EFFECTS OF HUMAN ACTIVITIES TO THE COMPOSITION OF WOODY PLANT SPECIES OF NGARAMA SOUTH FOREST RESERVE IN KILWA DISTRICT, TANZANIA

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ABSTRACT

This study assessed the effects of human activities on woody plant species composition of Ngarama South Forest Reserve (NSFR) in Kilwa District, Tanzania. Vegetation survey was carried out in 40 systematically established rectangular sample plots aligned in five transects across the entire forest of 2 070 ha. The information recorded in each plot included: species name, diameter at breast height (DBH), height of few selected woody species with diameter ≥ 5 cm and various indicators of human disturbance. Landsat TM and ETM+ images from year 1995, 2000 and 2011 were used to locate and quantify the land cover change in NSFR for the past 20 years. Inventory data were analysed by using Microsoft Excel and R software while Landsat images were analysed using ILWIS 3.0 academic software. About 126 plant species belonging to 34 families were identified. Out of these, trees contributed 63% (28 families) and shrubs 37% (17 families). Shannon-Wiener Index and Simpson Diversity Indices were 3.95 and 0.03 respectively. Moreover, a mean stem density of 667±19 stems ha^{-1} and basal area of 13.11±0.34 m^2 ha^{-1} were obtained. There were 23 stumps (7±3 stems ha^{-1}) with mean basal area of 0.24±0.09 m^2 ha^{-1} of stumps removed as indication of ongoing anthropogenic disturbances in the forest. Other recorded indicators of disturbances were fire damage (50%), paths/roads (13%), pit sawing (8%), timber/planks/poles collection (8%), cultivation (5%) and forest clearing (8%). Although NSFR has fair species richness and well diversified, there was consistently negative change in forest cover, relatively to low stem density, mean tree height, mean DBH and basal area, an indication of the presence of human disturbance. Conservation measures such as improving

governance and accountability are recommended as regards responsibility for intense management of the forest resources.

DECLARATION

I, ZAWADI JOSEPH JILALA do hereby declare to the Senate of Sokoine University of Agriculture (SUA) that this dissertation is my own original work and has never been submitted for a degree award in any other University.

Zawadi J. Jilala (Candidate)	Date

This declaration witnessed by

Dr. Ezekiel E. Mwakalukwa (Supervisor)	Date
Prof. Shabani A. O. Chamshama **(**Supervisor)	Date

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DEDICATION

To Almighty God and Jesus Christ who gave me life, courage and strength to pursue my studies. In addition, this work is dedicated to my adopted mother Mrs. Fikiri Karume who laid my academic foundation and to my fiancé Miss Rehema Malinda for her prayers, encouragements and support during the whole time of working on this report.

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LIST OF ABBREVIATIONS AND ACRONYMS

AOI	Area of Interest
Cm	Centimeter
DBH	Diameter at Breast Height
DED	District Executive Director
DFO	District Forest Officer
FAO	Food and Agriculture Organisation of the United Nations
GIS	Geographic Information System
GPS	Global Positioning System
Ha	Hectare
ILWIS	Integrated Land and Water Information System
IPPC	International Plant Protection Convention
IVI	Importance Value Index
Km	Kilometer
M	Meter
NSFR	Ngarama South Forest Reserve
NAFORMA	National Forest Resources Monitoring and Assessment
RAS	Regional Administrative Secretary
TAFORI	Tanzania Forest of Research Institute
TFS	Tanzania Forest Services Agency

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Tanzania has about 48.1 million Hectare (ha) of forest area, of which 93 % of this is woodlands and only 7 % are classified as forests (mangroves, coastal forests, humid montane forest and plantations) (NAFORMA, 2015). About 3.5% is coastal forests covering the area of 0 - 150 km along the coastal strip of Indian ocean and 0.3% is mangrove vegetation covering the area along the coast of Indian ocean (FAO, 2007; IPPC, 2011; FAO, 2012). Currently, statistics show that there are at least 70 000 ha of coastal forests in Tanzania found throughout the inland coastal strip from 0 - 150 km from the Indian ocean (Burgess *et al*., 2003). Coastal forests are commonly located 0 - 50 m and 300-500 m altitude bands but other sites are at more than double this upper limit where they start to become transitional with submontane forests (Burgess *et al*., 2003; Sumbi *et al*., 2003; Burgess *et al*., 2011).

More than 66 coastal forests are known to occur in Tanzania along these areas which fall under various forms of protection (Kibet, 2011). Currently there is only one coastal forest found within a national park and 41 forests that are managed by Tanzania Forest Services and Local Government (Burgess and Clarke, 2000; Dickinson *et al*., 2010). Also there are two forests that fall under game reserve and three forests under the private land (Burgess and Muir, 1994). There are 21 forests that have no formal status although some of them their gazettement has commenced through participatory forest management programme but their total numbers are not well known (Howell and Msuya, 2002).

Clarke *et al*., (2011) reported that pressure for fresh farmland together with an ever-increasing demand for charcoal, poles, firewood and uncontrolled bush fire was a threat to the existence of these forests particularly those found in the southeastern Tanzania as well as most of the remaining areas of Eastern Africa coastal forest at large. Consequently, these disturbances have contributed to the loss of species diversity as well as contributing to the emission of greenhouse gases such as carbon dioxide which contribute to global climate imbalance and ultimately climate change over time (Paavola, 2003; Dallu, 2004; Dickinson *et al*., 2010; Godoy *et al*., 2011).

Efforts to conserve these forests has been hampered due to the lack of reliable data of both flora and fauna found in these areas. Most of the biological surveys ever conducted in coastal forests have been highly uneven and selective. For example in Tanzania most of these surveys have been conducted in northern coast of the country with much of the forests found in the south eastern Tanzania remain almost unsurveyed regardless of the available evidence that these areas contain high floristic endemism than any other areas along the coast (Prins and Clarke, 2006). *Erythrina schliebenii* is a good example in demonstrating endemism in coastal forests of Tanzania. Once categorized as extinct in 1998 (Lovett *et al*., 2006), however in 2001 it was rediscovered and in May 2011 it was confirmed to be found in Namatimbili Forest located in Kilwa, Lindi Region in Southern Tanzania (Clarke *et al.*, 2011).

1.2 Problem statement and justification

In Tanzania, the coastal forests are acknowledged to be rich in endemic species and its forest patches are biologically and culturally diverse (Clarke *et al*., 2011; Kibet,

2011; Howell *et al*., 2012). However, their distribution, exact boundaries and forest resources are still poorly documented (Dallu, 2004). Ngarama South Forest Reserve (NSFR) in Lindi Region is one among the 66 coastal forests owned by Central Government of Tanzania (Perkin *et al*., 2008a; Kibet, 2011; Howell *et al*., 2012). There is recognition of anthropogenic pressure on the forest like illegal logging, gypsum mining, charcoal burning, fresh farming due to introduction of simsim crops around the reserved areas (Howell and Msuya, 2002; Prins and Clarke, 2006; Godoy *et al*., 2011). However, little has been done in assessing to what extent do these activities have affected the woody species composition and stocking of this forest, in relation to the delineation and condition of the forest (Burgess *et al.*, 2010; Clarke *et al*., 2011; Hassan *et al*., 2013).

With reference to the areas which had large coastal forest patches in the past like lowland of Matumbi Hills, Rondo Plateau and Makonde Plateau, farming and logging have been the major causes of forest loss in these areas (Perkin *et al*., 2008a). Understanding the current status of woody species composition and the effects of human activities on forest condition, is crucial for management and conservation strategies that aim to preserve the remaining threatened biodiversity which is important to the livelihoods of local peoples living around these forests (Godoy *et al*., 2011). The results from this study provide data, which form a basis for determining suitable conservation strategies and a regular monitoring programme of the forests.

1.3 Research objectives

1.3.1 Main objective

To assess the effects of human activities to the composition and stocking of woody plant species of NSFR in Kilwa District.

1.3.2 Specific objectives

1. To determine species richness and diversity of NSFR.
2. To determine the vegetation structure of NSFR in terms of basal area and stem density.
3. To assess the intensity and distribution of human activities within NSFR.
4. To assess land cover change in NSFR for the past 20 years.

1.3.3 Research questions

i. What is the species richness and diversity of NSFR?
ii. What is the vegetation structure of NSFR in terms of basal area and stem density?
iii. What are the types of human activities and their extent in NSFR?
iv. What has been the land cover change during the past 20 years?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The extent and legal status of coastal forests in Tanzania

The coastal forests of East Africa are among the 34 globally recognized biodiversity hotspots or regional centres of endemism for plants and animals, hosting more than 30 endemic vertebrate species and 1 750 plant species and 27 plant genera that are endemic (Myers *et al*., 2000; Prins and Clarke, 2006; Clarke *et al*., 2011; Howell *et al*., 2012). These forests play an important roles in providing various goods e.g. timber, poles and non-timber forest products such as fruits, nuts, medicinal plants, honey, beeswax and tannins (Hietz *et al*., 2006). They also provide important services including cultural and spiritual values, hydrological control, soil and biodiversity conservation (Prins and Clarke, 2006; Clarke *et al*., 2011).

Most of the coastal forest assessment studies were based on the satellite images while few studies were based on field visits within the forests with the aim of knowing their distribution, location and the extent of coastal forests (Burgess and Clarke, 2000; Dickinson *et al*., 2010; Clarke *et al*., 2011). It is known that, coastal forest in Tanzania cover an area of 700 km^2 followed by Kenya having 660 km^2 (Howell *et al.*, 2012). Making a total of 1 360 km^2 of coastal forests in East Africa which is probably the smallest and highly fragmented than any other major forest type in Africa (Burgess *et al.,* 2003; Dallu, 2004; Dickinson *et al*., 2010; Burgess *et al.,* 2011). But Dickinson *et al*., (2010) reported that the largest coastal forest have 370 km^2 found in Kenya and all other forests have less than 100 km^2. In this group, only 19 sites are greater than 30 km^2 including the poorly known coastal forests of

Mozambique. Most of coastal forest patches are isolated from each other and their isolation varies from less than 1 km to 10 km. The vegetation between forest patches is a mixture of farmland, savannah, woodland and thickets (Burgess and Muir, 1994). These features support the hypothesis that the coastal forests were formally much more extensive (Burgess *et al*., 2003).

It is widely assumed that before the influence of man, coastal forests covered the large part of coastal area of Tanzania even as recently as the 1950s there were large areas of lowland forests in Tanga which were cleared for sisal estate (Dickinson *et al*., 2010). Forests in and around the Pugu Hills near Dar es Salaam were also previously more extensive and have been cleared for agriculture by expanding human populations. Also several reserves in Kisarawe near Dar es Salaam have been degazetted due to human pressure (Godoy *et al*., 2011).

2.2 Species composition and structure of coastal forests in Tanzania

Coastal forest vegetation communities appear to be far more diverse and variable than it has been recognized before. At least 484 different tree species have been recorded as being dominant or common in at least one forest vegetation community type, leading to thousands of potential assemblage permutations (Burgess *et al*., 2003; Dickinson *et al*., 2010). About 48.4% of the 1 038 species recorded from 13 Tanzanian coastal forests were trees, 13.5% were lianas, 13.7% were shrubs, 14.6% were herbs, 3.9% were grasses, 2.3% were sedges, 2.1% were ferns and the remaining 1.1% were epiphytes and parasites (Dallu, 2004; Prins and Clarke, 2006; Dickinson *et al*., 2010). Lianas and climbers may actually be a more important

constituent of these forests, although they are neglected by collectors (Dickinson *et al*., 2010).

2.3 Effects of human activities on vegetation structure

Every forest has its own threats that it faces. Threats 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. The coastal forests of Tanzania are under threat due to the quest for social centre-economic development, especially urbanisation, industrialisation and tourism (Dickinson *et al*., 2010). Logging, mining, hunting and population growth are placing extreme stress on coastal forests and are thereby threatening many species and overall structure of the forest (Prins and Clarke, 2006). Non climatic environmental factors (human disturbance, rocky outcrops and the presence of ground water) appear to be important influences on the structure of coastal forests (Dallu, 2004; Kibet, 2011). However, when two or more of these influences are present in a site, it is not easy to predict the resulting structural physiognomy which may in addition be affected by other unquantified factors (Burgess *et al*., 2003; Dallu, 2004). This shows that the highly heterogeneous nature of coastal forests is a result of the complex interaction between climate, ground water availability, soils, substrate, aspect, disturbance and biogeography influences (Dallu, 2004).

According to Burgess and Clarke (2000), major human disturbance particularly agriculture clearance and logging tend to reduce the basal area and stem density of a forest stand. The two factors appear to have a consistently important influence in

determining the woody species composition of the vegetation and community association of many coastal forests, although their extent to which they influence is still not well known and documented. In general, soils of the Coastal East Africa are poor and cannot support settled agriculture (Howell and Msuya, 2002). This made Tanzania's coastal agriculture take the form of short-term shifting cultivation, concentrating on crops such as cassava, simsim and maize, along with some banana, pawpaw and fruit trees (Dickinson *et al*., 2010). Plantations of coconut, sisal, cloves, rubber and cashew nut also occupy considerable areas of coastal land, replacing lowland coastal forest and other natural habitats (Burgess *et al*., 2003). Degradation and loss of coastal forests and associated habitats and the species that they support is a result of a wide range of natural and man-made causes interacting at different levels and intensities in Tanzanian coastal forest ecosystems (Dallu, 2004; Clarke *et al*., 2011).

2.4 Loss of forest cover

The average loss of forest cover in the coastal forests of Tanzania during the 1990s was relatively high (1.0% $year^{-1}$) (Godoy *et al*., 2011). This compared unfavourably with the average rate for the African continent (0.2 % $year^{-1}$), and several African countries that range from 0.2% $year^{-1}$ in Liberia to 0.9% $year^{-1}$ in Madagascar (Godoy *et al*., 2011). Loss of forest cover in some parts of the coast had decreased substantially after 2000s, but remained relatively high near Dar es Salaam Region. After 2000s, areas like Bagamoyo and Rufiji still suffer the impacts of high and probably increasing demand for charcoal and wood for building materials from Dar es Salaam (Kashaigili, 2013).

The area of forest cover loss within reserves has been found to be nine times slower than in the unreserved forest lands (Godoy *et al*., 2011). However, reserves are not immune from forest loss. Significant losses are being experienced in some reserved areas, especially the forest reserves near Dar es Salaam, with forest being lost primarily due to charcoal burning (Ahrends, 2010). In Kiwengoma in Coast Region for example, a combination of logging and agricultural pressure resulted in forest loss and degradation (Dallu, 2004; Kashaigili, 2013). Tong'omba Forest Reserve, in Lindi Region near the border with Coast Region, was highly threatened by logging activities, contributed by improved road access (Ahrends, 2005). It is believed that deforestation in the reserved areas of Southern Tanzania is associated with both particularly high rural population density and lack of reserve management capacity in those large and remote areas (Kashaigili, 2013). As reserves contain most of the remaining forest resources, they face increasing pressure to supply materials for human use and thus account for a significant loss of the forest cover (Godoy *et al*., 2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

This study was conducted at Ngarama South Forest Reserve (NSFR), which is found in Kilwa District in Lindi Region, southern-eastern Tanzania (Figure 1). The forest reserve was established under the Government Notice No. 300 of 12/09/1955. It is located between latitudes 9°3'S-9°33'S and longitudes 39°23'E-39°26'E having an area of 2 070 ha (Prins and Clarke, 2006; Howell *et al*., 2012). It is bordered by Kiranjeranje village in the northern-east side and Makangaga village in southern-west side (Burgess *et al*., 2011). People in these villages belong to Ngindo, Matumbi, Mwera and immigrants such as Sukuma and Nyasa. Most of the villagers are peasants who own plots of land, which vary in size from two to five acres. The size of their families vary, with an average of six to seven members per family or even more. They cultivate mainly subsistence crops including maize, sorghum, coconuts, pigeon peas and beans (Perkin *et al*., 2008b).

Kilwa District has a coastal climate, which is hot and humid with the average temperature range between 22^{o}C to 30^{o}C. Humidity is high, nearly 98-100% during the long rains (Dickinson *et al.,* 2010*)*. The district receives a total rainfall of 800-1 400 mm year^{-1} and its distribution varies according to locality. The period of rainfall coincides with the onset of each monsoon where the long rains start from Mid-February to April, and the short rains start from late October to December.

