and 3.13 respectively. This result suggests that a Shannon and Simpson species index of 3.09 and 0.9437 respectively shows that plant species in MCFR are diversified with more evenness.

5.2 Stem Density, Basal Area and Volume

Forest structure usually refers to the way in which the attributes of trees are distributed within a forest ecosystem (Sutherland, 2006; Rands *et al.,* 2010; Peña-Claros *et al*., 2012). The structure of a forest is the result of natural processes, such as plant species-specific growth, mortality, recruitment and natural disturbance such as fire, wind or snow damage (Godoy *et al.*, 2011; Crausbay *et al*., 2016; Sánchez-Pinillos *et al*., 2016), to varying degrees, all forest that were impacted by some of human disturbance seemed to have consistently important influence on the forest structure of many Miombo woodland Forest Reserve.

Clearly, human activities causes disruption of forest structure and changes community composition of the forest and if disturbance are subjected to a forest for a long time will ultimately lead to disruption of tree population structure as well (Maliondo *et al.,* 2000; Kashaigili *et al*., 2006; Munishi *et al*., 2011; Arroyo-Rodríguez *et al.,* 2017). Based on the results on the forest structure in Mkulazi catchment forest reserve which showed a mean stem density of 255.9±61.7 stem/ha with (Dbh >5cm),and basal area 7.6±2.1m^2/ha which is lower than those reported by Malimbwi, (2007) which stated that there is about 1405 and 618 stems ha^{-1} in forest reserve and public land respectively. Moreover, Luoga *et al.* (2002) reported that average number of stems per ha in Kitulangalo SUA-Training Forest was 627stems per ha and 1424 stems/ha in the general land respectively. Mwakalukwa (2014) in Gangalamtumba village land forest reserve found that for large individuals with Dbh ≥5cm was 1521±594stems/ha and for all trees categories was 14318±6956 stems /ha similar results were reported by (Sawe, 2013) in Manga forest reserve where general land was found to have 207±12 and 213±16 stem/ha respectively.

This result is higher than the one found in Mkulazi catchment forest reserves due to the relative low stem density, basal area and few trees with large diameter due to human disturbance, stem density distribution are still on ‘J’ shape, which is common for natural forest with active regeneration and recruitment (Munishi *et al.,* 2011). Based on DBH classes, results indicates that the density of regenerants was 1400 ± 304 stem/ha in Mkulazi catchment forest reserve which are higher in number compared to the trees species found in DBH class of 5-20, 20-50 and very few in number under DBH class >50. This indicate that, there is high number of recruitments in the forest and in the past years there were high harvesting of mature trees with large diameters. This is the reason which justifies the presence of few trees in number with large DBH as shown in Figure 7. Thus, active regeneration and recruitment in Mkulazi catchment forest reserve as portrayed in this study is a good indicator of sustainability of the woodland stock which has chances of ensuring sustainable supply of products and service only if not subjected to further anthropogenic disturbance (Dickinsoni *et al*., 2010; Giliba *et al*., 2011).

5.3 Intensity and Distribution of Human Disturbance

Results for cover classes over an average period of 20 years since 1975 and 1995 as shown in Table 8 indicate that three cover classes CW-Closed woodland, BSL-Bush land and RV-Riverine decreases at the rate of 28301.55 ha (43.07%), 9260.947 ha (14.09 %) and 2674.84ha (4.07) respectively. These were converted to OP- open woodland and BL-Bare land which increased to 22221.16 ha (33.82 %) and 3251.55 (4.95%) respectively. The contributing factors in land cover changes as reported by Nkonoki and Msuya (2014); Ibrahim *et al*. (2015) include illegal logging, overgrazing, camping site, car truck and fire damage. The land cover changes was due to the direct effects of human activities such as habitat destruction land use changes, invasive species and over exploitation as well as indirect effects of human activities such as climate change Howell *et al*. (2002). Monela *et al.* (1998); Hoscilo *et al.* (2015) found that timber harvesting business in the miombo woodland has been encouraged by existence of all-weather roads from the area to other parts of the district and neighboring countries like Uganda.

Therefore, by comparing the rate change between (1975-1995) and (1995-2016) it shows that the bush land and closed woodland were more affected for the last 20 years 1995-2016 compared to other land cover changes probably due to overgrazing and illegal harvesting of timber which were almost observed in each cluster within the forest.

The observation in this study agrees with finding in MCFR that illegal timber harvesting,grazing,camping site and fire (Figure 12 and 13) were the activities which were contributes to decrease in forest cover for the past 41 years in Mkulazi catchment forest reserve.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The major aims of this study were to assess floristic composition, stocking and disturbance in MCFR, based on species richness, diversity, stem density, basal area, volume of the trees, intensity and distribution of disturbance and land cover changes for the past 41 years from 1975-2016. These informations provide a basis for management and conservation strategies of MCFR. This study shows that MCFR has higher species richness and diversity dominated by *Brachystegia boehmii, Combretum molle, Pseudolachnostylis glauca, Xeroderris stuhlmannii, Diplorhynchus condylocarpon* and *Pteleopsis myrtifolia* which generally represenst low land dry miombo woodland forest community type.

The vegetation structure of MCFR is characterized by very low mean tree diameter classes, low basal area and very low stem density of large trees indicating that the forest has been subjected to disturbances caused by human activities. The observed factors that disturbed the vegetation structure of the MCFR have been found to illegal harvesting, overgrazing, footpath, car truck, camping site and fire damage.

MCFR has also undergone notable changes in terms of land use and land cover changes for the period of the last 41 years from 1975/1995 -1995/2016. Whereby closed woodland, bush land and riverine vegetation changed into open woodland and bare land by 44.71%, 37.59% and 1.08% respectively. There has been a substantial change in land use and vegetation cover with almost resultant land degradation of the MCFR area decrease at the rate of 1% /year for closed woodland, 0.1%/year for bush land and

0.01%/year for riverine vegetation which converted to bare land and open woodland area. However, study concludes that there have been significant land cover changes in MCFR. This situation if left unattended would likely lead to reduced wildlife habitat, forest extinction and increased effect of climate change in future necessitating the need for improvement of the overall forest resources by controlling the human activities within the forest reserve.

6.2 Recommendations

i. MCFR has higher species richness and diversity. For sustaible forest management and conservation MCFR should be resurveyed, re-established and remarked with beacons for monitoring purpose. However, further studies should consider the assessment of liana and herbs.

ii. The Government through the Ministry of Natural Resources and Tourism should ensure that MCFR should be the focus for conservation forest management against inappropriate use, illegal logging, overgrazing, camping site, footpath, car truck and fire damage.

iii. Conservation measure like establishment of Joint Forest Management, Preparations of management plans, improving of governance and accountability for intensive management of the forest resources in MCFR should be put in place.

iv. The limited funds due to large size of the forest, this study focused only on assessment of floristic composition, stocking, disturbance and land cover change of MCFR. Therefore it is suggested that, other studies in future should further address the influence of other factors such as socio-economic and environmental.

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APPENDICES

Appendix 1: Checklist of tree and shrub species recorded in MCFR arranged in descending order as per their frequency occurrence

Species/Botanical name	Vernacular/local name	Familly	Habitat/life forms	Frequ ency%	Density (Stem/ha)
Acacia nilotica	Baryomodi	Mimosoideae	T	11.58	17324
Brachystegia boehmii	Mboua	Caesalpinioideae	T	9.55	14282
Pseudolachnostylis glauca	Msolo	Phyllanthaceae	T	7.47	11169
Albizia petersiana	Mkenge	Mimosoideae	T	6.04	9028
Dalbergia menaloxylon	Mpingo	Papilionoideae	T	5.37	8028
Annona senegalensis	mnyanza	Mimosoideae	T	4.92	7352
Bridelia cathartica	Mkwambe maji	Phyllanthaceae	T	4.88	7296
Dichrostachys cinerea	Girwang	Leguminosae	T	4.68	7000
Margaritaria discoidea	Mkwambe	Phyllanthaceae	T	4.68	7000
Pteleopsis myrtifolia	Mgovu	Combretaceae	T	4.52	6761
Burkea africana	Msekeseke	Caesalpinioideae	T	4.12	6155
Turraea floribunda	Ngingalaula	Meliaceae	T	4.04	6042
Combretum molle	Mlama	Combretaceae	T	4.00	5986
Lonchocarpus bussei	mfumbili	Papilionoideae	T	3.49	5225
Diplorhynchus condylocarpon	Mtogo	Apocynoideae	T	3.40	5085
Pterocarpus angolensis	Mninga	Papilionoideae	T	2.82	4225
Antidesma venosum	Msekela	Phyllanthaceae	T	2.67	4000
Suregada zanzibariensis	Kidimdim	Euphorbiaceae	S	2.67	4000
Maerua sp	lwito	Capparaceae	T	2.01	3000
Mystroxylon aethiopicum	Mlimbalimba	Celastraceae	S	1.40	2099
Vepris nobilis	Mndizi	Rutaceae	S	1.34	2000
Acacia robusta	Mkongowe	Mimosoideae	T	1.03	1535
Ochna macrocalyx	Mvumba	Ochnaceae	T	0.76	1141
Xeroderris stuhlmannii	Mnyenye	Papilionoideae	T	0.42	634
Combretum zeyheri	Mlama	Combretaceae	T	0.20	296

Species/Botanical name	Vernacular/local name	Familly	Habitat/life forms	Frequ ency%	Density (Stem/ha)
Boscia salicifolia	Mguluka	Capparaceae	T	0.19	282
Acacia nigrescens	Msengele	Mimosoideae	T	0.16	239
Sclerocarya birrea	Mngongo	Anacardiaceae	T	0.16	239
Combretum collinum	Mkolowanje	Combretaceae	T	0.14	211
Dalbergia arbutifolia	Mpingo	Papilionoideae	T	0.13	197
Diospyros mollis	Mkulwi	Ebenaceae	S	0.12	183
Spirostachys Africana	Mcharaka	Euphorbiaceae	S	0.10	155
Commiphora Africana	Mbavi	Burseraceae	S	0.09	141
Terminalia sericea	Mnyenze	Combretaceae	T	0.08	127
Vitex keniensis Turrill	Mufuu	Lamiaceae	S	0.08	113
Erythrophleum africanum	Mvumba	Caesalpinioideae	T	0.06	85
Monotes africanus	Mguguti	Dipterocarpaceae	T	0.06	85
Diospyros kirkii	Mkwilu	Ebenaceae	S	0.05	70
Tarenna nigrescens	Mkarati	Rubiaceae	T	0.05	70
Terminalia brownie	Mngovu	Combretaceae	T	0.05	70
Zanha africana	Mdaula	Sapindaceae	T	0.05	70
Albizia gummifera	Mkenge maji	Leguminosae	T	0.04	56
Albizia harveyi	Msirimisi	Mimosoideae	T	0.04	56
Elaeodendron buchananii	mjamofu	Celastraceae	S	0.04	56
Julbernardia globiflora	Mhangala	Caesalpinioideae	T	0.04	56
Swartzia madagascariensis	Msekeseke	Leguminosae	T	0.04	56
Tamarindus indica	Mkwaju	Leguminosae	T	0.03	42
Afzelia quanzensis	Mkongo	Caesalpinioideae	T	0.02	28
Cassia sp.	Mkunde pori	Leguminosae	T	0.02	28
Combretum padoides	Mkotama	Combretaceae	T	0.02	28
Grewia similis	Mkole	Malvaceae	T	0.02	28
Manilkara sulcata	Mgama	Sapotaceae	T	0.02	28
Vangueria madagascariensis	Msada	Rubiaceae	S	0.02	28
Zanthoxylum chalybeum	Mhunungu	Rutaceae	S	0.02	28
Gardenia ternifolia	Mlemandembo	Rubiaceae	S	0.01	14
Lannea schweinfurthii	Mhongwe	Anacardiaceae	T	0.01	14
Piliostigma thonningii	Mpikito	Caesalpinioideae	T	0.01	14