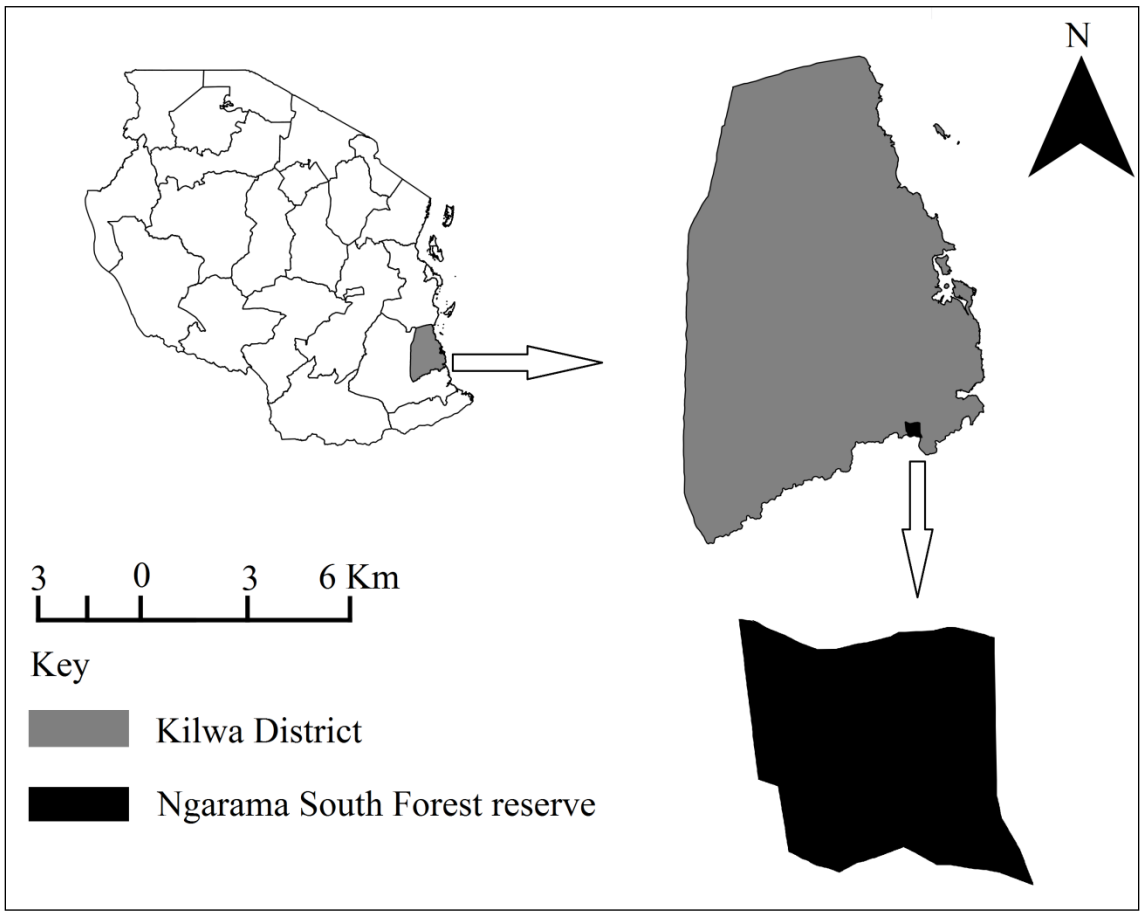

Figure 1: Sketch map of Kilwa District showing the location of NSFR in Tanzania

3.2 Data collection

3.2.1 Vegetation survey

The field survey was conducted in November 2013. Systematic sampling design was adopted since it increases the chance of including all vegetation types in the forest (Burgess and Muir, 1994; Sutherland, 2006). Five transects were established starting 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, ending points and plots were georeferenced by the use of GPS for mapping purposes.

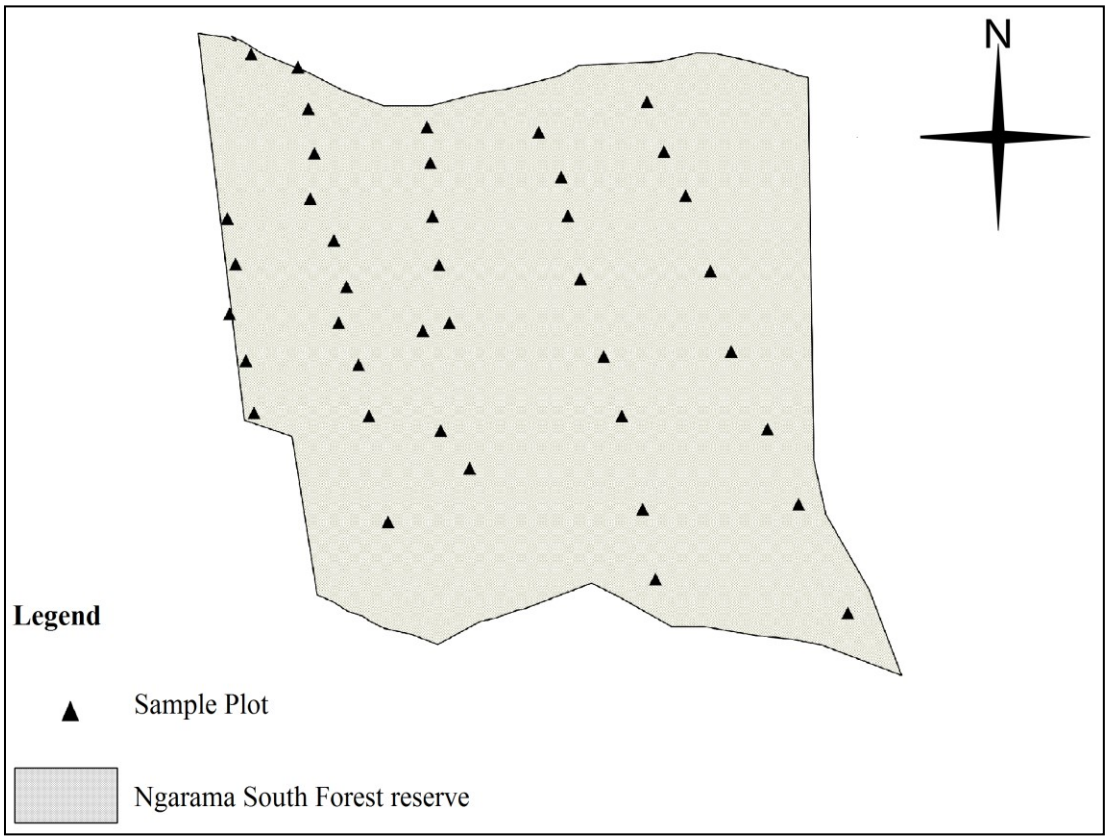

Figure 2: Sketch map of NSFR showing the distribution of the sample plots

Using a sampling intensity of 0.15%, a total number of 40 rectangular sample plots were established along transects. The distance between plots in the same transect was 400 m and 1 km from one transect to another (Figure 2). Rectangular sample plots were adopted as they are easy to establish, more accurate in area determination and more than 10% of species can be recorded than square plots (Sutherland, 2006; Jayakumar *et al*., 2011). This was also meant for comparison purposes with the previous studies conducted in this forest. Three levels sample plots (nested plots) were employed as adopted from Kibet (2011) and Howell *et al*., (2012) including 20 m x 40 m (0.08 ha plots) for woody plants species with diameter ≥ 10 cm, 10 m x 20 m (0.02 ha plots) nested in 0.08 ha plot for plants with diameter 10 > DBH ≥ 5 cm

and 1 m x 2 m (0.002 ha plots) nested in the 0.02 ha plots for regenerants and all trees/shrubs with 5 > DBH ≥ 1 (Figure 3).

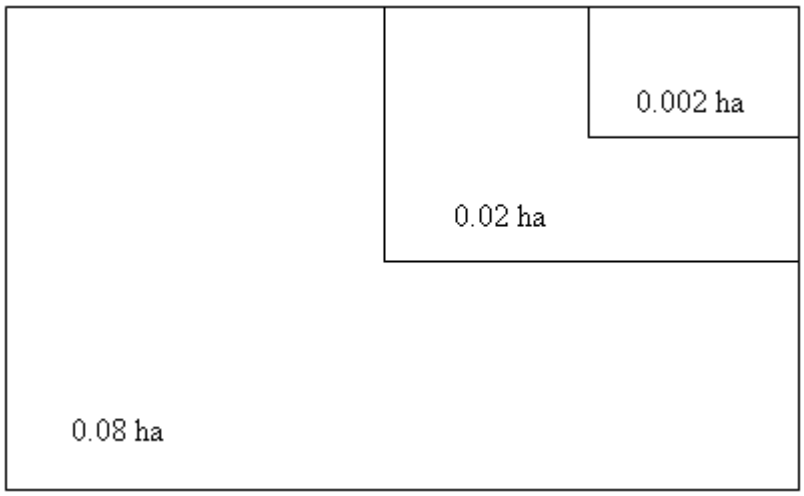

Figure 3: Three level rectangular sample plots (nested plot) used in this study

The information that was recorded from each sample plot included: the name of each trees/shrubs measured (local and scientific names), Diameter at breast height (DBH) for those trees/shrubs with diameter of 5 cm and above, height of selected sample trees (small, medium, large) and location of the plot using GPS readings. Trees and shrubs were identified to species level in the field and for those which were difficult to identify in the field, samples were collected and identified by a botanist at Tanzania Forest Research Institute (TAFORI) in Morogoro. The assistant researcher who was native to the area and competent in plant identification gave local names.

3.2.2 Intensity and distribution of human disturbance

The intensity and distribution of human disturbance was recorded as per Doggart (2006). The level of disturbance was assessed in terms of the number of incidences within a 0.08 ha sample plot. In this study, 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'. All stumps were measured for stump diameter and identified to species level. Other indicators of human disturbance that were considered were the areas that were evidenced by the presence of burnt trees and ground vegetation. These areas were described as "Fire damage". Another type of disturbance was area cleared for pit sawing activities, with pitsaw platform in the area, or remains of such pieces. These areas were described as "Pitsaw". Cut timber, planks or cut poles laying on the ground ready for transport were described as "Timber/planks/poles". Animal traps of all varieties whether set or sprung were described as "Trapping". Evidence of crop cultivation (past or present) was described as "Cultivation", all human used paths as "Footpath" and the well-established clearings within the forest as a consequence of human disturbance (usually short grassland, potentially previous settlement) were described as "Clearing". Once encountered in each plot, those types of disturbance were recorded and tallied.

3.2.3 Land cover changes in Ngarama South Forest Reserve

Mapping was done through available images of the forest cover obtained from internet (Table 1). The target was to obtain the recent images that acquired during the dry season (June–October) and with minimum cloud cover. As a consequence, three images acquired during the year 1995, 2000 and 2011 were used to meet the objective of the study. Nevertheless, recent images i.e. beyond 2011 were not available.

Table 1: Landsat images used in the analysis of land cover changes of NSFR

Image	Path/row	Acquisition date	Season	% Cloud
LANDSAT 5	165 / 067	02-June-1995	Dry	0
LANDSAT 7	165 / 067	22-June-2000	Dry	0
LANDSAT 5	165 / 067	17-Aug-2011	Dry	0

In addition, ground truthing was done in order to verify and modify land covers during the preliminary image interpretation. GPS was used to locate sampled land cover observations while digital camera recorded photos of features like water bodies, infrastructures, habitats and forest use. All sampled GPS points were booked as way points on a booking paper and photograph numbered. The information used to increase the accuracy of satellite image interpretation and the mapping process. Local people were also involved in the team to give information on boundaries, land cover history and land use particularly for the past 20 years. The exercise was done during the dry season (November 2013) to enable access to all the areas that may be inaccessible during the wet season.

3.3 Data Analysis

3.3.1 Vegetation survey data

Using Microsoft Excel Programme and Biodiversity R- software for Statistical and Quantitative analysis, the following measures were analysed. Species composition was expressed through species richness, diversity and Species Importance Value Index (IVI). Forest stocking was expressed through mean tree diameter, mean tree height and mean stem density and basal area for all trees with the following diameter classes ($5 \leq DBH < 20$ cm, 20 cm $\leq DBH < 50$ cm and ≥ 50 cm). IVI were computed

as the average of the relative basal area, density and frequency (Malimbwi, 2009). Ecologically, density and frequency of a species measure the distribution of a species within the population while basal area measures the area occupied by the stems of trees.

Species diversity was computed using Shannon-Wiener and Simpson's diversity indices. The Shannon-Wiener diversity index was computed as ($H' = SP_i * \ln P_i$) where H' is the index of diversity, P_i is the importance value of a species as a proportion of all species. Simpson's diversity index was computed as $C = SP^2_i$ where C is the index number and P_i as defined above (Sutherland, 2006; Rands *et al*., 2010). The knowledge of species diversity is useful for establishing the influence of biotic disturbance, and the state of succession and stability in the environment. This species diversity index increases with the number of species in the community (Armstrong *et al*., 2011). Furthermore, using Microsoft excel software, the human disturbance data were organized using simple descriptive statistics, listed, tabulated and ranked based on their number of occurrences.

3.3.2 Land cover change in Ngarama South Forest Reserve

Methods for images analysis combined both visual and digital image processing (ILWIS, 2001). Prior to image processing, images layers/bands were rectified, georeferenced and enhanced using the GPS reading obtained from the field. Then the image layers/bands were stretched and filtered. All image processing and subsequent image analysis were carried out using Quantum GIS Desktop (1.8.0) and ILWIS Academic software Version 3.3. Often, image files contain areas much larger than a

particular study area. The image file was reduced to include only the area of interest (AOI). This not only eliminates the extraneous data in the file, but it speeds up processing due to the smaller amount of data to process (ILWIS, 2001; Kashaigili *et al.*, 2006).

Supervised classification process involved selection of training sites on the image, which represented specific land classes to be mapped. Training sites are sites of pixels that represent specific land classes to be mapped (Kashaigili and Majaliwa, 2010). They are pixels that represent what were recognized as a potential land cover class during ground truthing. The training sites were generated by on-screen digitizing of selected areas for each land cover class identified on colour composite. Training is an iterative process; basically 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 (Kashaigili and Majaliwa, 2010).

Based on the inspection of results, training samples were refined until satisfactory result obtained. The objective was to produce thematic classes that resemble or can be related to actual land cover types on the earth's surface. The advantage of digital image classification is that it can provide efficient, consistent and repeatable routines for mapping large areas (Kashaigili and Majaliwa, 2010). Classified images were recorded to respective classes (i.e. forest, woodland and grassland). Following the recording, images were filtered using a 3 x 3 majority-neighbourhood filter in order to eliminate patches smaller than a specified value and replace them with the value

that is most common among the neighbouring pixels. A mosaic operation was performed to multiple classified images to produce one map for the entire study area. Change detection is a very common and powerful application of satellite based remote sensing. Change detection analysis entails findings the type, amount and location of land use changes that are taking place (Kashaigili and Majaliwa, 2010). In this study, a post classification comparison method was used to assess land use and cover changes. The advantage of post-classification comparison is that it bypasses the difficulties associated with the analysis of images acquired at different times of the year and/or by different sensors (Kashaigili *et al*., 2006). The method has been found to be the most suitable for detecting land cover changes as this enables estimation of the amount, location, and nature of change. The estimation for the rate of change for the different covers was computed based on the following formulae;

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

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

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

Where;

$\text{Area}_{i\ \text{year}\ x}$ = area of cover i at the first date.

$\text{Area}_{i\text{year}x+1}$= area of cover i at the second date.

$\sum_{i=1}^{n} \text{Area}_{i\ \text{year}\ x}$ = total cover area at the first date.

t_{years} = period in years between the first and second scene acquisition dates.

CHAPTER FOUR

4.0 RESULTS

4.1 Species richness

126 plant species containing 79 tree species and 47 shrub species belonging to 34 families were identified in NSFR (Tables 2, 3 and Appendix 1). Out of these, trees contributed 63% (28 families) and shrubs 37% (17 families). Plant species from the family Fabaceae contributed most (26%) to the total number of species, followed by those from the families Combretaceae (9%), Euphorbiaceae (8%), Rubiaceae (6%), and Tiliaceae (5%) as indicated in Appendix 1. Families that had the highest number of tree species in descending order were Fabaceae (27) followed by Euphorbiaceae (6) Combretaceae (6), and Malvaceae (4). For shrub species, the most dominant families were Tiliaceae (6), Fabaceae (6), Rubiaceae (6), Combretaceae (5) and Euphorbiaceae (4) (Appendix 1).