Appendix 2: Checklist of tree and shrubs species recorded in MCFR arranged in descending order as per their Importance Value Index (IVI)

Botanical Name	Local _Name	Family	Frequ Ency%	Vol/Ha	Basal Area m²/ha	Density stem/ha	IVI
Brachystegia boehmii	Mboua	Caesalpinioideae	2.1	2043.9	165.89	2282	20.59
Combretum molle	Mlama	Combretaceae	0.8	702.5	75.07	1986	10.82
Pseudolachnostylis glauca	Msolo	Phyllanthaceae	2.3	944.8	81.77	1169	10.02
Xeroderris stuhlmannii	Mnyenye	Papilionoideae	1.5	786.6	61.07	634	7.20
Diplorhynchus condylocarpon	Mtogo	Apocynoideae	2.1	297.3	33.03	1085	5.23
Pteleopsis myrtifolia	Mgovu	Combretaceae	1.3	396.4	33.73	761	4.84
Sclerocarya birrea	Mngongo	Anacardiaceae	4.1	601.3	44.49	239	4.81
Acacia robusta	Mkongowe	Mimosoideae	0.8	286.3	25.42	535	3.51
Julbernardia globiflora	Mhangala	Caesalpinioideae	2.8	351.5	23.48	56	2.49
Manilkara sulcata	Mgama	Sapotaceae	1.8	280.4	18.30	28	1.93
Pterocarpus angolensis	Mninga	Papilionoideae	0.8	175.1	14.88	225	1.87
Annona senegalensis	Mnyanza	Mimosoideae	1.8	110.4	11.27	352	1.78
Diospyros mollis	Mkulwi	Ebenaceae	4.6	166.9	15.10	155	1.67
Acacia nigrescens	Msengele	Mimosoideae	0.5	126.0	12.24	239	1.60
Acacia nilotica	Baryomodi	Mimosoideae	4.6	76.9	9.10	324	1.48
Dalbergia melanoxylon	Mpingo	Papilionoideae	3.1	128.4	11.45	197	1.47
Combretum zeyheri	Mlama Mweupe	Combretaceae	0.8	80.8	9.31	296	1.44
Boscia salicifolia	Mguluka	Capparaceae	3.1	82.4	9.25	282	1.41
Bridelia cathartica	Mkwambe	Phyllanthaceae	1.8	57.2	6.53	296	1.23
Burkea africana	Msekeseke	Caesalpinioideae	1.8	92.1	8.62	155	1.11
Lonchocarpus bussei	Mfumbili	Papilionoideae	1.5	60.3	6.17	225	1.05
Erythrophleum africanum	Mvumba	Caesalpinioideae	1	116.2	8.71	85	1.03
Ochna macrocalyx	Mvumba	Ochnaceae	0.3	75.0	6.56	141	0.92
Combretum collinum	Matoti	Combretaceae	1.8	38.4	4.29	211	0.85
Zanha africana	Mdaula	Sapindaceae	0.5	86.3	6.71	70	0.79
Terminalia sericea	Mnyenze	Combretaceae	0.5	56.5	5.26	127	0.75
Spirostachys Africana	Mcharaka	Euphorbiaceae	1.8	36.6	3.67	155	0.68
Tarenna nigrescens	Mkarati	Rubiaceae	2.1	59.8	5.32	70	0.63
Albizia gummifera	Mkenge maji	Leguminosae	1.8	67.5	5.11	56	0.62
Diospyros kirkii	mkulwi	Ebenaceae	2.8	54.0	5.13	70	0.60
Elaeodendron buchananii	Mjamofu	Celastraceae	2.8	51.9	4.84	56	0.55

Botanical Name	Local _Name	Family	Frequ Ency%	Vol/Ha	Basal Area m²/ha	Density stem/ha	IVI
Swartzia madagascariensis	Msekeseke	Leguminosae	0.8	38.9	3.60	56	0.44
Tamarindus indica	Mkwaju	Leguminosae	3.1	51.5	3.84	28	0.43
Monotes africanus	Mguguti	Dipterocarpaceae	3.1	20.5	2.58	85	0.40
Vitex keniensis Turrill	Mufuu	Lamiaceae	2.3	11.3	1.55	113	0.39
Lannea schweinfurthii	Mhongwe	Anacardiaceae	1.5	39.1	3.32	14	0.33
Afzelia quanzensis	Mkongo	Caesalpinioideae	3.3	31.6	3.08	28	0.32
Mystroxylon aethiopicum	Mlimbalimba	Celastraceae	2.8	2.9	0.46	99	0.27
Cassia sp.	Mkunde pori	Leguminosae	1	18.2	1.84	28	0.22
Terminalia brownie	Mngovu	Combretaceae	1	1.1	0.19	70	0.19
Zanthoxylum chalybeum	Mhunungu	Rutaceae	2.6	10.5	1.35	28	0.17
Tamarindus indica	Mkwaju	Leguminosae	2.1	15.8	1.33	14	0.15
Turraea floribunda	Ngingalaula	Meliaceae	1.3	2.4	0.36	42	0.13
Dalbergia arbitufolia	Mpingo	Papilionoideae	3.6	4.3	0.58	28	0.11
Diospyros sp.	Mkoko	Ebenaceae	0.3	4.6	0.55	28	0.11
Grewia similis	Mkole	Malvaceae	0.5	3.1	0.38	28	0.10
Combretum padoides	*Mkotama*	Combretaceae	2.6	1.9	0.23	28	0.09
Albizia petersiana	Mkenge	Mimosoideae	1.3	1.2	0.18	28	0.08
Vangueria madagascariensis	Msaada	Rubiaceae	1.5	0.9	0.16	28	0.08
Gardenia ternifolia	Mlemandembo	Rubiaceae	1	0.8	0.10	14	0.04
Piliostigma thonningii	Mpikito	Caesalpinioideae	1.8	0.6	0.10	14	0.04