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Table 2: Average stem density (stem ha^{-1}) of tree and shrub species recorded in NSFR

Trees species	Density (Stem/ha)	Shrubs species	Density (Stem/ha)
Hymenocardia ulmoides Oliv	58	*Strychnos spinosa* Lam.	22
Spirostachys africana Sond	53	*Diospyros kabuyeana* F. White	13
Markhamia lutea (Benth.) K. Schum	33	*Grewia bicolor* Juss	11
Isoberlinia globiflora (Benth.) Hutch. ex Greenway	32	*Commiphora africana (*A. Rich.) Engl	11
Pseudolachnostylis maprouneifolia Pax	24	*Combretum adenogonium* Steud. ex A. Rich	9
Combretum molle (Klotzsch) Engl. & Diels	24	*Bauhinia petersiana* Bolle	7
Terminalia mollis M. A. Lawson	20	*Dichrostachys cinerea (L.)* Wight & Arn	7
Crossopteryx febrifuga (Afzel. ex G. Don) Benth.	18	*Catunaregam spinosa* (Thunb.) Tirveng	6
Diplorhynchus mossambicensis Benth. ex Oliv.	16	*Millettia dura* Dunn	5
Pteleopsis myrtifolia (M. A. Lawson) Engl. & Diels	16	*Allophylus rubifolius* (Hochst. ex A. Rich.) Engl	5
Combretum collinum Fresen	15	*Uvaria welwitschii* (Hiern) Engl. & Diels	5
Brachystegia boehmii Taub	12	*Ehretia stuhlmannii* Gürke	5
Dalbergia melanoxylon Guill. & Perr	10	*Canthium oligocarpum* Hiern	4
Hymenocardia mollis Pax	10	*Holarrhena pubescens* (Buch.-Ham.) Wall. ex G. Don	3
Tamarindus indica L	9	*Ehretia amoena* Klotzsch	3
Lannea stuhlmannii (Engl.) Engl	9	*Grewia platyclada* K. Schum	3
Acacia robusta Burch	8	*Spermacoce assurgens* Ruiz & Pav.	3
Stereospermum kunthianum Cham	8	*Acacia hockii* De Wild	3
Terminalia sambesiaca Engl. & Diels	8	*Grewia similis* K. Schum	2
Combretum zeyheri Sond	8	*Ptaeroxylon obliquum* (Thunb.) Radlk	2
Acacia nigrescens Oliv.	7	*Manilkara mochisia* (Baker) Dubard	2
Carpodiptera africana Mast	7	*Maytenus lancifolia* (Thonn.) Loes.	2
Ochna holstii Engl	7	*Lannea humilis* (Oliv.) Engl.	2

Trees species	Density (Stem/ha)	Shrubs species	Density (Stem/ha)
Bridelia cathartica Bertol	7	*Strychnos innocua* Delile	2
Xeroderris stuhlmannii (Taub.) Mendonça & E. C. Sousa	5	*Margaritaria discoidea* (Baill.) G.L. Webster	2
Lonchocarpus capassa Rolfe	5	*Diospyros fischeri* Gürke	1
Diospyros kirkii Hiern	4	*Ziziphus mucronata* Willd.	1
Albizia harveyi E. Fourn.	4	*Rytigynia uhligii* (K. Schum. & K. Krause) Verdc	1
Oxystigma msoo Harms	4	*Antidesma venosum* E. Mey. ex Tul.	1
Diospyros mespiliformis Hochst. ex A. DC.	4	*Combretum schumannii* Engl	1
Commiphora eminii Engl.	4	*Grewia holstii* Burret	1
Bombax rhodognaphalon K. Schum	4	*Suregada zanzibariensis* Baill	1
Lonchocarpus eriocalyx Harms	3	*Combretum padoides* Engl. & Diels	1
Afzelia quanzensis Welw.	3	*Grewia trichocarpa* Hochst. ex A. Rich	1
Dombeya acutangula Cav	3	*Zanthoxylum chalybeum* Engl	1
Cylicomorpha parviflora Urb.	3	*Sericanthe odoratissima* (K. Schum.) Robbr	1
Erythroxylum emarginatum Thonn.	3	*Erythrococca kirkii* (Müll. Arg.) Prain	1
Lecaniodiscus fraxinifolius Baker	2	*Grewia monticola* Sond	1
Dobera loranthifolia (Warb.) Harms	2	*Rotheca myricoides* (Hochst.) Steane & Mabb	1
Lonchocarpus bussei Harms	2		
Balanites aegyptiaca (L.) Delile	2		
Diospyros abyssinica (Hiern) F. White	2		
Terminalia sericea Burch. ex DC.	2		
Julbernardia globiflora (Benth.) Troupin	2		
Dalbergia nitidula Baker	2		
Deinbollia borbonica f. glabrata Radlk.	2		
Dombeya rotundifolia (Hochst.) Planch	2		

Trees species	Density (Stem/ha)	Shrubs species	Density

		(Stem/ha)
Euphorbia candelabrum Trémaux ex Kotschy	1	
Pterocarpus rotundifolius (Sond.) Druce	1	
Dalbergia boehmii Taub	1	
Boscia salicifolia Oliv	1	
Ehretia silvatica Gürke	1	
Sclerocarya birrea (A. Rich.) Hochst.	1	
Pterocarpus chrysothrix Taub	1	
Haplocoelum inoploeum Radlk	1	
Albizia lebbeck (L.) Benth	1	
Acacia goetzei Harms	1	
Sterculia quinqueloba (Garcke) K. Schum	1	
Ricinodendron gracilius Mildbr	1	
Schrebera alata (Hochst.) Welw	1	
Adansonia digitata L	1	
Pterocarpus angolensis DC.	1	
Cassine aethiopica Thunb	1	
Markhamia obtusifolia (Baker) Sprague	1	
Lannea fulva (Engl.) Engl.	1	
Piliostigma thonningii (Schumach.) Milne-Redh	1	
Milicia excelsa (Welw.) C.C. Berg	1	

Table 3: Richness, diversity and stem density of woody plant species in NSFR

Parameter	Values
Sample size (n)	40
Richness (total number of species)	126
Mean tree height (m)	8.7
Mean tree diameter (cm)	13.1
Mean stem density (stems ha^{-1})	667±19
Basal area (m^2 ha^{-1})	12.78±0.34
Shannon's index	3.95
Simpson's index	0.03

The species accumulation curve (Figure 4) 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 40 plots, the graph has not yet reached its asymptotic level but is starting to converge, implying that any further increase of sample size would be expected to lead to inclusion of additional rare species.

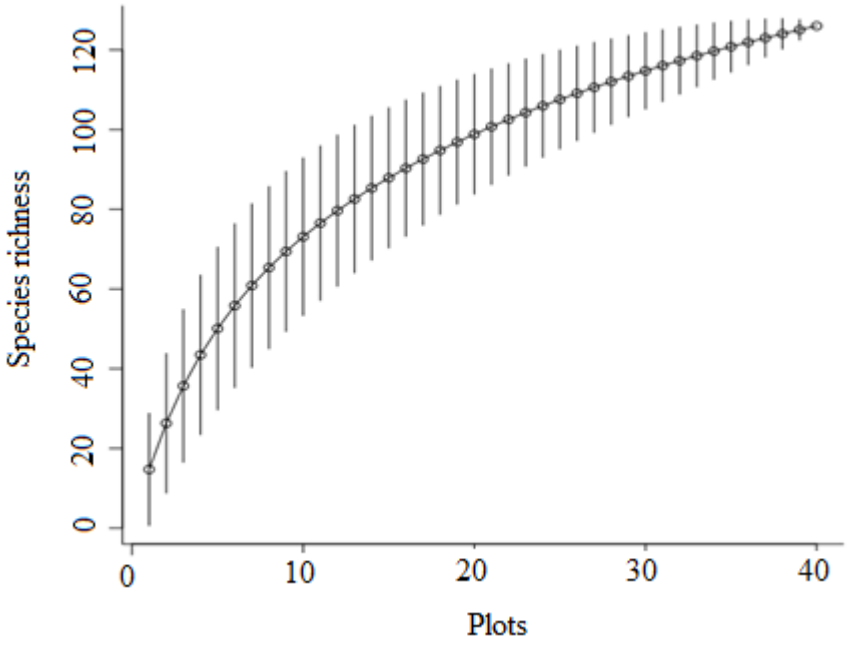

Figure 4: Species accumulation curve of trees/shrubs sampled in NSFR

4.2 Species diversity

Species diversity as per Shannon-Wiener and Simpson indices in the NSFR are presented in Table 3 and Figure 5. The species that contributed to high species diversity according to Shannon-Wiener index included *Spirostachys africana* (0.185), *Pseudolachnostylis maprouneifolia* (0.163), *Isoberlinia globiflora* (0.162), *Crossopteryx febrifuga* (0.151) and *Terminalia mollis* (0.150). In terms of frequency of occurrence for individual trees and shrubs, *Hymenocardia ulmoides* was the most frequent species by 9% of all 126 species, followed by *Spirostachys africana* (8%), *Markhamia lutea* (5%) and *Isoberlinia globiflora* (5%). Based on IVI, *Spirostachys africana* (2.78) was the most dominant species followed by *Pseudolachnostylis maprouneifolia* (2.28), *Isoberlinia globiflora* (2.25), *Crossopteryx febrifuga* (2.02), *Terminalia mollis* (2) and *Combretum molle* (1.47). *Brachystegia spiciformis* and *Diospyros squarrosa* were the least important species by having small IVI (Figure 5 and Appendix1).

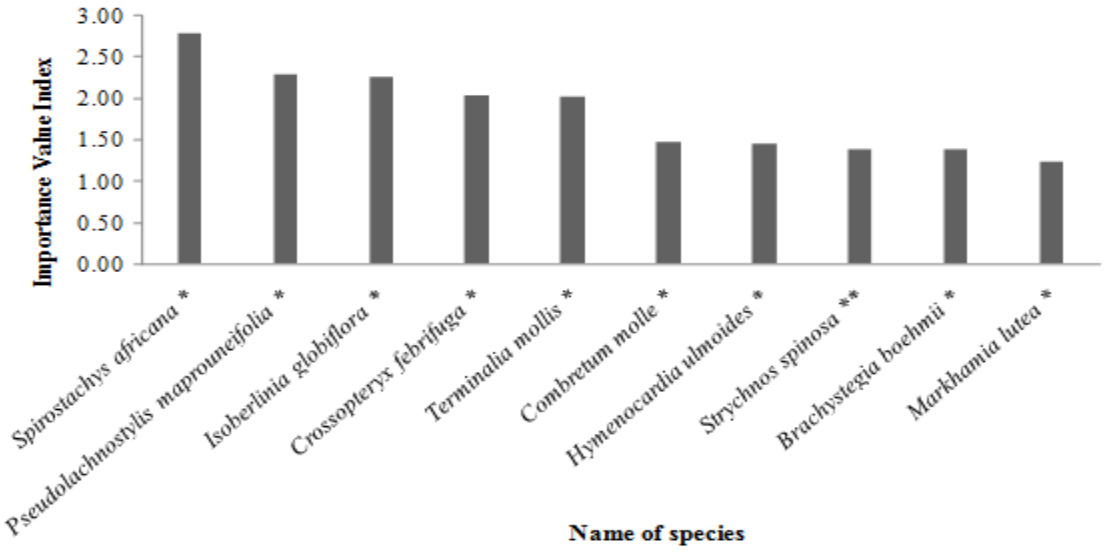

Figure 5: Species diversity according to Importance Value Index (IVI) in NSFR. (= shrubs and * = trees)**

4.3 Vegetation structure

The mean stem density in NSFR was 667±19 stem ha^{-1}, where the stem density for shrubs were 165±8 stem ha^{-1} and that of trees were 503±11 stem ha^{-1} (Tables 2 and 3). Among the trees, the most abundant tree species was *Hymenocardia ulmoides* (11% of 503 stem ha^{-1}) followed by *Spirostachys africana* (11%), *Pteleopsis myrtifolia* (10%), *Markhamia lutea* (7%), *Isoberlinia globiflora* (6%) and *Pseudolachnostylis maprouneifolia* (5%). Among the shrubs, the most abundant shrub species were *Strychnos spinosa* (13% of 165 stem ha^{-1}) followed by *Diospyros kabuyeana* (8%), *Grewia bicolor* (7%) and *Commiphora africana* (6%). The stem density of trees/shrubs species having diameter 5 – 20 cm were 565±18 stem ha^{-1}, while those with diameter 20 – 50 cm were 99±3 stem ha^{-1} and those with diameter > 50 cm were 3±0 stem ha^{-1} (Figure 6).

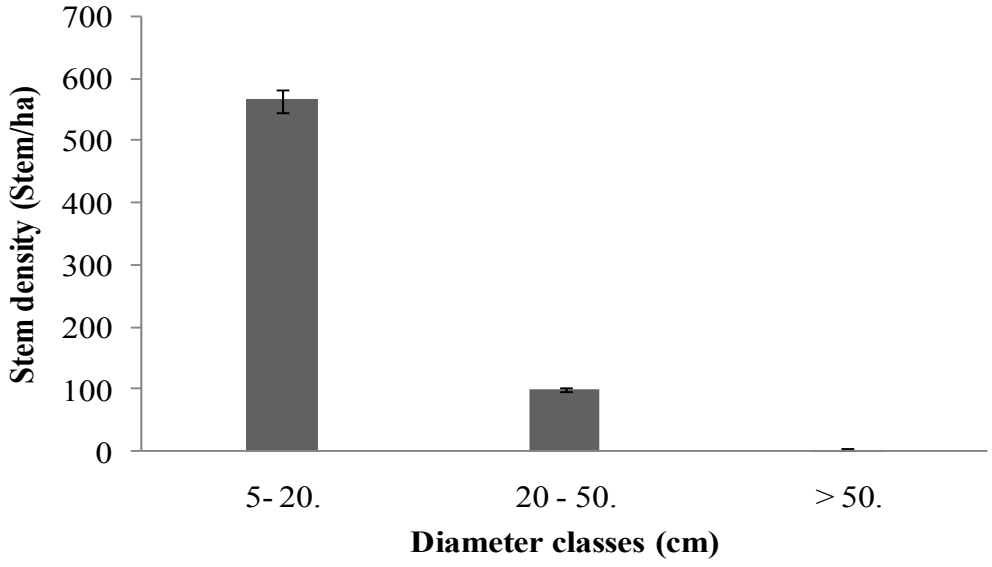

Figure 6: Stem density of woody plant species in NSFR

The total basal area in NSFR was 12.78±0.34 m^2 ha^{-1}, where the basal area for shrubs were 2.7±0.21 m^2 ha^{-1} and that of trees were 10.4±0.18 m^2 ha^{-1} (Table 3, Figure 7 and

Appendix 1). The shrub species contributing most to the basal area were *Strychnos spinosa* (26%) followed by *Commiphora africana* (11%), *Grewia bicolor* (5%) and *Spermacoce assurgens* (4%). Species contributing most to the basal area for tree species were *Spirostachys africana* (8%), *Isoberlinia globiflora* (6%), *Dalbergia melanoxylon* (6%), *Pseudolachnostylis maprouneifolia* (5%) and *Hymenocardia ulmoides* (4%). The basal area of trees/shrubs species having diameter 5 – 20 cm were 5.3±0.15 m² ha^{-1}, while those with diameter 20 – 50 cm were 6.1±0.17 m² ha^{-1} and those with diameter > 50 cm were1.7±0.23 m² ha^{-1} (Figure 7).

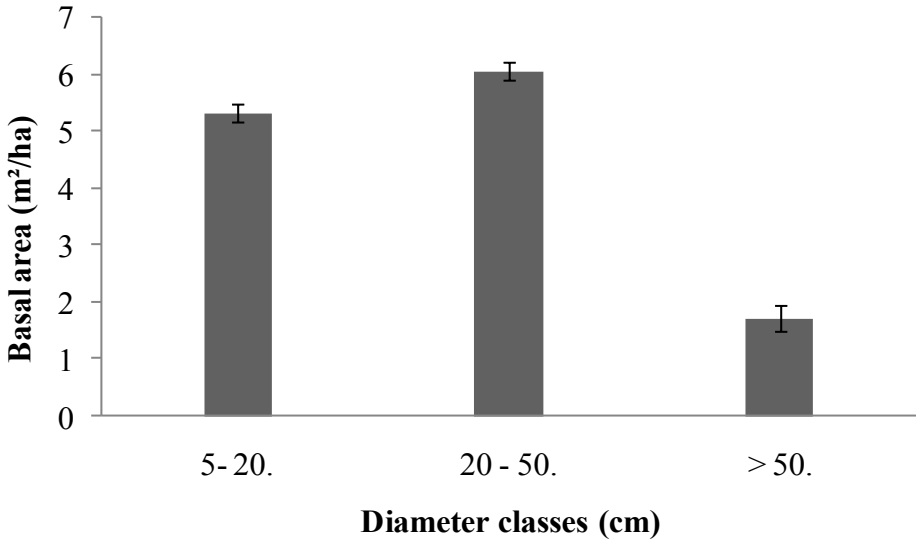

Figure 7: Basal area of woody plant species in NSFR

4.4 Intensity and distribution of human disturbance

The number of stumps recorded in NSFR were 23 stumps, equivalent to 7±3 stumps ha^{-1} with mean basal area of 0.24±0.09 m^2 ha^{-1} (Figure 8 and Appendix 5). Fresh cuts were 78% and 22% were old cuts. In term of frequency, *Spirostachys africana* seems to be more harvested by having 56% of all stumps followed by *Allophylus rubifolius* (17%), *Grewia platyclada* having (09%), *Dalbergia melanoxylon* (09%) and the rest

(09%) were *Terminalia sambesiaca* and *Carpodiptera Africana*. Also all other forms of anthropogenic disturbance within sample plots were observed in this study, where 51% were fire damage, 13% were paths or roads, 8% were pitsaw, 8% were timber/planks/poles, 5% were trapping, 5% were cultivation and 8% were forest clearing (Figure 9).

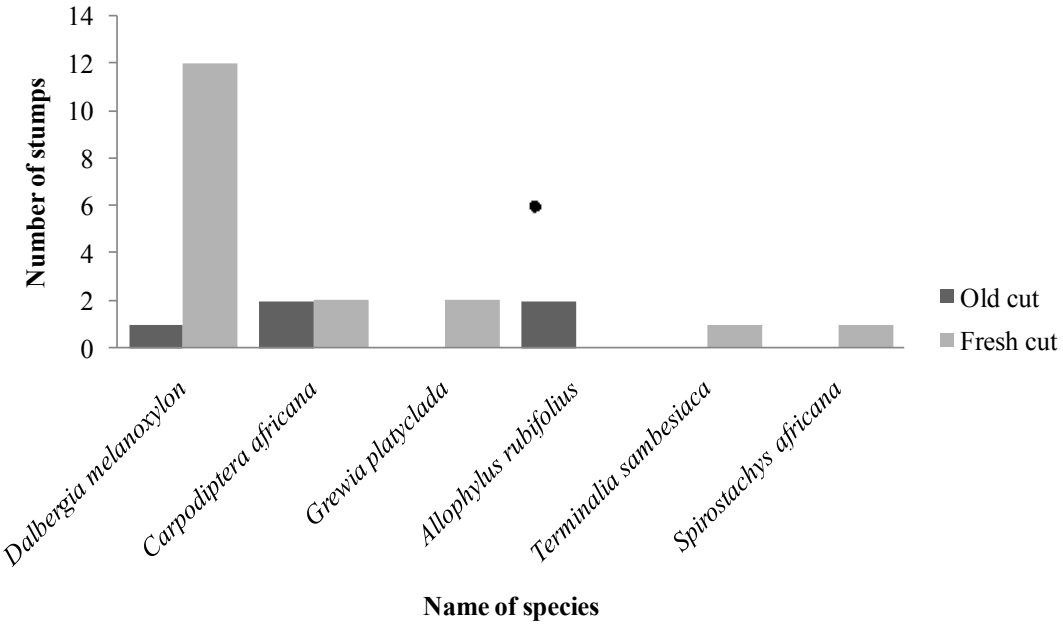

Figure 8: Quantity of old cut and fresh cut stumps recorded in NSFR

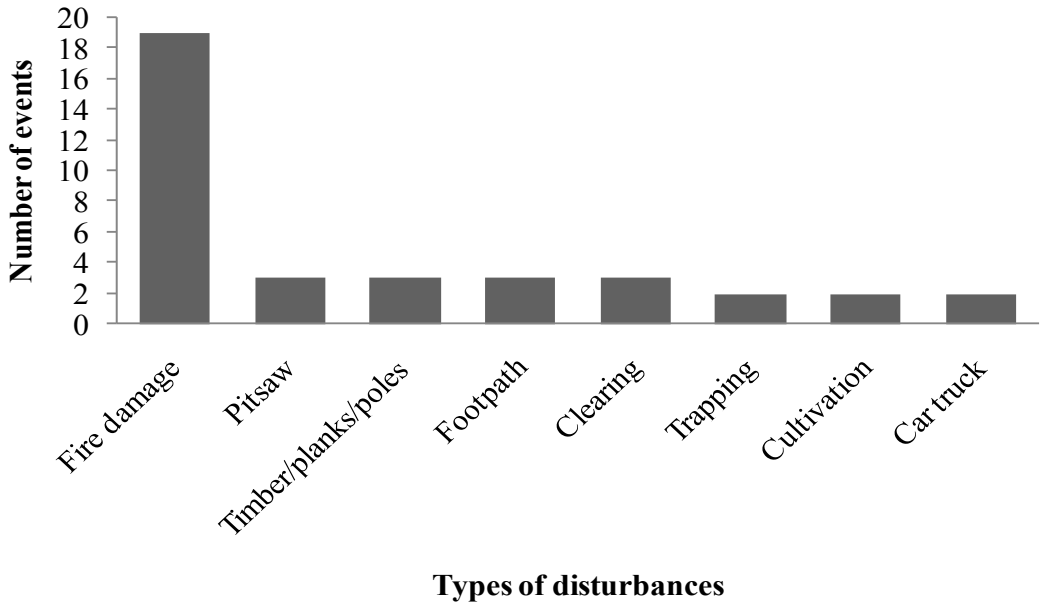

Figure 9: Types of disturbance observed in NSFR

4.5 Land cover change in Ngarama South Forest Reserve

The land cover maps for 1995, 2000 and 2011 are presented in Figure 10. The figure that shows the variation in forest coverage between the three periods under consideration. The coverage of each land cover/use class in 1995, 2000 and 2011 including the area and percentage area change between the three periods for the NSFR are shown on Tables 4 and 5. From the year 1995 to 2000 the cover classes of forest and woodland increased at a rate of +15.9 ha year^{-1} (+1% year^{-1}) and +12.6 ha year^{-1} (+3% year^{-1}) respectively while grassland cover decreased at the rate of -28.5 ha year^{-1} (-7% year^{-1}). From the year 2000 to 2011, the grassland and woodland cover increased at the rate of +32.1 ha year^{-1} (+13% year^{-1}) and +43.2 ha year^{-1} (+8% year^{-1}) respectively while forest cover decreased at the rate of -75.4 ha year^{-1} (-4% year^{-1}). Generally, NSFR has undergone notable changes in terms of land cover for the period 1995–2000 and 2000–2011 where, forest cover areas were highly

impacted from 68% (1995) to 39% (2011) and woodland and grassland cover were found to have consistently increased from 15% and 17% (1995) to 23% and 38% (2011) respectively.

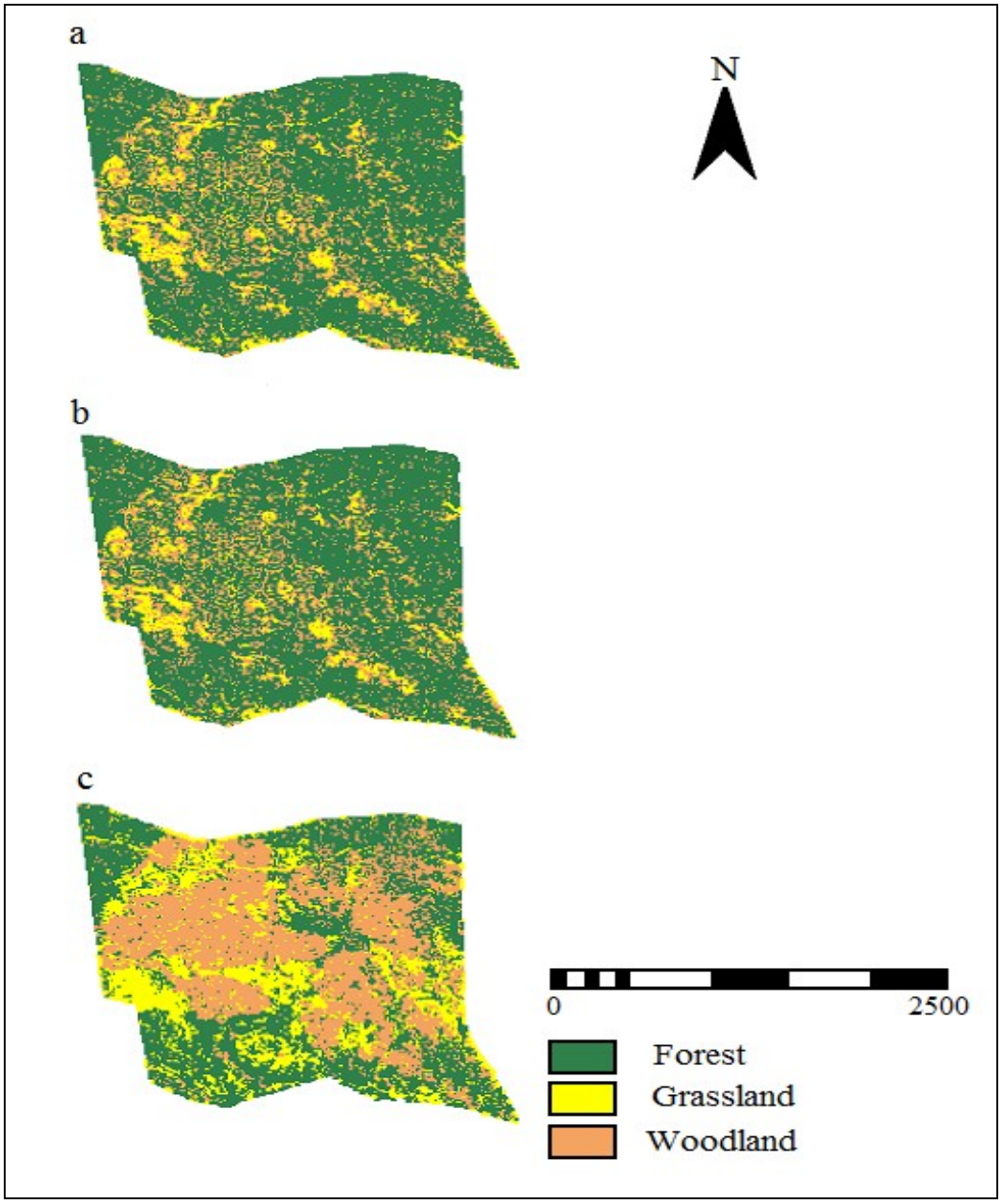

Figure 10: Classified land cover map of (a) 1995 (b) 2000 and (c) 2011 of NSFR

Table 4: Cover area, changed area and the rate of change between 1995 and 2000

Cover class	1995		2000		Change area (ha)	% Change	Annual rate of change (ha year^{-1})	% Annual rate of change (% year^{-1})
	Cover area (ha)	% Cover coverage	Cover area (ha)	% Cover coverage				
Forest	1 770.84	68%	1 850.31	71%	79.47	3%	15.894	1%
Grassland	380.61	15%	238.32	9%	-142.29	-5%	-28.458	-7%
Woodland	453.96	17%	516.78	20%	62.82	2%	12.564	3%
	2 605.41	**100%**	**2 605.41**	**100%**				

Table 5: Cover area, changed area and the rate of change between 2000 and 2011

Cover class	2000		2011		Change area (ha)	% Change	Annual rate of change (ha year^{-1})	% Annual rate of change (% year^{-1})
	Cover area (ha)	% Cover coverage	Cover area (ha)	% Cover coverage				
Forest	1 850.31	71%	1 021.41	39%	-828.9	-32%	-75.35	-4%
Grassland	238.32	9%	591.66	23%	353.34	14%	32.12	13%
Woodland	516.78	20%	992.34	38%	475.56	18%	43.23	8%
	2 605.41	**100%**	**2 605.41**	**100%**				

CHAPTER FIVE

5.0 DISCUSSION

5.1 Floristic composition

The definition of an optimum sample size is based on the idea that the larger the sample size the greater the number of species in the sample, but the rate of increase becomes progressively smaller so the curve tends to a flat line (Rands *et al*., 2010). The point where the curve becomes horizontal is the minimal area to represent the plant community (Sutherland, 2006). This concept assumes that the plant community is a spatially discrete entity with fixed species composition. In tropical forests, identification of community's boundaries is particularly difficult and due to their high species richness, the species accumulation curves do not become flat, even with large sample sizes (Sutherland, 2006; Rands *et al*., 2010). Hence, the species accumulation curve shows that at 40 plots, the graph has not yet reached its asymptotic level but it is starting to converge. Implying that 40 sites/plots used in this study was sufficient to cover much of the variation and species diversity of the study area and any further increase of sample size would be expected to lead to inclusion of additional rare species.

The species composition found in the NSFR, based on the dominance of species from the family Euphorbiaceae and Fabaceae comply well with previous descriptions of coastal forest that belong to the mixed scrub forest type of coastal forest community. Characterised by rarely single species dominance and having the most frequent species such as *Hymenocardia ulmoides*, *Pteleopsis myrtifolia*, *Bombax rhodognaphalon*, *Afzelia quanzensis* and the genera such as *Albizia*, *Combretum*,

Diospyros, *Grewia* and *Strychnos* that are well presented in the forest composition of NSFR (Burgess and Clarke, 2000; Burgess *et al*., 2003; Burgess *et al*., 2011; Godoy *et al*., 2011). The high species richness in the study area is attributed probably to the presence of the riverine forest along Mbwemkulu River that contributes to the growth of many species (Burgess *et al*., 2003).

Shannon-Wiener Index of diversity (H') tells about species richness and evenness, where the larger the value of H' the greater the species diversity and vice versa (Rands *et al*., 2010). An ecosystem with H' value greater than 2 has been regarded as medium to high diverse in terms of species (Rands *et al*., 2010). Thus, having Shannon-Wiener Index of diversity (H') of 3.95, NSFR has high species diversity.

Munishi *et al*., (2011) reported that the greater the Simpson's index value the lower the species diversity and vice versa in the scale of 0 to 1. The Simpson's index value of 0.03 (Table 3) in NSFR implying that the probability of picking randomly two individuals belonging to the same species is very low or the probability that any species encountered at random would be different species (Prins and Clarke, 2006; Dickinson *et al*., 2010). Thus having that index shows that plant species found in NSFR are diversified with more evenness.

5.2 Forest structure

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). 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). Nevertheless, the condition of the majority of coastal forest ecosystems today is the result of human disturbance like clear felling, logging and fire damage that often results in the formation of modified ecosystems with new species composition and structures (Burgess *et al*., 2011; Godoy *et al*., 2011). Characterised by various structural features like low stem density, low basal area, low mean tree height and low mean tree diameter. In explaining this, Burgess and Clarke (2000) described some forests that were affected by a range of human disturbance of which the most prevalent ones in terms of affected area were fire damage, pole harvesting, timber logging and charcoal burning (Table 6).

To varying degrees, all forests that were impacted by some form of human disturbance seemed to have consistently important influence on the forest structure of many coastal forest sites like having relative low stem density, low mean tree height and diameter. Cleary, human disturbance causes disruption of forest structure and changes community composition of the forest and if such 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; Godoy *et al.*, 2011; Kibet, 2011; Munishi *et al.*, 2011). Based on the results on the forest structure in NSFR (Table 6 and Figure 7) with considerable number of stumps and number of events of other forms of human disturbance (Figures 8 and 9). It suggests that the major human disturbance is likely to influence the vegetation structure of NSFR and further more such disturbance remain detectable in the resulting forest physiognomy of NSFR.

Apart from having the relative low stem density, basal area and few trees with large diameter that may possibly be due to human disturbance, stem density distribution still reflect an inverted 'J' shape, which is common for natural forests with active regeneration and recruitment (Munishi *et al*., 2011). Accordingly, active regeneration and recruitment in coastal forest NSFR as portrayed in this study is a good sign of sustainability of the woodland stock which has chances of ensuring sustainable supply of products and services only if not subjected to more anthropogenic disturbance (Ahrends, 2005; Dickinson *et al.*, 2010; Giliba *et al*., 2011).

Table 6: Structural parameters of the forest sites with known history of disturbance

Site	Plot Area (ha)	Sample size (n)	Mean tree height (m)	Mean Tree DBH (m)	Mean stem density (trees/ha)	Stem density/ha by DBH class			Basal area (m^2/ha)
						10 - 20 (cm)	20 - 50 (cm)	> 50 (cm)	
Gendagenda B*	0.03	15	14	0.277	500	267	200	33	30.1
Namakutwa 1*	0.16	88	15.2	0.226	550	331	181	38	22
Kazimzumbwi 4*	0.025	11	13.5	0.248	440	280	80	80	21.3
Kazimzumbwi 2*	0.075	40	9.9	0.204	533	373	133	27	16.4
Kazimzumbwi 3*	0.25	148	11.4	0.169	592	444	144	4	13.3
Namakutwa 2*	0.16	95	12.7	0.162	594	456	138	0	12.2
Ruvu North*	0.16	47	14.1	0.222	294	70	212	12	11.4
Litipo 1*	0.16	49	14.6	0.21	306	156	125	25	10.7
Kilulu C*	0.03	13	10.1	0.173	433	300	133	0	10.2
Litipo 2*	0.16	62	12.1	0.178	387	244	143	0	9.7
Rondo Plantation*	0.16	48	13.4	0.189	300	238	50	12	8.4
Kazimzumbwi 1*	0.25	93	9.9	0.167	372	300	24	48	8.2
Namburika Hill*	0.16	22	12.3	0.259	138	68	56	12	7.3
Gendagenda C*	0.03	10	10.3	0.16	333	267	67	0	6.6
NSFR**	0.08	40	8.7	0.131	667	565	99	3	13.1

* **Adopted from**: Burgess and Clarke. (2000) **This study, 2013

5.3 Forest condition

Results for cover classes over an average period of 5 years (i.e.1995 and 2000) (Table 4) show that two cover classes of forest and woodland increased at a rate of +15.9 ha $year^{-1}$ (+1% $year^{-1}$) and +12.6 ha $year^{-1}$ (+3% $year^{-1}$) respectively, where grassland cover decreased at the rate of -28.5 ha $year^{-1}$ (-7% $year^{-1}$). It is possible that the increase in forest cover is attributed to reduced forest disturbance following the poor infrastructure before the opening of Mkapa Bridge across Rufiji River on 2003 (Burgess and Clarke, 2000). Also the limited technological capability and low population in the villages around the study area had little impact on the forest hence had a much lower effect on the condition of the forest reserve compared to other factors such as elephants damage and climate change effects (Howell and Msuya, 2002; Perkin *at al.*, 2008b). The effects were also described by Howell *et al.,* (2012) in their study as they found that increase of forest cover was due to prior exploration of gypsum mining activities occurring in Makangaga village. Where the extraction machinery in the area destroyed vegetation by removing the rock deposits below the surface in the southern part of NSFR and the nearby areas (Howell and Msuya, 2002).