Appendix 3: Checklist of tree species recorded in MCFR (DBH>5CM) arranged in descending order as per their frequency of occurrences

Botanical Name	Local_Name	Family	Frequ Ency%	Vol/Ha	Basal Area M/	Density Stem/Ha	Ivi
Brachystegia boehmii	Mboua	Caesalpinioideae	2.1	2043.9	165.89	2282	20.59
Combretum molle	Mlama	Combretaceae	0.8	702.5	75.07	1986	10.82
Pseudolachnostylis glauca	Msolo	Phyllanthaceae	2.3	944.8	81.77	1169	10.02
Diplorhynchus condylocarpon	Mtogo	Apocynoideae	2.1	297.3	33.03	1085	5.23
Pteleopsis myrtifolia	mgovu	Combretaceae	1.3	396.4	33.73	761	4.84
Xeroderris stuhlmannii	Mnyenye	Papilionoideae	1.5	786.6	61.07	634	7.20
Acacia robusta	Mkougoe	Mimosoideae	0.8	286.3	25.42	535	3.51
Annona senegalensis	mnyanza	Mimosoideae	1.8	110.4	11.27	352	1.78
Acacia nilotica	Baryomodi	Mimosoideae	4.6	76.9	9.10	324	1.48
Combretum zeyheri	Mlama mweupe	Combretaceae	0.8	80.8	9.31	296	1.44
Bridelia cathartica	Mkwambe maji	Phyllanthaceae	1.8	57.2	6.53	296	1.23
Boscia salicifolia	Mguluka	Capparaceae	3.1	82.4	9.25	282	1.41
Sclerocarya birrea	Mngougo	Anacardiaceae	4.1	601.3	44.49	239	4.81
Acacia nigrescens	Msengele	Mimosoideae	0.5	126.0	12.24	239	1.60
Pterocarpus angolensis	Mninga	Papilionoideae	0.8	175.1	14.88	225	1.87
Lonchocarpus bussei	Mfumbili	Papilionoideae	1.5	60.3	6.17	225	1.05
Combretum collinum	Matoti	Combretaceae	1.7	38.4	4.29	211	0.85
Dalbergia melanoxylon	Mpingo	Papilionoideae	3.1	128.4	11.45	197	1.47
Diospyros mollis	Mkulwi	Ebenaceae	4.6	166.9	15.10	155	1.67
Burkea africana	Msekeseke	Caesalpinioideae	1.8	92.1	8.62	155	1.11
Spirostachys africana	Mcharaka	Euphorbiaceae	1.8	36.6	3.67	155	0.68
Ochna macrocalyx	Mvumba	Ochnaceae	0.3	75.0	6.56	141	0.92
Commiphora africana	Mbamvi	Burseraceae	1.3	12.3	1.68	141	0.47
Terminalia sericea	Mnyenze	Combretaceae	0.5	56.5	5.26	127	0.75
Vitex keniensis Turrill	Mufuu	Lamiaceae	2.3	11.3	1.55	113	0.39
Mystroxylon aethiopicum	Mlimbalimba	Celastraceae	2.8	2.9	0.46	99	0.27