Fire is one of the greatest threat to the forests of the coastal areas including NSFR as shown in Figure 9. Although woodlands are usually tolerant of low temperature fires, most forest species are sensitive to fire and easily destroyed by it (Maliondo *et al*., 2000; Howell *et al*., 2012). Intrusion of fire opens up the forest to widespread woodland species, thereby reducing habitats and their biodiversity values both in terms of species diversity and greatly affecting species of restricted distribution

patterns (Edwin, 2004; Munishi *et al*., 2011). This possibly is the reason for the increase in woodland cover as seen in Table 4.

From 2000 to 2011 (Table 4), the grassland and woodland cover increased at the rate of +32.1 ha $year^{-1}$ (+13% $year^{-1}$) and +43.2 ha $year^{-1}$ (+8% $year^{-1}$) respectively while forest cover decreased at the rate of -75.4 ha $year^{-1}$ (-4% $year^{-1}$). The reason for such decrease in forest cover is attributed to increased forest disturbance following the opening of Mkapa bridge and infrastructure improvement that increased the pressure and put at risk of destruction and overexploitation of forests in southern Tanzanian coastal areas (Ahrends, 2005). Also Howell *et al*., (2012) and Mhache (2014) pointed out that the rapid increase of population has created a high demand for wood and non-wood products in Dar es Salaam, Zanzibar, Tanga and areas around NSFR. This results into forest loss due to the direct effects of human activities such as habitat destruction (deforestation), land use changes, invasive species and over-exploitation, as well as indirect effects of human activities such as climate change (Howell *et al*., 2012). This observation agrees with findings of this study in NSFR that fire events, timber sawing, logging and clearance for cultivation (Figure 9) were activities that probably resulted in decrease in forest cover area and increase in woodland and grassland cover area for the past 20 years in this forest.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The major aims of this study were to assess the floristic composition, stocking and effects of anthropogenic activities on the forest condition of NSFR and to provide data, which will form a basis for determining suitable conservation strategies and regular monitoring of the forest. It was found out that the coastal forest of NSFR has a reasonably good trees/shrubs species composition and richness. In addition, trees/shrubs species noted to be dominant and with high diversity fit quite well within the general definition of coastal forest that belong to mixed scrub forest community type.

The vegetation structure of NSFR is characterized by relatively low stem density, low mean tree height, low mean tree diameter, low basal area and scarcity of large diameter trees, which indicate that the forest has been subjected to anthropogenic disturbances and unwise use of the forest resources. In addition, the indicators of anthropogenic disturbances observed in the forest suggest that human disturbance were the key factors that influenced the vegetation structure of the forest.

The study has also revealed that NSFR has undergone notable changes in terms of land cover for the period of past 20 years (1995- 2011). Comparing the two periods (1995-2000 and 2000- 2011), more changes in cover areas occurred during the 2000-2011 period. Forest cover were found to be highly impacted notably woodland and grassland cover were found to have consistently increased indicating the poor forest

trend and the need for improvement of the overall forest resources by controlling the human disturbances and restricting unwise use of forest resources so as to protect the integrity of the forest.

6.2 Recommendations

Given its high biodiversity values, NSFR should remain the focus for conservation initiatives. Its reserve borders need to be re-surveyed, re-established and clearly indicated by installing beacons for monitoring purposes. In addition, other conservation measures should be taken like improving governance and accountability as regards responsibility for intense management of the remaining threatened biodiversity, which is potential to the livelihoods of the local people living around these forests and form a basis for determining suitable conservation strategies and a regular monitoring programme of this forest.

Due to limited funds and time, this survey was of limited duration and scope and was conducted during a relatively dry season. It is suggested that surveys of longer duration in NSFR during a rainy period would probably yield more species and provide more information on the forest and its values. Since this study focused only on the influence of anthropogenic disturbances on the vegetation structure of the NSFR, it is suggested that future study should address the influence of other environmental factor such as e.g. soil, water availability and topographic factor on the vegetation structure and forest status of the NSFR.

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APPENDICES

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

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Hymenocardia ulmoides Oliv	Mtoto	Euphorbiaceae	T	9.0	58	0.45	1.44
Spirostachys africana Sond	Msagawi	Euphorbiaceae	T	8.3	53	0.89	2.78
Markhamia lutea (Benth.) K. Schum	Mtandawala	Bignoniaceae	T	5.2	33	0.35	1.23
Isoberlinia globiflora (Benth.) Hutch. ex Greenway	Mtupa	Fabaceae	T	4.9	32	0.66	2.25
Pseudolachnostylis maprouneifolia Pax	Msolo	Euphorbiaceae	T	4.0	24	0.51	0.09
Combretum molle (Klotzsch) Engl. & Diels	Kimbala	Combretaceae	T	3.8	24	0.37	1.47
Strychnos spinosa Lam.	Muhaja	Loganiaceae	S	3.4	22	0.68	1.39
Terminalia mollis M. A. Lawson	Mkuliungu	Combretaceae	T	3.2	20	0.39	2.01
Crossopteryx febrifuga (Afzel. ex G. Don) Benth.	Mchenjele	Rubiaceae	T	2.9	18	0.43	2.02
Diplorhynchus mossambicensis Benth. ex Oliv.	Mtogo	Apocynaceae	T	2.5	16	0.21	1.13
Pteleopsis myrtifolia (M. A. Lawson) Engl. & Diels	Mnepa	Combretaceae	T	2.5	16	0.51	1.02
Combretum collinum Fresen	Mkolowanje	Combretaceae	T	2.3	15	0.27	1.15
Diospyros kabuyeana F. White	Mkolyongo	Ebenaceae	S	2.0	13	0.10	0.35
Brachystegia boehmii Taub	Muyombo	Fabaceae	T	1.8	12	0.37	1.38
Grewia bicolor Juss	Mtapwiche	Tiliaceae	S	1.8	11	0.13	0.50
Commiphora africana (A. Rich.) Engl	Mkorolakoo	Burseraceae	S	1.7	11	0.30	0.76
Dalbergia melanoxylon Guill. & Perr	Mpingo	Fabaceae	T	1.6	10	0.59	0.92
Hymenocardia mollis Pax	Mpala	Euphorbiaceae	T	1.6	10	0.09	0.30
Tamarindus indica L	Mkwaju	Fabaceae	T	1.5	9	0.33	0.43

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Combretum adenogonium Steud. ex A. Rich	Mnondoto/ Muhindila	Combretaceae	S	1.4	9	0.11	0.81
Lannea stuhlmannii (Engl.) Engl	Mpwipwi	Anacardiaceae	T	1.4	9	0.28	0.68
Acacia robusta Burch	Muhungo/ Mngung'o	Fabaceae	T	1.3	8	0.40	0.95
Combretum zeyheri Sond	Tepeliwaile/ Nakapwee	Combretaceae	T	1.2	8	0.09	0.41
Stereospermum kunthianum Cham	Mpindibago	Bignoniaceae	T	1.2	8	0.29	0.66
Terminalia sambesiaca Engl. & Diels	Mkulyungu	Combretaceae	T	1.2	8	0.42	0.51
Acacia nigrescens Oliv.	Msengele	Fabaceae	T	1.1	7	0.27	0.69
Bauhinia petersiana Bolle	Nng'ekea	Fabaceae	S	1.1	7	0.08	0.29
Carpodiptera africana Mast	Mpweke	Malvaceae	T	1.1	7	0.05	0.22
Dichrostachys cinerea (L.) Wight & Arn	Mkungati	Fabaceae	T	1.1	7	0.02	0.23
Ochna holstii Engl	Mnungamo	Ochnaceae	T	1.1	7	0.05	0.46
Bridelia cathartica Bertol	Mnong'omela	Phyllanthaceae	T	1.0	7	0.04	0.40
Catunaregam spinosa (Thunb.) Tirveng	Ng'ochangoko	Rubiaceae	S	0.9	6	0.03	0.33
Allophylus rubifolius (Hochst. ex A. Rich.) Engl	Mpaya/Mjavuu	Sapindaceae	S	0.8	5	0.02	0.15
Lonchocarpus capassa Rolfe	Mkonya	Fabaceae	T	0.8	5	0.13	0.34
Millettia dura Dunn	Mpande	Fabaceae	S	0.8	5	0.11	0.21
Uvaria welwitschii (Hiern) Engl. & Diels	Msofu	Annonaceae	S	0.8	5	0.02	0.11
Xeroderris stuhlmannii (Taub.) Mendonça & E. C. Sousa	Mtumbatimlima	Fabaceae	T	0.8	5	0.23	0.46
Albizia harveyi E. Fourn.	Mjande	Fabaceae	T	0.7	4	0.12	0.27
Diospyros kirkii Hiern	Mhelela	Ebenaceae	T	0.7	4	0.06	0.30
Ehretia stuhlmannii Gürke	Chifakata/Kitagata	Boraginaceae	S	0.7	5	0.02	0.18
Bombax rhodognaphalon K. Schum	Msufipori	Bombacaceae	T	0.6	4	0.16	0.20
Canthium oligocarpum Hiern	Mchongawiko	Rubiaceae	S	0.6	4	0.02	0.12
Commiphora eminii Engl.	Mkolora	Burseraceae	T	0.6	4	0.03	0.13

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Diospyros mespiliformis Hochst. ex A. DC.	Mdaha	Ebenaceae	T	0.6	4	0.04	0.13
Holarrhena pubescens (Buch.-Ham.) Wall. ex G. Don	Mvelevele	Apocynaceae	S	0.6	4	0.04	0.16
Lonchocarpus eriocalyx Harms	Mnyamwezi	Fabaceae	T	0.6	4	0.08	0.20
Oxystigma msoo Harms	Msosonga	Fabaceae	T	0.6	4	0.08	0.15
Afzelia quanzensis Welw.	Mtamaa	Fabaceae	T	0.5	3	0.14	0.19
Dombeya acutangula Cav	Mkwelengala	Malvaceae	T	0.5	3	0.02	0.12
Ehretia amoena Klotzsch	Mkakatale/Mkilika/Chitagata	Boraginaceae	S	0.5	3	0.02	0.14
Grewia platyclada K. Schum	Mtapwiche	Tiliaceae	S	0.5	3	0.02	0.09
Acacia hockii De Wild	Mtarara/ Nnyenye	Fabaceae	S	0.4	3	0.02	0.10
Cylicomorpha parviflora Urb.	Mtogodume	Caricaceae	T	0.4	3	0.01	0.08
Erythroxylum emarginatum Thonn.	Msaluti	Erythroxylaceae	T	0.4	3	0.01	0.12
Grewia similis K. Schum	Mchiu	Tiliaceae	S	0.4	3	0.02	0.07
Lecaniodiscus fraxinifolius Baker	Mbwewe	Sapindaceae	T	0.4	3	0.02	0.07
Spermacoce assurgens Ruiz & Pav.	Mbeja	Rubiaceae	S	0.4	3	0.11	0.19
Balanites aegyptiaca (L.) Delile	Mwambangoma/Mduguya	Zygophyllaceae	T	0.3	2	0.02	0.09
Dalbergia nitidula Baker	Mulengwe	Fabaceae	T	0.3	2	0.01	0.19
Deinbollia borbonica f. glabrata Radlk.	Mdalamwaka/Mpugamahoke	Sapindaceae	T	0.3	2	0.01	0.06
Diospyros abyssinica (Hiern) F. White	Mlindimila	Ebenaceae	T	0.3	2	0.01	0.05
Dobera loranthifolia (Warb.) Harms	Mswaki/ Mtele	Salvadoraceae	T	0.3	2	0.11	0.17
Julbernardia globiflora (Benth.) Troupin	Mowe	Fabaceae	T	0.3	2	0.20	0.22
Lannea humilis (Oliv.) Engl.	Kipwipwi	Anacardiaceae	S	0.3	2	0.02	0.10
Lonchocarpus bussei Harms	Chigwaja	Fabaceae	T	0.3	2	0.02	0.11
Manilkara mochisia (Baker) Dubard	Mwakala	Sapotaceae	S	0.3	2	0.02	0.03
Margaritaria discoidea (Baill.) G.L. Webster	Mumihyo	Euphorbiaceae	S	0.3	2	0.02	0.09

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Maytenus lancifolia (Thonn.) Loes.	Mpapala	Celastraceae	S	0.3	2	0.01	0.05
Ptaeroxylon obliquum (Thunb.) Radlk	Unknown	Ptaeroxylaceae	S	0.3	2	0.02	0.06
Strychnos innocua Delile	Ngaja/Mlungulungu	Loganiaceae	S	0.3	2	0.02	0.09
Terminalia sericea Burch. ex DC.	Mchuya	Combretaceae	T	0.3	2	0.09	0.30
Boscia salicifolia Oliv	Mtukuli	Capparaceae	T	0.2	1	0.01	0.06
Dalbergia boehmii Taub	Mzeza	Fabaceae	T	0.2	1	0.03	0.09
Dombeya rotundifolia (Hochst.) Planch	Mchiu	Malvaceae	T	0.2	2	0.02	0.15
Ehretia silvatica Gürke	Mkakala	Boraginaceae	T	0.2	1	0.02	0.06
Euphorbia candelabrum Trémaux ex Kotschy	Mpangapanga, Mlangati	Euphorbiaceae	T	0.2	2	0.10	0.08
Haplocoelum inoploeum Radlk	Mjengo	Sapindaceae	T	0.2	1	0.00	0.03
Pterocarpus chrysothrix Taub	Mtumbatibonde	Fabaceae	T	0.2	1	0.02	0.04
Pterocarpus rotundifolius (Sond.) Druce	Mtumbati	Fabaceae	T	0.2	1	0.10	0.09
Rytigynia uhligii (K. Schum. & K. Krause) Verdc	Mmbapa/ Mtulavula	Rubiaceae	S	0.2	1	0.00	0.04
Sclerocarya birrea (A. Rich.) Hochst.	Mng'ongo	Anacardiaceae	T	0.2	1	0.01	0.05
Ziziphus mucronata Willd.	Mpiripiri	Rhamnaceae	S	0.2	1	0.01	0.05
Acacia goetzei Harms	Msengele	Fabaceae	T	0.1	1	0.01	0.11
Adansonia digitata L	Mbuyu	Bombacaceae	T	0.1	1	0.24	0.48
Albizia lebbeck (L.) Benth	Uturubani	Fabaceae	T	0.1	1	0.19	0.12
Antidesma venosum E. Mey. ex Tul.	Mhale	Euphorbiaceae	S	0.1	1	0.02	0.05
Cassine aethiopica Thunb	Mtugulu/ Mlimbolimbo	Celastraceae	T	0.1	1	0.02	0.04
Chrysophyllum gorungosanum Engl.	Mlembelembe	Sapotaceae	T	0.1	1	0.00	0.01
Rotheca myricoides (Hochst.) Steane & Mabb	Mpugamizuka	Lamiaceae	S	0.1	1	0.00	0.02
Combretum padoides Engl. & Diels	Mkungulungo	Combretaceae	S	0.1	1	0.01	0.02
Combretum schumannii Engl	Mkolyongo	Combretaceae	S	0.1	1	0.01	0.04