Botanical Name	Local_Name	Family	Frequ Ency%	Vol/Ha	Basal Area M/	Density Stem/Ha	Ivi
Erythrophleum africanum	Mvumba	Caesalpinioideae	1	116.2	8.71	85	1.03
Monotes africanus	Mguguti	Dipterocarpaceae	3.1	20.5	2.58	85	0.40
Zanha africana	Mdaula	Sapindaceae	0.5	86.3	6.71	70	0.79
Tarenna nigrescens	Mkarati	Rubiaceae	2.1	59.8	5.32	70	0.63
Diospyros kirkii	mkulwi	Ebenaceae	2.8	54.0	5.13	70	0.60
Terminalia brownii	Mngovu	Combretaceae	1	1.1	0.19	70	0.19
Julbernardia globiflora	Mhangala	Caesalpinioideae	2.8	351.5	23.48	56	2.49
Albizia gummifera	Mkenge maji	Leguminosae	1.8	67.5	5.11	56	0.62
Elaeodendron buchananii	Mjamofu	Celastraceae	2.8	51.9	4.84	56	0.55
Albizia harveyi	Msirimisi	Mimosoideae	2.1	44.5	4.02	56	0.48
Swartzia madagascariensis	Msekeseke	Leguminosae	0.8	38.9	3.60	56	0.44
Turraea floribunda	Ngingalaula	Meliaceae	1.3	2.4	0.36	42	0.13
Manilkara sulcata	Mgama	Sapotaceae	1.8	280.4	18.30	28	1.93
Tamarindus indica	Mkwaju	Leguminosae	3.1	51.5	3.84	28	0.43
Afzelia quanzensis	Mkongo	Caesalpinioideae	3.3	31.6	3.08	28	0.32
Cassia sp.	Mkunde pori	Leguminosae	1	18.2	1.84	28	0.22
Zanthoxylum chalybeum	Mhunungu	Rutaceae	2.6	10.5	1.35	28	0.17
Dalbergia nitidula	Mpingo	Papilionoideae	3.6	4.3	0.58	28	0.11
Diospyros sp.	Mkoko	Ebenaceae	0.3	4.6	0.55	28	0.11
Grewia similis	Mkole	Malvaceae	0.5	3.1	0.38	28	0.10
Combretum padoides	*Mkotama*	Combretaceae	2.6	1.9	0.23	28	0.09
Albizia petersiana	Mkenge	Mimosoideae	1.3	1.2	0.18	28	0.08
Vangueria madagascariensis	Msaada	Rubiaceae	1.5	0.9	0.16	28	0.08
Lannea schweinfurthii	Mhongwe	Anacardiaceae	1.5	39.1	3.32	14	0.33
Tamarindus indica	Mkwaju	Leguminosae	2.1	15.8	1.33	14	0.15
Gardenia ternifolia Schumac	Mlemandembo	Rubiaceae	1	0.8	0.10	14	0.04
Piliostigma thonningii	Mpikito	Caesalpinioideae	1.8	0.6	0.10	14	0.04

Appendix 4: Checklist of all tree species recorded by percentage in MCFR arranged in descending order as per their frequency of occurrences

Species/botanical name	Localname	Family	% Frequency	Dbh (cm)	Ht(m)	Vol	Vol/Ha	G/ha	Stems/ha	IVI
Acacia nilotica	Baryomodi	Mimosoideae	4.62	28.5	8	0.462	76.94	9.10	324	1.48
Diospyros mollis	Mkulwi	Ebenaceae	4.62	29	17	5.044	166.88	15.10	155	1.67
Sclerocarya birrea	Mngougo	Anacardiaceae	4.10	24.5	13	0.442	601.33	44.49	239	4.81
Dalbergia melanoxylon	Mpingo	Papilionoideae	3.59	16	11	0.162	4.32	0.58	28	0.11
Afzelia quanzensis	Mkongo	Caesalpinioideae	3.33	8.1	8	0.033	31.62	3.08	28	0.32
Boscia salicifolia	Mguluka	Capparaceae	3.08	10.5	12	0.069	82.39	9.25	282	1.41
Dalbergia arbitufolia	Mpingo	Papilionoideae	3.08	36.5	13	1.036	128.42	11.45	197	1.47
Monotes africanus	Mguguti	Dipterocarpaceae	3.08	38.5	9	0.939	20.47	2.58	85	0.40
Tamarindus indica	Mkwaju	Leguminosae	3.08	47.6	23	2.534	51.48	3.84	28	0.43
Mystroxylon aethiopicum	Mlimbalimba	Celastraceae	2.82	7	8	0.023	2.91	0.46	99	0.27
Diospyros kirkii	Mkulwi	Ebenaceae	2.82	30.2	19	0.860	53.97	5.13	70	0.60
Elaeodendron buchananii	Mjamofu	Celastraceae	2.82	49.7	18	2.413	51.91	4.84	56	0.55
Julbernardia globiflora	Mhangala	Caesalpinioideae	2.82	132.5	23	22.499	351.54	23.48	56	2.49
Combretum padoides	Mkotama	Combretaceae	2.56	8.9	10	0.044	1.87	0.23	28	10.09
Zanthoxylum chalybeum	Mhunungu	Rutaceae	2.56	22.6	10	0.320	10.52	1.35	28	0.17
Pseudolachnostylis glauca	Msolo	Phyllanthaceae	2.31	21.3	13	0.328	944.78	81.77	1169	10.02
Vitex keniensis Turrill	Mufuu	Lamiaceae	2.31	14.5	11	0.131	11.30	1.55	113	0.39
Brachystegia boehmii	Mboua	Caesalpinioideae	2.05	10.7	7	0.053	2043.94	165.89	2282	20.59
Diplorhynchus condylocarpon	Mtogo	Apocynoideae	2.05	32.1	10	0.677	297.33	33.03	1085	5.23
Tarenna nigrescens	Mkarati	Rubiaceae	2.05	20.8	15	0.339	59.78	5.32	70	0.63
Albizia harveyi	Msirimisi	Mimosoideae	2.05	27.3	13	0.557	44.47	4.02	56	0.48
Tamarindus indica	Mkwaju	Leguminosae	2.05	34.7	18	1.121	15.79	1.33	14	10.40
Annona senegalensis	mnyanza	Mimosoideae	1.79	54.2	17	2.809	110.43	11.27	352	1.78
Bridelia cathartica	Mkwambe maji	Phyllanthaceae	1.79	18.7	7	0.174	57.15	6.53	296	1.23
Combretum collinum	Mlama	Combretaceae	1.79	22.6	13	0.372	38.35	4.29	211	0.85
Burkea africana	Msekeseke	Caesalpinioideae	1.79	20.2	12	0.280	92.09	8.62	155	1.11
Spirostachys africana	Mcharaka	Euphorbiaceae	1.79	8.2	8	0.034	36.58	3.67	155	0.68
Albizia gummifera	Mkenge maji	Leguminosae	1.79	56.7	24	3.771	67.47	5.11	56	0.62
Manilkara sulcata	Mgama	Sapotaceae	1.79	89.5	21	9.246	280.42	18.30	28	108.96