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Erythrococca kirkii (Müll. Arg.) Prain	Chifakata/Kitagata	Euphorbiaceae	S	0.1	1	0.00	0.02
Grewia holstii Burret	Mnunje	Tiliaceae	S	0.1	1	0.01	0.03
Grewia monticola Sond	Mng'elela	Tiliaceae	S	0.1	1	0.00	0.02
Grewia trichocarpa Hochst. ex A. Rich	Mkolamakaa	Tiliaceae	S	0.1	1	0.01	0.03
Lannea fulva (Engl.) Engl.	Mchengachenga	Anacardiaceae	T	0.1	1	0.02	0.03
Markhamia obtusifolia (Baker) Sprague	Mpugupugu	Bignoniaceae	T	0.1	1	0.00	0.02
Milicia excelsa (Welw.) C.C. Berg	Mvule	Moraceae	T	0.1	1	0.01	0.01
Piliostigma thonningii (Schumach.) Milne-Redh	Msigisi	Fabaceae	T	0.1	1	0.04	0.05
Pterocarpus angolensis DC.	Mtumbati	Fabaceae	T	0.1	1	0.04	0.10
Ricinodendron gracilius Mildbr	Mtene	Euphorbiaceae	T	0.1	1	0.06	0.07
Rytigynia celastroides (Baill.) Verdc	Mkokomlima	Rubiaceae	S	0.1	1	0.00	0.01
Schrebera alata (Hochst.) Welw	Machanjere	Oleaceae	T	0.1	1	0.01	0.03
Sericanthe odoratissima (K. Schum.) Robbr	Kahawamwitu	Rubiaceae	S	0.1	1	0.00	0.02
Sterculia quinqueloba (Garcke) K. Schum	Mn'guja/ Munane	Sterculiaceae	T	0.1	1	0.03	0.09
Suregada zanzibariensis Baill	Mdimupori	Euphorbiaceae	S	0.1	1	0.01	0.03
Zanthoxylum chalybeum Engl	Mlungulungu	Rutaceae	S	0.1	1	0.01	0.02
Acacia pentagona (Schumach. & Thonn.) Hook. F	Murhuu	Fabaceae	S	0.0	0	0.00	0.01
Acacia polyacantha Willd	Mkwanga/ Mlonga	Fabaceae	T	0.0	0	0.01	0.02
Annona senegalensis Pers.	Mtope	Annonaceae	S	0.0	0	0.00	0.04
Azanza garckeana (F. Hoffm.) Exell & Hillc	Mutogho	Malvaceae	T	0.0	0	0.00	0.01
Brachystegia spiciformis Benth.	Mtondo	Fabaceae	T	0.0	0	0.00	0.01
Commiphora boiviniana Engl.	Mpome	Burseraceae	T	0.0	0	0.00	0.01
Dalbergia obovata E. Mey	Unknown	Fabaceae	S	0.0	0	0.01	0.02
Dichrostachys glomerata (Forssk.) Chiov	Mgegela	Fabaceae	T	0.0	0	0.00	0.01

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Diospyros squarrosa Klotzsch	Mpeke	Ebenaceae	S	0.0	0	0.00	0.01
Hyphaene compressa H. Wendl.	Mlala/mkoche	Arecaceae	T	0.0	0	0.01	0.06
Millettia usaramensis Taub. var. usaramensis	Mpande	Fabaceae	T	0.0	0	0.00	0.01
Ochna mossambicensis Klotzsch	Muhindama	Ochnaceae	T	0.0	0	0.00	0.02
Pteleopsis sp.	Mtachi	Combretaceae	S	0.0	0	0.00	0.01
Sterculia africana (Lour.) Fiori var. africana	Miza	Sterculiaceae	T	0.0	0	0.04	0.03
Trachylobium verrucosum (Gaerth) Oliv	Mkumbo	Fabaceae	T	0.0	0	0.00	0.01
Vepris simplicifolia (Engl.) Mziray	Mndizi	Rutaceae	S	0.0	0	0.00	0.01
Ximenia caffra Sond	Mpingi	Olacaceae	S	0.0	0	0.00	0.02
Zanha africana (Radlk.) Exell	Muranga	Sapindaceae	T	0.0	0	0.01	0.03

T= Tree, S= Shrubs/ small tree

Appendix 2: Checklist of tree and shrub species recorded in NSFR arranged in descending order as per their density (stem ha^{-1})

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Hymenocardia ulmoides Oliv	Mtoto	Euphorbiaceae	T	9.0	58	0.45	1.44
Spirostachys africana Sond	Msagawi	Euphorbiaceae	T	8.3	53	0.89	2.78
Markhamia lutea (Benth.) K. Schum	Mtandawala	Bignoniaceae	T	5.2	33	0.35	1.23
Isoberlinia globiflora (Benth.) Hutch. ex Greenway	Mtupa	Fabaceae	T	4.9	32	0.66	2.25
Pseudolachnostylis maprouneifolia Pax	Msolo	Euphorbiaceae	T	4.0	24	0.51	0.09
Combretum molle (Klotzsch) Engl. & Diels	Kimbala	Combretaceae	T	3.8	24	0.37	1.47
Strychnos spinosa Lam.	Muhaja	Loganiaceae	S	3.4	22	0.68	1.39
Terminalia mollis M. A. Lawson	Mkuliungu	Combretaceae	T	3.2	20	0.39	2.01
Crossopteryx febrifuga (Afzel. ex G. Don) Benth.	Mchenjele	Rubiaceae	T	2.9	18	0.43	2.02
Diplorhynchus mossambicensis Benth. ex Oliv.	Mtogo	Apocynaceae	T	2.5	16	0.21	1.13
Pteleopsis myrtifolia (M. A. Lawson) Engl. & Diels	Mnepa	Combretaceae	T	2.5	16	0.51	1.02
Combretum collinum Fresen	Mkolowanje	Combretaceae	T	2.3	15	0.27	1.15
Diospyros kabuyeana F. White	Mkolyongo	Ebenaceae	S	2.0	13	0.10	0.35
Brachystegia boehmii Taub	Muyombo	Fabaceae	T	1.8	12	0.37	1.38
Grewia bicolor Juss	Mtapwiche	Tiliaceae	S	1.8	11	0.13	0.50
Commiphora africana (A. Rich.) Engl	Mkorolakoo	Burseraceae	S	1.7	11	0.30	0.76
Dalbergia melanoxylon Guill. & Perr	Mpingo	Fabaceae	T	1.6	10	0.59	0.92
Hymenocardia mollis Pax	Mpala	Euphorbiaceae	T	1.6	10	0.09	0.30
Tamarindus indica L	Mkwaju	Fabaceae	T	1.5	9	0.33	0.43
Combretum adenogonium Steud. ex A. Rich	Mnondoto/ Muhindila	Combretaceae	S	1.4	9	0.11	0.81
Lannea stuhlmannii (Engl.) Engl	Mpwipwi	Anacardiaceae	T	1.4	9	0.28	0.68
Acacia robusta Burch	Muhungo/ Mngung'o	Fabaceae	T	1.3	8	0.40	0.95

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Combretum zeyheri Sond	Tepeliwaile/ Nakapwee	Combretaceae	T	1.2	8	0.09	0.41
Stereospermum kunthianum Cham	Mpindibago	Bignoniaceae	T	1.2	8	0.29	0.66
Terminalia sambesiaca Engl. & Diels	Mkulyungu	Combretaceae	T	1.2	8	0.42	0.51
Acacia nigrescens Oliv.	Msengele	Fabaceae	T	1.1	7	0.27	0.69
Bauhinia petersiana Bolle	Nng'ekea	Fabaceae	S	1.1	7	0.08	0.29
Carpodiptera africana Mast	Mpweke	Malvaceae	T	1.1	7	0.05	0.22
Dichrostachys cinerea (L.) Wight & Arn	Mkungati	Fabaceae	T	1.1	7	0.02	0.23
Ochna holstii Engl	Mnungamo	Ochnaceae	T	1.1	7	0.05	0.46
Bridelia cathartica Bertol	Mnong'omela	Phyllanthaceae	T	1.0	7	0.04	0.40
Catunaregam spinosa (Thunb.) Tirveng	Ng'ochangoko	Rubiaceae	S	0.9	6	0.03	0.33
Allophylus rubifolius (Hochst. ex A. Rich.) Engl	Mpaya/Mjavuu	Sapindaceae	S	0.8	5	0.02	0.15
Lonchocarpus capassa Rolfe	Mkonya	Fabaceae	T	0.8	5	0.13	0.34
Millettia dura Dunn	Mpande	Fabaceae	S	0.8	5	0.11	0.21
Uvaria welwitschii (Hiern) Engl. & Diels	Msofu	Annonaceae	S	0.8	5	0.02	0.11
Xeroderris stuhlmannii (Taub.) Mendonça & E. C. Sousa	Mtumbatimlima	Fabaceae	T	0.8	5	0.23	0.46
Ehretia stuhlmannii Gürke	Chifakata/Kitagata	Boraginaceae	S	0.7	5	0.02	0.18
Albizia harveyi E. Fourn.	Mjande	Fabaceae	T	0.7	4	0.12	0.27
Diospyros kirkii Hiern	Mhelela	Ebenaceae	T	0.7	4	0.06	0.30
Bombax rhodognaphalon K. Schum	Msufipori	Bombacaceae	T	0.6	4	0.16	0.20
Canthium oligocarpum Hiern	Mchongawiko	Rubiaceae	S	0.6	4	0.02	0.12
Commiphora eminii Engl.	Mkolora	Burseraceae	T	0.6	4	0.03	0.13
Diospyros mespiliformis Hochst. ex A. DC.	Mdaha	Ebenaceae	T	0.6	4	0.04	0.13
Holarrhena pubescens (Buch.-Ham.) Wall. ex G. Don	Mvelevele	Apocynaceae	S	0.6	4	0.04	0.16
Lonchocarpus eriocalyx Harms	Mnyamwezi	Fabaceae	T	0.6	4	0.08	0.20
Oxystigma msoo Harms	Msosonga	Fabaceae	T	0.6	4	0.08	0.15

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Afzelia quanzensis Welw.	Mtamaa	Fabaceae	T	0.5	3	0.14	0.19
Dombeya acutangula Cav	Mkwelengala	Malvaceae	T	0.5	3	0.02	0.12
Ehretia amoena Klotzsch	Mkakatale/Mkilika/Chitagata	Boraginaceae	S	0.5	3	0.02	0.14
Grewia platyclada K. Schum	Mtapwiche	Tiliaceae	S	0.5	3	0.02	0.09
Acacia hockii De Wild	Mtarara/ Nnyenye	Fabaceae	S	0.4	3	0.02	0.10
Cylicomorpha parviflora Urb.	Mtogodume	Caricaceae	T	0.4	3	0.01	0.08
Erythroxylum emarginatum Thonn.	Msaluti	Erythroxylaceae	T	0.4	3	0.01	0.12
Lecaniodiscus fraxinifolius Baker	Mbwewe	Sapindaceae	T	0.4	3	0.02	0.07
Spermacoce assurgens Ruiz & Pav.	Mbeja	Rubiaceae	S	0.4	3	0.11	0.19
Balanites aegyptiaca (L.) Delile	Mwambangoma/Mduguya	Zygophyllaceae	T	0.3	2	0.02	0.09
Dalbergia nitidula Baker	Mulengwe	Fabaceae	T	0.3	2	0.01	0.19
Deinbollia borbonica f. glabrata Radlk.	Mdalamwaka/Mpugamahoke	Sapindaceae	T	0.3	2	0.01	0.06
Diospyros abyssinica (Hiern) F. White	Mlindimila	Ebenaceae	T	0.3	2	0.01	0.05
Dobera loranthifolia (Warb.) Harms	Mswaki/ Mtele	Salvadoraceae	T	0.3	2	0.11	0.17
Julbernardia globiflora (Benth.) Troupin	Mowe	Fabaceae	T	0.3	2	0.20	0.22
Lannea humilis (Oliv.) Engl.	Kipwipwi	Anacardiaceae	S	0.3	2	0.02	0.10
Lonchocarpus bussei Harms	Chigwaja	Fabaceae	T	0.3	2	0.02	0.11
Manilkara mochisia (Baker) Dubard	Mwakala	Sapotaceae	S	0.3	2	0.02	0.03
Margaritaria discoidea (Baill.) G.L. Webster	Mumihyo	Euphorbiaceae	S	0.3	2	0.02	0.09
Maytenus lancifolia (Thonn.) Loes.	Mpapala	Celastraceae	S	0.3	2	0.01	0.05
Ptaeroxylon obliquum (Thunb.) Radlk	Unknown	Ptaeroxylaceae	S	0.3	2	0.02	0.06
Strychnos innocua Delile	Ngaja/Mlungulungu	Loganiaciae	S	0.3	2	0.02	0.09
Terminalia sericea Burch. ex DC.	Mchuya	Combretaceae	T	0.3	2	0.09	0.30
Dombeya rotundifolia (Hochst.) Planch	Mchiu	Malvaceae	T	0.2	2	0.02	0.15
Euphorbia candelabrum Trémaux ex Kotschy	Mpangapanga, Mlangati	Euphorbiaceae	T	0.2	2	0.10	0.08

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Boscia salicifolia Oliv	Mtukuli	Capparaceae	T	0.2	1	0.01	0.06
Dalbergia boehmii Taub	Mzeza	Fabaceae	T	0.2	1	0.03	0.09
Ehretia silvatica Gürke	Mkakala	Boraginaceae	T	0.2	1	0.02	0.06
Haplocoelum inoploeum Radlk	Mjengo	Sapindaceae	T	0.2	1	0.00	0.03
Pterocarpus chrysothrix Taub	Mtumbatibonde	Fabaceae	T	0.2	1	0.02	0.04
Pterocarpus rotundifolius (Sond.) Druce	Mtumbati	Fabaceae	T	0.2	1	0.10	0.09
Rytigynia uhligii (K. Schum. & K. Krause) Verdc	Mmbapa/ Mtulavula	Rubiaceae	S	0.2	1	0.00	0.04
Sclerocarya birrea (A. Rich.) Hochst.	Mng'ongo	Anacardiaceae	T	0.2	1	0.01	0.05
Ziziphus mucronata Willd.	Mpiripiri	Rhamnaceae	S	0.2	1	0.01	0.05
Acacia goetzei Harms	Msengele	Fabaceae	T	0.1	1	0.01	0.11
Albizia lebbeck (L.) Benth	Uturubani	Fabaceae	T	0.1	1	0.19	0.12
Antidesma venosum E. Mey. ex Tul.	Mhale	Euphorbiaceae	S	0.1	1	0.02	0.05
Cassine aethiopica Thunb	Mtugulu/ Mlimbolimbo	Celastraceae	T	0.1	1	0.02	0.04
Chrysophyllum gorungosanum Engl.	Mlembelembe	Sapotaceae	T	0.1	1	0.00	0.01
Rotheca myricoides (Hochst.) Steane & Mabb	Mpugamizuka	Lamiaceae	S	0.1	1	0.00	0.02
Combretum padoides Engl. & Diels	Mkungulungo	Combretaceae	S	0.1	1	0.01	0.02
Combretum schumannii Engl	Mkolyongo	Combretaceae	S	0.1	1	0.01	0.04
Erythrococca kirkii (Müll. Arg.) Prain	Chifakata/Kitagata	Euphorbiaceae	S	0.1	1	0.00	0.02
Grewia holstii Burret	Mnunje	Tiliaceae	S	0.1	1	0.01	0.03
Grewia monticola Sond	Mng'elela	Tiliaceae	S	0.1	1	0.00	0.02
Grewia trichocarpa Hochst. ex A. Rich	Mkolamakaa	Tiliaceae	S	0.1	1	0.01	0.03
Lannea fulva (Engl.) Engl.	Mchengachenga	Anacardiaceae	T	0.1	1	0.02	0.03
Markhamia obtusifolia (Baker) Sprague	Mpugupugu	Bignoniaceae	T	0.1	1	0.00	0.02
Milicia excelsa (Welw.) C.C. Berg	Mvule	Moraceae	T	0.1	1	0.01	0.01

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Piliostigma thonningii (Schumach.) Milne-Redh	Msigisi	Fabaceae	T	0.1	1	0.04	0.05
Pterocarpus angolensis DC.	Mtumbati	Fabaceae	T	0.1	1	0.04	0.10
Ricinodendron gracilius Mildbr	Mtene	Euphorbiaceae	T	0.1	1	0.06	0.07
Rytigynia celastroides (Baill.) Verdc	Mkokomlima	Rubiaceae	S	0.1	1	0.00	0.01
Schrebera alata (Hochst.) Welw	Machanjere	Oleaceae	T	0.1	1	0.01	0.03
Sericanthe odoratissima (K. Schum.) Robbr	Kahawamwitu	Rubiaceae	S	0.1	1	0.00	0.02
Sterculia quinqueloba (Garcke) K. Schum	Mn'guja/ Munane	Sterculiaceae	T	0.1	1	0.03	0.09
Suregada zanzibariensis Baill	Mdimupori	Euphorbiaceae	S	0.1	1	0.01	0.03
Zanthoxylum chalybeum Engl	Mlungulungu	Rutaceae	S	0.1	1	0.01	0.02
Acacia pentagona (Schumach. & Thonn.) Hook. f	Murhuu	Fabaceae	S	0.0	0	0.00	0.01
Acacia polyacantha Willd	Mkwanga/ Mlonga	Fabaceae	T	0.0	0	0.01	0.02
Annona senegalensis Pers.	Mtope	Annonaceae	S	0.0	0	0.00	0.04
Azanza garckeana (F. Hoffm.) Exell & Hillc	Mutogho	Malvaceae	T	0.0	0	0.00	0.01
Brachystegia spiciformis Benth.	Mtondo	Fabaceae	T	0.0	0	0.00	0.01
Commiphora boiviniana Engl.	Mpome	Burseraceae	T	0.0	0	0.00	0.01
Dalbergia obovata E. Mey	Unknown	Fabaceae	S	0.0	0	0.01	0.02
Dichrostachys glomerata (Forssk.) Chiov	Mgegela	Fabaceae	T	0.0	0	0.00	0.01
Diospyros squarrosa Klotzsch	Mpeke	Ebenaceae	S	0.0	0	0.00	0.01
Hyphaene compressa H. Wendl.	Mlala/mkoche	Arecaceae	T	0.0	0	0.01	0.06
Millettia usaramensis Taub. var. usaramensis	Mpande	Fabaceae	T	0.0	0	0.00	0.01
Ochna mossambicensis Klotzsch	Muhindama	Ochnaceae	T	0.0	0	0.00	0.02
Pteleopsis sp.	Mtachi	Combretaceae	S	0.0	0	0.00	0.01
Sterculia africana (Lour.) Fiori var. africana	Miza	Sterculiaceae	T	0.0	0	0.04	0.03