Species/botanical name	Localname	Family	% Frequ ency	Dbh (cm)	Ht(m)	Vol	Vol/Ha	G/ha	Stems/ha	IVI
Piliostigma thonningii	Mpikito	Caesalpinioideae	1.79	9.3	9	0.045	0.64	0.10	14	4.94
Xeroderris stuhlmannii	Mnyenye	Papilionoideae	1.54	31.7	13	0.767	786.58	61.07	634	7.20
Lonchocarpus bussei	Mfumbili	Papilionoideae	1.54	8.1	11	0.038	60.35	6.17	225	1.05
Vangueria madagascariensis	Msaada	Rubiaceae	1.54	9.2	7	0.038	0.92	0.16	28	9.75
Lannea schweinfurthii	Mhongwe	Anacardiaceae	1.54	54.8	16	2.777	39.11	3.32	14	18.84
Pteleopsis myrtifolia	Mgovu	Combretaceae	1.28	5.3	5	0.010	396.39	33.73	761	4.84
Commiphora africana	Mbamvi	Burseraceae	1.28	8.7	6	0.031	12.33	1.68	141	0.47
Turraea floribunda	Ngingalaula	Meliaceae	1.28	11.6	7	0.063	2.38	0.36	42	0.13
Albizia petersiana	Mkenge	Mimosoideae	1.28	9.1	8	0.043	1.15	0.18	28	9.83
Erythrophleum africanum	Mvumba	Caesalpinioideae	1.03	18.8	9	0.204	116.16	8.71	85	1.03
Terminalia brownie	Mngovu	Combretaceae	1.03	5.8	7	0.014	1.12	0.19	70	23.91
Cassia sp.	Mkunde pori	Leguminosae	1.03	14.6	8	0.111	18.24	1.84	28	16.08
Gardenia ternifolia	Mlemandembo	Rubiaceae	1.03	9.7	12	0.059	0.82	0.10	14	5.00
Combretum molle	Mlama	Combretaceae	0.77	19.1	9	0.211	702.53	75.07	1986	10.82
Acacia robusta	Mkongowe	Mimosoideae	0.77	31.6	14	0.795	286.26	25.42	535	3.51
Combretum zeyheri	Mlama mweupe	Combretaceae	0.77	11.7	10	0.079	80.77	9.31	296	1.44
Pterocarpus angolensis	Mninga	Papilionoideae	0.77	27.8	14	0.605	175.12	14.88	225	1.87
Swartzia madagascariensis	Msekeseke	Leguminosae	0.77	7.2	7	0.023	38.93	3.60	56	0.44
Acacia nigrescens	Msengele	Mimosoideae	0.51	18.2	10	0.202	125.96	12.24	239	1.60
Terminalia sericea	Mnyenze	Combretaceae	0.51	17	11	0.184	56.51	5.26	127	0.75
Zanha africana	Mdaula	Sapindaceae	0.51	17.2	7	0.146	86.35	6.71	70	0.79
Grewia similis	Mkole	Malvaceae	0.51	9.3	7	0.039	3.14	0.38	28	0.10
Ochna macrocalyx	Mvumba	Ochnaceae	0.26	29.5	9	0.532	75.00	6.56	141	0.92
Diospyros sp.	Mkoko	Ebenaceae	0.26	20.5	12	0.293	4.64	0.55	28	11.12

Appendix 5: Checklist of tree and shrubs species recorded in MCFR arranged in descending order as per their basal area G (m^2/ha)

Botanical Name	Local Name	Family	Frequency%	Vol/Ha	Basal Area m^2/ha	Density stem/ha	IVI
Brachystegia boehmii	Mboua	Caesalpinioideae	2.1	2043.9	165.89	2282	20.59
Pseudolachnostylis glauca	Msolo	Phyllanthaceae	2.3	944.8	81.77	1169	10.02
Combretum molle	Mlama	Combretaceae	0.8	702.5	75.07	1986	10.82
Xeroderris stuhlmannii	Mnyenye	Papilionoideae	1.5	786.6	61.07	634	7.20
Sclerocarya birrea	Mngougo	Anacardiaceae	4.1	601.3	44.49	239	4.81
Pteleopsis myrtifolia	Mgovu	Combretaceae	1.3	396.4	33.73	761	4.84
Diplorhynchus condylocarpon	Mtogo	Apocynoideae	2.1	297.3	33.03	1085	5.23
Acacia robusta	Mkongowe	Mimosoideae	0.8	286.3	25.42	535	3.51
Julbernardia globiflora	Mhangala	Caesalpinioideae	2.8	351.5	23.48	56	2.49
Manilkara sulcata	Mgama	Sapotaceae	1.8	280.4	18.30	28	1.93
Diospyros mollis	Mkulwi	Ebenaceae	4.6	166.9	15.10	155	1.67
Pterocarpus angolensis	Mninga	Papilionoideae	0.8	175.1	14.88	225	1.87
Acacia nigrescens	Msengele	Mimosoideae	0.5	126.0	12.24	239	1.60
Dalbergia melanoxylon	Mpingo	Papilionoideae	3.1	128.4	11.45	197	1.47
Annona senegalensis	mnyanza	Mimosoideae	1.8	110.4	11.27	352	1.78
Combretum zeyheri	Mlama mweupe	Combretaceae	0.8	80.8	9.31	296	1.44
Boscia salicifolia	Mguluka	Capparaceae	3.1	82.4	9.25	282	1.41
Acacia nilotica	Baryomodi	Mimosoideae	4.6	76.9	9.10	324	1.48
Erythrophleum africanum	Mvumba	Caesalpinioideae	1	116.2	8.71	85	1.03
Burkea africana	Msekeseke	Caesalpinioideae	1.8	92.1	8.62	155	1.11
Zanha africana	Mdaula	Sapindaceae	0.5	86.3	6.71	70	0.79
Ochna macrocalyx	Mvumba	Ochnaceae	0.3	75.0	6.56	141	0.92
Bridelia cathartica	Mkwambe Maji	Phyllanthaceae	1.8	57.2	6.53	296	1.23
Lonchocarpus bussei	Mfumbili	Papilionoideae	1.5	60.3	6.17	225	1.05
Tarenna nigrescens	Mkarati	Rubiaceae	2.1	59.8	5.32	70	0.63
Terminalia sericea	Mnyenze	Combretaceae	0.5	56.5	5.26	127	0.75
Diospyros kirkii	Mkulwi	Ebenaceae	2.8	54.0	5.13	70	0.60