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Trachylobium verrucosum (Gaerth) Oliv	Mkumbo	Fabaceae	T	0.0	0	0.00	0.01
Vepris simplicifolia (Engl.) Mziray	Mndizi	Rutaceae	S	0.0	0	0.00	0.01
Ximenia caffra Sond	Mpingi	Olacaceae	S	0.0	0	0.00	0.02
Zanha africana (Radlk.) Exell	Muranga	Sapindaceae	T	0.0	0	0.01	0.03

T= Tree, S= Shrubs/ small tree

Appendix 3: Checklist of tree and shrub species recorded in NSFR arranged in descending order as per their basal area (G) (m^2 ha^{-1})

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Dalbergia melanoxylon Guill. & Perr	Mpingo	Fabaceae	T	1.6	10	0.59	0.92
Pseudolachnostylis maprouneifolia Pax	Msolo	Euphorbiaceae	T	4.0	24	0.51	0.09
Pteleopsis myrtifolia(M. A. Lawson) Engl. & Diels	Mnepa	Combretaceae	T	2.5	16	0.51	1.02
Hymenocardia ulmoides Oliv	Mtoto	Euphorbiaceae	T	9.0	58	0.45	1.44
Crossopteryx febrifuga (Afzel. ex G. Don) Benth.	Mchenjele	Rubiaceae	T	2.9	18	0.43	2.02
Terminalia sambesiaca Engl. & Diels	Mkulyungu	Combretaceae	T	1.2	8	0.42	0.51
Acacia Robusta Burch	Muhungo/ Mngung'o	Fabaceae	T	1.3	8	0.40	0.95
Terminalia mollis M. A. Lawson	Mkuliungu	Combretaceae	T	3.2	20	0.39	2.01
Combretum molle(Klotzsch) Engl. & Diels	Kimbala	Combretaceae	T	3.8	24	0.37	1.47
Brachystegia boehmii Taub	Muyombo	Fabaceae	T	1.8	12	0.37	1.38
Markhamia lutea (Benth.) K. Schum	Mtandawala	Bignoniaceae	T	5.2	33	0.35	1.23
Tamarindus indica L	Mkwaju	Fabaceae	T	1.5	9	0.33	0.43
Commiphora africana (A. Rich.) Engl	Mkorolakoo	Burseraceae	S	1.7	11	0.30	0.76
Stereospermum kunthianum Cham	Mpindibago	Bignoniaceae	T	1.2	8	0.29	0.66
Lannea stuhlmannii (Engl.) Engl	Mpwipwi	Anacardiaceae	T	1.4	9	0.28	0.68
Combretum collinum Fresen	Mkolowanje	Combretaceae	T	2.3	15	0.27	1.15
Acacia nigrescens Oliv.	Msengele	Fabaceae	T	1.1	7	0.27	0.69
Adansonia digitata L	Mbuyu	Bombacaceae	T	0.1	1	0.24	0.48
Xeroderris stuhlmannii (Taub.) Mendonça & E. C. Sousa	Mtumbatimlima	Fabaceae	T	0.8	5	0.23	0.46
Diplorhynchus mossambicensis Benth. ex Oliv.	Mtogo	Apocynaceae	T	2.5	16	0.21	1.13
Julbernardia globiflora (Benth.) Troupin	Mowe	Fabaceae	T	0.3	2	0.20	0.22
Albizia lebbeck (L.) Benth	Uturubani	Fabaceae	T	0.1	1	0.19	0.12

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Bombax rhodognaphalon K. Schum	Msufipori	Bombacaceae	T	0.6	4	0.16	0.20
Afzelia quanzensis Welw.	Mtamaa	Fabaceae	T	0.5	3	0.14	0.19
Grewia bicolor Juss	Mtapwiche	Tiliaceae	S	1.8	11	0.13	0.50
Lonchocarpus capassa Rolfe	Mkonya	Fabaceae	T	0.8	5	0.13	0.34
Albizia harveyi E. Fourn.	Mjande	Fabaceae	T	0.7	4	0.12	0.27
Combretum adenogonium Steud. ex A. Rich	Mnondoto/ Muhindila	Combretaceae	S	1.4	9	0.11	0.81
Millettia dura Dunn	Mpande	Fabaceae	S	0.8	5	0.11	0.21
Spermacoce assurgens Ruiz & Pav.	Mbeja	Rubiaceae	S	0.4	3	0.11	0.19
Dobera loranthifolia (Warb.) Harms	Mswaki/ Mtele	Salvadoraceae	T	0.3	2	0.11	0.17
Diospyros kabuyeana F. White	Mkolyongo	Ebenaceae	S	2.0	13	0.10	0.35
Euphorbia candelabrum Trémaux ex Kotschy	Mpangapanga, Mlangati	Euphorbiaceae	T	0.2	2	0.10	0.08
Pterocarpus rotundifolius (Sond.) Druce	Mtumbati	Fabaceae	T	0.2	1	0.10	0.09
Hymenocardia mollis Pax	Mpala	Euphorbiaceae	T	1.6	10	0.09	0.30
Combretum zeyheri Sond	Tepeliwaile/ Nakapwee	Combretaceae	T	1.2	8	0.09	0.41
Terminalia sericea Burch. ex DC.	Mchuya	Combretaceae	T	0.3	2	0.09	0.30
Bauhinia petersiana Bolle	Nng'ekea	Fabaceae	S	1.1	7	0.08	0.29
Lonchocarpus eriocalyx Harms	Mnyamwezi	Fabaceae	T	0.6	4	0.08	0.20
Oxystigma msoo Harms	Msosonga	Fabaceae	T	0.6	4	0.08	0.15
Diospyros kirkii Hiern	Mhelela	Ebenaceae	T	0.7	4	0.06	0.30
Ricinodendron gracilius Mildbr	Mtene	Euphorbiaceae	T	0.1	1	0.06	0.07
Carpodiptera africana Mast	Mpweke	Malvaceae	T	1.1	7	0.05	0.22
Ochna holstii Engl	Mnungamo	Ochnaceae	T	1.1	7	0.05	0.46
Bridelia cathartica Bertol	Mnong'omela	Phyllanthaceae	T	1.0	7	0.04	0.40
Diospyros mespiliformis Hochst. Ex A. DC.	Mdaha	Ebenaceae	T	0.6	4	0.04	0.13

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Holarrhena pubescens (Buch.-Ham.) Wall. ex G. Don	Mvelevele	Apocynaceae	S	0.6	4	0.04	0.16
Piliostigma thonningii (Schumach.) Milne-Redh	Msigisi	Fabaceae	T	0.1	1	0.04	0.05
Pterocarpus angolensis DC.	Mtumbati	Fabaceae	T	0.1	1	0.04	0.10
Sterculia africana (Lour.) Fiori var. africana	Miza	Sterculiaceae	T	0.0	0	0.04	0.03
Catunaregam spinosa (Thunb.) Tirveng	Ng'ochangoko	Rubiaceae	S	0.9	6	0.03	0.33
Commiphora eminii Engl.	Mkolora	Burseraceae	T	0.6	4	0.03	0.13
Dalbergia boehmii Taub	Mzeza	Fabaceae	T	0.2	1	0.03	0.09
Sterculia quinqueloba(Garcke) K. Schum	Mn'guja/ Munane	Sterculiaceae	T	0.1	1	0.03	0.09
Dichrostachys cinerea (L.) Wight & Arn	Mkungati	Fabaceae	T	1.1	7	0.02	0.23
Allophylus rubifolius (Hochst. ex A. Rich.) Engl	Mpaya/Mjavuu	Sapindaceae	S	0.8	5	0.02	0.15
Uvaria welwitschii(Hiern) Engl. & Diels	Msofu	Annonaceae	S	0.8	5	0.02	0.11
Ehretia stuhlmannii Gürke	Chifakata/Kitagata	Boraginaceae	S	0.7	5	0.02	0.18
Canthium oligocarpum Hiern	Mchongawiko	Rubiaceae	S	0.6	4	0.02	0.12
Dombeya acutangula Cav	Mkwelengala	Malvaceae	T	0.5	3	0.02	0.12
Ehretia amoena Klotzsch	Mkakatale/Mkilika/Chitagata	Boraginaceae	S	0.5	3	0.02	0.14
Grewia platyclada K. Schum	Mtapwiche	Tiliaceae	S	0.5	3	0.02	0.09
Acacia hockii De Wild	Mtarara/ Nnyenye	Fabaceae	S	0.4	3	0.02	0.10
Grewia similis K. Schum	Mchiu	Tiliaceae	S	0.4	3	0.02	0.07
Lecaniodiscus fraxinifolius Baker	Mbwewe	Sapindaceae	T	0.4	3	0.02	0.07
Balanites aegyptiaca (L.) Delile	Mwambangoma/Mduguya	Zygophyllaceae	T	0.3	2	0.02	0.09
Lannea humilis (Oliv.) Engl.	Kipwipwi	Anacardiaceae	S	0.3	2	0.02	0.10
Lonchocarpus bussei Harms	Chigwaja	Fabaceae	T	0.3	2	0.02	0.11
Manilkara mochisia(Baker) Dubard	Mwakala	Sapotaceae	S	0.3	2	0.02	0.03
Margaritaria discoidea (Baill.) G.L. Webster	Mumihyo	Euphorbiaceae	S	0.3	2	0.02	0.09
Ptaeroxylon obliquum (Thunb.) Radlk	Unknown	Ptaeroxylaceae	S	0.3	2	0.02	0.06

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Strychnos innocua Delile	Ngaja/Mlungulungu	Loganiaceae	S	0.3	2	0.02	0.09
Dombeya rotundifolia (Hochst.) Planch	Mchiu	Malvaceae	T	0.2	2	0.02	0.15
Ehretia silvatica Gürke	Mkakala	Boraginaceae	T	0.2	1	0.02	0.06
Pterocarpus chrysothrix Taub	Mtumbatibonde	Fabaceae	T	0.2	1	0.02	0.04
Antidesma venosum E. Mey. ex Tul.	Mhale	Euphorbiaceae	S	0.1	1	0.02	0.05
Cassine aethiopica Thunb	Mtugulu/ Mlimbolimbo	Celastraceae	T	0.1	1	0.02	0.04
Lannea fulva(Engl.) Engl.	Mchengachenga	Anacardiaceae	T	0.1	1	0.02	0.03
Cylicomorpha parviflora Urb.	Mtogodume	Caricaceae	T	0.4	3	0.01	0.08
Erythroxylum emarginatum Thonn.	Msaluti	Erythroxylaceae	T	0.4	3	0.01	0.12
Dalbergia nitidula Baker	Mulengwe	Fabaceae	T	0.3	2	0.01	0.19
Deinbollia borbonica f. glabrata Radlk.	Mdalamwaka/Mpugamahoke	Sapindaceae	T	0.3	2	0.01	0.06
Diospyros abyssinica(Hiern) F. White	Mlindimila	Ebenaceae	T	0.3	2	0.01	0.05
Maytenus lancifolia (Thonn.) Loes.	Mpapala	Celastraceae	S	0.3	2	0.01	0.05
Boscia salicifolia Oliv	Mtukuli	Capparaceae	T	0.2	1	0.01	0.06
Sclerocarya birrea (A. Rich.) Hochst.	Mng'ongo	Anacardiaceae	T	0.2	1	0.01	0.05
Ziziphus mucronata Willd.	Mpiripiri	Rhamnaceae	S	0.2	1	0.01	0.05
Acacia goetzei Harms	Msengele	Fabaceae	T	0.1	1	0.01	0.11
Combretum padoides Engl. & Diels	Mkungulungo	Combretaceae	S	0.1	1	0.01	0.02
Combretum schumannii Engl	Mkolyongo	Combretaceae	S	0.1	1	0.01	0.04
Grewia holstii Burret	Mnunje	Tiliaceae	S	0.1	1	0.01	0.03
Grewia trichocarpa Hochst. ex A. Rich	Mkolamakaa	Tiliaceae	S	0.1	1	0.01	0.03
Milicia excelsa (Welw.) C.C. Berg	Mvule	Moraceae	T	0.1	1	0.01	0.01
Schrebera alata (Hochst.) Welw	Machanjere	Oleaceae	T	0.1	1	0.01	0.03
Suregada zanzibariensis Baill	Mdimupori	Euphorbiaceae	S	0.1	1	0.01	0.03

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Zanthoxylum chalybeum Engl	Mlungulungu	Rutaceae	S	0.1	1	0.01	0.02
Acacia polyacantha Willd	Mkwanga/ Mlonga	Fabaceae	T	0.0	0	0.01	0.02
Dalbergia obovata E. Mey	Unknown	Fabaceae	S	0.0	0	0.01	0.02
Hyphaene compressa H. Wendl.	Mlala/mkoche	Arecaceae	T	0.0	0	0.01	0.06
Zanha africana (Radlk.) Exell	Muranga	Sapindaceae	T	0.0	0	0.01	0.03
Haplocoelum inoploeum Radlk	Mjengo	Sapindaceae	T	0.2	1	0.00	0.03
Rytigynia uhligii (K. Schum. & K. Krause) Verdc	Mmbapa/ Mtulavula	Rubiaceae	S	0.2	1	0.00	0.04
Chrysophyllum gorungosanum Engl.	Mlembelembe	Sapotaceae	T	0.1	1	0.00	0.01
Rotheca myricoides (Hochst.) Steane & Mabb	Mpugamizuka	Lamiaceae	S	0.1	1	0.00	0.02
Erythrococca kirkii (Müll. Arg.) Prain	Chifakata/Kitagata	Euphorbiaceae	S	0.1	1	0.00	0.02
Grewia monticola Sond	Mng'elela	Tiliaceae	S	0.1	1	0.00	0.02
Markhamia obtusifolia(Baker) Sprague	Mpugupugu	Bignoniaceae	T	0.1	1	0.00	0.02
Rytigynia celastroides (Baill.) Verdc	Mkokomlima	Rubiaceae	S	0.1	1	0.00	0.01
Sericanthe odoratissima (K. Schum.) Robbr	Kahawamwitu	Rubiaceae	S	0.1	1	0.00	0.02
Acacia pentagona (Schumach. & Thonn.) Hook. f	Murhuu	Fabaceae	S	0.0	0	0.00	0.01
Annona senegalensis Pers.	Mtope	Annonaceae	S	0.0	0	0.00	0.04
Azanza garckeana (F. Hoffm.) Exell & Hillc	Mutogho	Malvaceae	T	0.0	0	0.00	0.01
Brachystegia spiciformis Benth.	Mtondo	Fabaceae	T	0.0	0	0.00	0.01
Commiphora boiviniana Engl.	Mpome	Burseraceae	T	0.0	0	0.00	0.01
Dichrostachys glomerata (Forssk.) Chiov	Mgegela	Fabaceae	T	0.0	0	0.00	0.01
Diospyros squarrosa Klotzsch	Mpeke	Ebenaceae	S	0.0	0	0.00	0.01
Millettia usaramensis Taub. var. usaramensis	Mpande	Fabaceae	T	0.0	0	0.00	0.01
Ochna mossambicensis Klotzsch	Muhindama	Ochnaceae	T	0.0	0	0.00	0.02
Pteleopsis sp.	Mtachi	Combretaceae	S	0.0	0	0.00	0.01

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Trachylobium verrucosum (Gaerth) Oliv	Mkumbo	Fabaceae	T	0.0	0	0.00	0.01
Vepris simplicifolia (Engl.) Mziray	Mndizi	Rutaceae	S	0.0	0	0.00	0.01
Ximenia caffra Sond	Mpingi	Olacaceae	T	0.0	0	0.00	0.02
Spirostachys africana Sond	Msagawi	Euphorbiaceae	T	8.3	53	0.89	2.78
Isoberlinia globiflora (Benth.) Hutch. ex Greenway	Mtupa	Fabaceae	T	4.9	32	0.66	2.25
Strychnos spinosa Lam.	Muhaja	Loganiaceae	S	3.4	22	0.68	1.39