Botanical Name	Local Name	Family	Frequency%	Vol/Ha	Basal Area m²/ha	Density stem/ha	IVI
Albizia gummifera	Mkenge maji	Leguminosae	1.8	67.5	5.11	56	0.62
Elaeodendron buchananii	Mjamofu	Celastraceae	2.8	51.9	4.84	56	0.55
Combretum collinum	Mlama	Combretaceae	1.8	38.4	4.29	211	0.85
Albizia harveyi	Msirimisi	Mimosoideae	2.1	44.5	4.02	56	0.48
Tamarindus indica	Mkwaju	Leguminosae	3.1	51.5	3.84	28	0.43
Spirostachys Africana	Mcharaka	Euphorbiaceae	1.8	36.6	3.67	155	0.68
Swartzia madagascariensis	Msekeseke	Leguminosae	0.8	38.9	3.60	56	0.44
Lannea schweinfurthii	Mhongwe	Anacardiaceae	1.5	39.1	3.32	14	0.33
Afzelia quanzensis	Mkongo	Caesalpinioideae	3.3	31.6	3.08	28	0.32
Monotes africanus	Mguguti	Dipterocarpaceae	3.1	20.5	2.58	85	0.40
Cassia sp.	Mkunde pori	Leguminosae	1	18.2	1.84	28	0.22
Commiphora Africana	Mbamvi	Burseraceae	1.3	12.3	1.68	141	0.47
Vitex keniensis Turrill	Mufuu	Lamiaceae	2.3	11.3	1.55	113	0.39
Zanthoxylum chalybeum	Mhunungu	Rutaceae	2.6	10.5	1.35	28	0.17
Tamarindus indica	Mkwaju	Leguminosae	2.1	15.8	1.33	14	0.15
Dalbergia arbitufolia	Mpingo	Papilionoideae	3.6	4.3	0.58	28	0.11
Diospyros sp.	Mkoko	Ebenaceae	0.3	4.6	0.55	28	0.11
Mystroxylon aethiopicum	Mlimbalimba	Celastraceae	2.8	2.9	0.46	99	0.27
Grewia similis	Mkole	Malvaceae	0.5	3.1	0.38	28	0.10
Turraea floribunda	Ngingalaula	Meliaceae	1.3	2.4	0.36	42	0.13
Combretum padoides	Mkotama	Combretaceae	2.6	1.9	0.23	28	0.09
Terminalia brownie	Mngovu	Combretaceae	1	1.1	0.19	70	0.19
Albizia petersiana	Mkenge	Mimosoideae	1.3	1.2	0.18	28	0.08
Vangueria madagascariensis	Msaada	Rubiaceae	1.5	0.9	0.16	28	0.08
Gardenia ternifolia	Mlemandembo	Rubiaceae	1	0.8	0.10	14	0.04
Piliostigma thonningii	Mpikito	Caesalpinioideae	1.8	0.6	0.10	14	0.04

Appendix 6: Checklist of tree and shrubs species recorded in MCFR arranged in descending order as per their volume (m^3/ha)

Botanical Name	Local_Name	Family	Frequency%	Vol/Ha	Basal Aream²/ha	Density stem/ha	IVI
Brachystegia boehmii	Mboua	Caesalpinioideae	2.1	2043.9	165.89	2282	20.59
Pseudolachnostylis glauca	Msolo	Phyllanthaceae	2.3	944.8	81.77	1169	10.02
Xeroderris stuhlmannii	Mnyenye	Papilionoideae	1.5	786.6	61.07	634	7.20
Combretum molle	Mlama	Combretaceae	0.8	702.5	75.07	1986	10.82
Sclerocarya birrea	Mngongo	Anacardiaceae	4.1	601.3	44.49	239	4.81
Pteleopsis myrtifolia	Mgovu	Combretaceae	1.3	396.4	33.73	761	4.84
Julbernardia globiflora	Mhangala	Caesalpinioideae	2.8	351.5	23.48	56	2.49
Diplorhynchus condylocarpon	Mtogo	Apocynoideae	2.1	297.3	33.03	1085	5.23
Acacia robusta	Mkongowe	Mimosoideae	0.8	286.3	25.42	535	3.51
Manilkara sulcata	Mgama	Sapotaceae	1.8	280.4	18.30	28	1.93
Pterocarpus angolensis	Mninga	Papilionoideae	0.8	175.1	14.88	225	1.87
Diospyros mollis	Mkulwi	Ebenaceae	4.6	166.9	15.10	155	1.67
Dalbergia melanoxylon	Mpingo	Papilionoideae	3.1	128.4	11.45	197	1.47
Acacia nigrescens	Msengele	Mimosoideae	0.5	126.0	12.24	239	1.60
Erythrophleum africanum	Mvumba	Caesalpinioideae	1	116.2	8.71	85	1.03
Annona senegalensis	Mnyanza	Mimosoideae	1.8	110.4	11.27	352	1.78
Burkea africana	Msekeseke	Caesalpinioideae	1.8	92.1	8.62	155	1.11
Zanha africana	Mdaula	Sapindaceae	0.5	86.3	6.71	70	0.79
Boscia salicifolia	Mguluka	Capparaceae	3.1	82.4	9.25	282	1.41
Combretum zeyheri	Mlama mweupe	Combretaceae	0.8	80.8	9.31	296	1.44
Acacia nilotica	Baryomodi	Mimosoideae	4.6	76.9	9.10	324	1.48
Ochna macrocalyx	Mvumba	Ochnaceae	0.3	75.0	6.56	141	0.92
Albizia gummifera	Mkenge maji	Leguminosae	1.8	67.5	5.11	56	0.62
Lonchocarpus bussei	Mfumbili	Papilionoideae	1.5	60.3	6.17	225	1.05
Tarenna nigrescens	Mkarati	Rubiaceae	2.1	59.8	5.32	70	0.63