T= Tree, S= Shrubs/ small tree

Appendix 4: Checklist of tree and shrub species recorded in NSFR arranged in descending order as per their Importance Value Index (IVI)

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Spirostachys africana Sond	Msagawi	Euphorbiaceae	T	8.3	53	0.89	2.78
Isoberlinia globiflora (Benth.) Hutch. ex Greenway	Mtupa	Fabaceae	T	4.9	32	0.66	2.25
Crossopteryx febrifuga (Afzel. ex G. Don) Benth.	Mchenjele	Rubiaceae	T	2.9	18	0.43	2.02
Terminalia mollis M. A. Lawson	Mkuliungu	Combretaceae	T	3.2	20	0.39	2.01
Combretum molle(Klotzsch) Engl. & Diels	Kimbala	Combretaceae	T	3.8	24	0.37	1.47
Hymenocardia ulmoides Oliv	Mtoto	Euphorbiaceae	T	9.0	58	0.45	1.44
Strychnos spinosa Lam.	Muhaja	Loganiaceae	S	3.4	22	0.68	1.39
Brachystegia boehmii Taub	Muyombo	Fabaceae	T	1.8	12	0.37	1.38
Markhamia lutea (Benth.) K. Schum	Mtandawala	Bignoniaceae	T	5.2	33	0.35	1.23
Combretum collinum Fresen	Mkolowanje	Combretaceae	T	2.3	15	0.27	1.15
Diplorhynchus mossambicensis Benth. ex Oliv.	Mtogo	Apocynaceae	T	2.5	16	0.21	1.13
Pteleopsis myrtifolia(M. A. Lawson) Engl. & Diels	Mnepa	Combretaceae	T	2.5	16	0.51	1.02
Acacia Robusta Burch	Muhungo/ Mngung'o	Fabaceae	T	1.3	8	0.40	0.95
Dalbergia melanoxylon Guill. & Perr	Mpingo	Fabaceae	T	1.6	10	0.59	0.92
Combretum adenogonium Steud. ex A. Rich	Mnondoto/ Muhindila	Combretaceae	S	1.4	9	0.11	0.81
Commiphora africana (A. Rich.) Engl	Mkorolakoo	Burseraceae	S	1.7	11	0.30	0.76
Acacia nigrescens Oliv.	Msengele	Fabaceae	T	1.1	7	0.27	0.69
Lannea stuhlmannii (Engl.) Engl	Mpwipwi	Anacardiaceae	T	1.4	9	0.28	0.68
Stereospermum kunthianum Cham	Mpindibago	Bignoniaceae	T	1.2	8	0.29	0.66
Terminalia sambesiaca Engl. & Diels	Mkulyungu	Combretaceae	T	1.2	8	0.42	0.51
Grewia bicolor Juss	Mtapwiche	Tiliaceae	S	1.8	11	0.13	0.50
Adansonia digitata L	Mbuyu	Bombacaceae	T	0.1	1	0.24	0.48

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Xeroderris stuhlmannii (Taub.) Mendonça & E. C. Sousa	Mtumbatimlima	Fabaceae	T	0.8	5	0.23	0.46
Ochna holstii Engl	Mnungamo	Ochnaceae	T	1.1	7	0.05	0.46
Tamarindus indica L	Mkwaju	Fabaceae	T	1.5	9	0.33	0.43
Combretum zeyheri Sond	Tepeliwaile/ Nakapwee	Combretaceae	T	1.2	8	0.09	0.41
Bridelia cathartica Bertol	Mnong'omela	Phyllanthaceae	T	1.0	7	0.04	0.40
Diospyros kabuyeana F. White	Mkolyongo	Ebenaceae	S	2.0	13	0.10	0.35
Lonchocarpus capassa Rolfe	Mkonya	Fabaceae	T	0.8	5	0.13	0.34
Catunaregam spinosa (Thunb.) Tirveng	Ng'ochangoko	Rubiaceae	S	0.9	6	0.03	0.33
Hymenocardia mollis Pax	Mpala	Euphorbiaceae	T	1.6	10	0.09	0.30
Terminalia sericea Burch. ex DC.	Mchuya	Combretaceae	T	0.3	2	0.09	0.30
Diospyros kirkii Hiern	Mhelela	Ebenaceae	T	0.7	4	0.06	0.30
Bauhinia petersiana Bolle	Nng'ekea	Fabaceae	S	1.1	7	0.08	0.29
Albizia harveyi E. Fourn.	Mjande	Fabaceae	T	0.7	4	0.12	0.27
Dichrostachys cinerea (L.) Wight & Arn	Mkungati	Fabaceae	T	1.1	7	0.02	0.23
Julbernardia globiflora (Benth.) Troupin	Mowe	Fabaceae	T	0.3	2	0.20	0.22
Carpodiptera africana Mast	Mpweke	Malvaceae	T	1.1	7	0.05	0.22
Millettia dura Dunn	Mpande	Fabaceae	S	0.8	5	0.11	0.21
Bombax rhodognaphalon K. Schum	Msufipori	Bombacaceae	T	0.6	4	0.16	0.20
Lonchocarpus eriocalyx Harms	Mnyamwezi	Fabaceae	T	0.6	4	0.08	0.20
Afzelia quanzensis Welw.	Mtamaa	Fabaceae	T	0.5	3	0.14	0.19
Spermacoce assurgens Ruiz & Pav.	Mbeja	Rubiaceae	S	0.4	3	0.11	0.19
Dalbergia nitidula Baker	Mulengwe	Fabaceae	T	0.3	2	0.01	0.19
Ehretia stuhlmannii Gürke	Chifakata/Kitagata	Boraginaceae	S	0.7	5	0.02	0.18
Dobera loranthifolia (Warb.) Harms	Mswaki/ Mtele	Salvadoraceae	T	0.3	2	0.11	0.17
Holarrhena pubescens (Buch.-Ham.) Wall. ex G. Don	Mvelevele	Apocynaceae	S	0.6	4	0.04	0.16

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Oxystigma msoo Harms	Msosonga	Fabaceae	T	0.6	4	0.08	0.15
Allophylus rubifolius (Hochst. ex A. Rich.) Engl	Mpaya/Mjavuu	Sapindaceae	S	0.8	5	0.02	0.15
Dombeya rotundifolia (Hochst.) Planch	Mchiu	Malvaceae	T	0.2	2	0.02	0.15
Ehretia amoena Klotzsch	Mkakatale/Mkilika/Chitagata	Boraginaceae	S	0.5	3	0.02	0.14
Diospyros mespiliformis Hochst. ex A. DC.	Mdaha	Ebenaceae	T	0.6	4	0.04	0.13
Commiphora eminii Engl.	Mkolora	Burseraceae	T	0.6	4	0.03	0.13
Albizia lebbeck (L.) Benth	Uturubani	Fabaceae	T	0.1	1	0.19	0.12
Canthium oligocarpum Hiern	Mchongawiko	Rubiaceae	S	0.6	4	0.02	0.12
Dombeya acutangula Cav	Mkwelengala	Malvaceae	T	0.5	3	0.02	0.12
Erythroxylum emarginatum Thonn.	Msaluti	Erythroxylaceae	T	0.4	3	0.01	0.12
Uvaria welwitschii(Hiern) Engl. & Diels	Msofu	Annonaceae	S	0.8	5	0.02	0.11
Lonchocarpus bussei Harms	Chigwaja	Fabaceae	T	0.3	2	0.02	0.11
Acacia goetzei Harms	Msengele	Fabaceae	T	0.1	1	0.01	0.11
Pterocarpus angolensis DC.	Mtumbati	Fabaceae	T	0.1	1	0.04	0.10
Acacia hockii De Wild	Mtarara/ Nnyenye	Fabaceae	S	0.4	3	0.02	0.10
Lannea humilis (Oliv.) Engl.	Kipwipwi	Anacardiaceae	S	0.3	2	0.02	0.10
Pseudolachnostylis maprouneifolia Pax	Msolo	Euphobiaceae	T	4.0	24	0.51	0.09
Pterocarpus rotundifolius (Sond.) Druce	Mtumbati	Fabaceae	T	0.2	1	0.10	0.09
Dalbergia boehmii Taub	Mzeza	Fabaceae	T	0.2	1	0.03	0.09
Sterculia quinqueloba(Garcke) K. Schum	Mn'guja/ Munane	Sterculiaceae	T	0.1	1	0.03	0.09
Grewia platyclada K. Schum	Mtapwiche	Tiliaceae	S	0.5	3	0.02	0.09
Balanites aegyptiaca (L.) Delile	Mwambangoma/Mduguya	Zygophyllaceae	T	0.3	2	0.02	0.09
Margaritaria discoidea (Baill.) G.L. Webster	Mumihyo	Euphorbiaceae	S	0.3	2	0.02	0.09
Strychnos innocua Delile	Ngaja/Mlungulungu	Loganiaceae	S	0.3	2	0.02	0.09
Euphorbia candelabrum Trémaux ex Kotschy	Mpangapanga, Mlangati	Euphorbiaceae	T	0.2	2	0.10	0.08

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Cylicomorpha parviflora Urb.	Mtogodume	Caricaceae	T	0.4	3	0.01	0.08
Ricinodendron gracilius Mildbr	Mtene	Euphorbiaceae	T	0.1	1	0.06	0.07
Grewia similis K. Schum	Mchiu	Tiliaceae	S	0.4	3	0.02	0.07
Lecaniodiscus fraxinifolius Baker	Mbwewe	Sapindaceae	T	0.4	3	0.02	0.07
Ptaeroxylon obliquum (Thunb.) Radlk	Unknown	Ptaeroxylaceae	S	0.3	2	0.02	0.06
Ehretia silvatica Gürke	Mkakala	Boraginaceae	T	0.2	1	0.02	0.06
Deinbollia borbonica f. glabrata Radlk.	Mdalamwaka/Mpugamahoke	Sapindaceae	T	0.3	2	0.01	0.06
Boscia salicifolia Oliv	Mtukuli	Capparaceae	T	0.2	1	0.01	0.06
Hyphaene compressa H. Wendl.	Mlala/mkoche	Arecaceae	T	0.0	0	0.01	0.06
Piliostigma thonningii (Schumach.) Milne-Redh	Msigisi	Fabaceae	T	0.1	1	0.04	0.05
Antidesma venosum E. Mey. ex Tul.	Mhale	Euphorbiaceae	S	0.1	1	0.02	0.05
Diospyros abyssinica(Hiern) F. White	Mlindimila	Ebenaceae	T	0.3	2	0.01	0.05
Maytenus lancifolia (Thonn.) Loes.	Mpapala	Celastraceae	S	0.3	2	0.01	0.05
Sclerocarya birrea (A. Rich.) Hochst.	Mng'ongo	Anacardiaceae	T	0.2	1	0.01	0.05
Ziziphus mucronata Willd.	Mpiripiri	Rhamnaceae	S	0.2	1	0.01	0.05
Pterocarpus chrysothrix Taub	Mtumbatibonde	Fabaceae	T	0.2	1	0.02	0.04
Cassine aethiopica Thunb	Mtugulu/ Mlimbolimbo	Celastraceae	T	0.1	1	0.02	0.04
Combretum schumannii Engl	Mkolyongo	Combretaceae	S	0.1	1	0.01	0.04
Rytigynia uhligii (K. Schum. & K. Krause) Verdc	Mmbapa/ Mtulavula	Rubiaceae	S	0.2	1	0.00	0.04
Annona senegalensis Pe*rs.*	Mtope	Annonaceae	S	0.0	0	0.00	0.04
Sterculia africana (Lour.) Fiori var. africana	Miza	Sterculiaceae	T	0.0	0	0.04	0.03
Manilkara mochisia(Baker) Dubard	Mwakala	Sapotaceae	S	0.3	2	0.02	0.03
Lannea fulva(Engl.) Engl.	Mchengachenga	Anacardiaceae	T	0.1	1	0.02	0.03
Grewia holstii Burret	Mnunje	Tiliaceae	S	0.1	1	0.01	0.03
Grewia trichocarpa Hochst. ex A. Rich	Mkolamakaa	Tiliaceae	S	0.1	1	0.01	0.03

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Schrebera alata (Hochst.) Welw	Machanjere	Oleaceae	T	0.1	1	0.01	0.03
Suregada zanzibariensis Baill	Mdimupori	Euphorbiaceae	S	0.1	1	0.01	0.03
Zanha africana (Radlk.) Exell	Muranga	Sapindaceae	T	0.0	0	0.01	0.03
Haplocoelum inoploeum Radlk	Mjengo	Sapindaceae	T	0.2	1	0.00	0.03
Combretum padoides Engl. & Diels	Mkungulungo	Combretaceae	S	0.1	1	0.01	0.02
Zanthoxylum chalybeum Engl	Mlungulungu	Rutaceae	S	0.1	1	0.01	0.02
Acacia polyacantha Willd	Mkwanga/ Mlonga	Fabaceae	T	0.0	0	0.01	0.02
Dalbergia obovata E. Mey	Unknown	Fabaceae	S	0.0	0	0.01	0.02
Rotheca myricoides (Hochst.) Steane & Mabb	Mpugamizuka	Lamiaceae	S	0.1	1	0.00	0.02
Erythrococca kirkii (Müll. Arg.) Prain	Chifakata/Kitagata	Euphorbiaceae	S	0.1	1	0.00	0.02
Grewia monticola Sond	Mng'elela	Tiliaceae	S	0.1	1	0.00	0.02
Markhamia obtusifolia(Baker) Sprague	Mpugupugu	Bignoniaceae	T	0.1	1	0.00	0.02
Sericanthe odoratissima (K. Schum.) Robbr	Kahawamwitu	Rubiaceae	S	0.1	1	0.00	0.02
Ochna mossambicensis Klotzsch	Muhindama	Ochnaceae	T	0.0	0	0.00	0.02
Ximenia caffra Sond	Mpingi	Olacaceae	S	0.0	0	0.00	0.02
Milicia excelsa (Welw.) C.C. Berg	Mvule	Moraceae	T	0.1	1	0.01	0.01
Chrysophyllum gorungosanum Engl.	Mlembelembe	Sapotaceae	T	0.1	1	0.00	0.01
Rytigynia celastroides (Baill.) Verdc	Mkokomlima	Rubiaceae	S	0.1	1	0.00	0.01
Acacia pentagona (Schumach. & Thonn.) Hook. F	Murhuu	Fabaceae	S	0.0	0	0.00	0.01
Azanza garckeana (F. Hoffm.) Exell & Hillc	Mutogho	Malvaceae	T	0.0	0	0.00	0.01
Brachystegia spiciformis Benth.	Mtondo	Fabaceae	T	0.0	0	0.00	0.01
Commiphora boiviniana Engl.	Mpome	Burseraceae	T	0.0	0	0.00	0.01
Dichrostachys glomerata (Forssk.) Chiov	Mgegela	Fabaceae	T	0.0	0	0.00	0.01
Diospyros squarrosa Klotzsch	Mpeke	Ebenaceae	S	0.0	0	0.00	0.01

Species/Botanical name	Vernacular/Local name	Family	Habit/ Life forms	Frequency (%)	Density Stem/ha	Basal area (G) (m^2/ha)	IVI
Millettia usaramensis Taub. var. usaramensis	Mpande	Fabaceae	T	0.0	0	0.00	0.01
Pteleopsis sp.	Mtachi	Combretaceae	S	0.0	0	0.00	0.01
Trachylobium verrucosum (Gaerth) Oliv	Mkumbo	Fabaceae	T	0.0	0	0.00	0.01
Vepris simplicifolia (Engl.) Mziray	Mndizi	Rutaceae	S	0.0	0	0.00	0.01

T= Tree, S= Shrubs/ small tree

Appendix 5: Checklist of tree and shrub species stumps recorded in NSFR

Species/ Botanical name	Vernacular/ Local name	Family	Habitat/ Life forms	Frequency (%)	Stem Density (stem/ha)	Basal area (G) (m^2/ha)	IVI
Allophylus rubifolius (Hochst. ex A. Rich.) Engl	Mpaya/Mjavuu	Sapindaceae	S	17	1	0.02	0.14
Carpodiptera africana Mast	Mpweke	Malvaceae	T	4	0	0.00	0.04
Dalbergia melanoxylon Guill. & Perr	Mpingo	Fabaceae	T	9	1	0.11	0.22
Grewia platyclada K. Schum	Mtapwiche	Tiliaceae	S	9	1	0.01	0.07
Spirostachys africana Sond	Msagawi	Euphorbiaceae	T	57	4	0.09	0.50
Terminalia sambesiaca Engl. & Diels	Mkulyungu	Combretaceae	T	4	0	0.01	0.04

T= Tree, S= Shrubs/ small tree