Botanical Name	Local_Name	Family	Frequency%	Vol/Ha	Basal Area m²/ha	Density stem/ha	IVI
Terminalia sericea	Mnyenze	Combretaceae	0.5	56.5	5.26	127	0.75
Diospyros kirkii	Mkulwi	Ebenaceae	2.8	54.0	5.13	70	0.60
Elaeodendron buchananii	Mjamofu	Celastraceae	2.8	51.9	4.84	56	0.55
Tamarindus indica	Mkwaju	Leguminosae	3.1	51.5	3.84	28	0.43
Albizia harveyi	Msirimisi	Mimosoideae	2.1	44.5	4.02	56	0.48
Lannea schweinfurthii	Mhongwe	Anacardiaceae	1.5	39.1	3.32	14	0.33
Swartzia madagascariensis	Msekeseke	Leguminosae	0.8	38.9	3.60	56	0.44
Combretum collinum	Mlama	Combretaceae	1.8	38.4	4.29	211	0.85
Spirostachys Africana	Mcharaka	Euphorbiaceae	1.8	36.6	3.67	155	0.68
Afzelia quanzensis	Mkongo	Caesalpinioideae	3.3	31.6	3.08	28	0.32
Monotes africanus	Mguguti	Dipterocarpaceae	3.1	20.5	2.58	85	0.40
Cassia sp.	Mkunde pori	Leguminosae	1	18.2	1.84	28	0.22
Tamarindus indica	Mkwaju	Leguminosae	2.1	15.8	1.33	14	0.15
Commiphora Africana	Mbamvi	Burseraceae	1.3	12.3	1.68	141	0.47
Vitex keniensis Turrill	Mufuu	Lamiaceae	2.3	11.3	1.55	113	0.39
Zanthoxylum chalybeum	Mhunungu	Rutaceae	2.6	10.5	1.35	28	0.17
Diospyros sp.	Mkoko	Ebenaceae	0.3	4.6	0.55	28	0.11
Dalbergia arbitufolia	Mpingo	Papilionoideae	3.6	4.3	0.58	28	0.11
Grewia similis	Mkole	Malvaceae	0.5	3.1	0.38	28	0.10
Mystroxylon aethiopicum	Mlimbalimba	Celastraceae	2.8	2.9	0.46	99	0.27
Turraea floribunda	Ngingalaula	Meliaceae	1.3	2.4	0.36	42	0.13
Combretum padoides	Mkotama	Combretaceae	2.6	1.9	0.23	28	0.09
Albizia petersiana	Mkenge	Mimosoideae	1.3	1.2	0.18	28	0.08
Terminalia brownie	Mngovu	Combretaceae	1	1.1	0.19	70	0.19
Vangueria madagascariensis	Msaada	Rubiaceae	1.5	0.9	0.16	28	0.08
Gardenia ternifolia	Mlemandembo	Rubiaceae	1	0.8	0.10	14	0.04
Piliostigma thonningii	Mpikito	Caesalpinioideae	1.8	0.6	0.10	14	0.04

Appendix 7: Stump volume for ALL Species and its percentages

Species_Name	Family	Volume (M^3/Ha)	% Volume
Afzelia quanzensis	*Caesalpinioideae*	417.53	17.0
Burkea Africana	*Caesalpinioideae*	414.94	16.9
Pterocarpus angolensis	*Papilionoideae*	359.50	14.7
Julbernardia globiflora	*Caesalpinioideae*	342.62	14.0
Burkea africana New cut	*Caesalpinioideae*	198.22	8.1
Brachystegia spiciformis	*Caesalpinioideae*	193.10	7.9
Boscia salicifolia Oliv	*Capparaceae*	183.25	7.5
Combretum molle	*Combretaceae*	73.49	3.0
Acacia robusta	*Mimosoideae*	67.93	2.8
Xeroderris stuhlmannii	*Papilionoideae*	52.35	2.1
Pterocarpus angolensisNew cut	*Papilionoideae*	45.32	1.8
Brachystegia boehmii	*Caesalpinioideae*	43.22	1.8
Erythrophleum africanum	*Caesalpinioideae*	38.44	1.6
Boscia salicifolia Oliv New cut	*Capparaceae*	12.63	0.5
Dalbergia melanoxylon	*Papilionoideae*	7.76	0.3

Appendix 8: Checklist of counts other disturbance recorded in MCFR arranged in descending order within cluster

Types of Disturbance	Number of Events In Cluster	% Types of Disturbance
Grazing	20	43.5
Foot Path	10	21.7
Camping Site	8	17.4
Car Truck	7	15.2
Fire	1	2.2