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Original Article

The Extent of Forest Recovery from the Previous Disturbances in the Magombera Nature Forest Reserve, Tanzania

Fredy Ndandika[1] *Paulo Lyimo*[1] *& Ezekiel E. Mwakalukwa*[1]

[1] Sokoine University of Agriculture, P. O. Box 3010, Morogoro, Tanzania.
[*] Author for Correspondence Email: stalonalfred@yahoo.com

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Woody Species Diversity, Forest Recovery, Changes in Vegetation Cover, Soil Quality, Forest Health, Lowland Forests.

ABSTRACT

There is an increased interest in understanding the rate of forest recovery from previous disturbances. This information is helpful for the formulation of better conservation strategies for the respective forest reserves. This study aimed to assess the extent of forest recovery from the previous disturbances in the Magombera Nature Forest Reserve (MNFR) located in Kilombero District, Morogoro region, Tanzania. Specifically, the study assessed the current status of; i) woody species diversity and regeneration, ii) soil quality (Texture, pH, Bulk Density and Soil Organic Carbon), and iii) vegetation cover in comparison with the previous cover before it was upgraded to nature forest reserve in 2019. Vegetation data were collected from 46 concentric sample plots of 0.071ha established systematically across the forest area of 2,623 ha; soil samples were collected from 24 plots systematically with an interval of one plot to a depth of 0 – 30 cm. Vegetation cover analysis spans from year 2016 to 2022. The results indicated that a total of 352 plant species (trees = 170, herbs = 63, grasses = 43, shrubs =42, climbers =15, sedges = 14 and lianas =5) which belong to 109 plant families were identified. The diversity status of trees and herbs was higher compared to other life forms (H' values range from 3.12 to 4.09). Average soil characteristics were bulk density =1.59, soil texture = Sandy Clay Loam, soil pH =4.58 and soil organic carbon=0.95 indicating soil has a good quality supporting the growth of a variety of plant species. There was a significant improvement in vegetation cover with a gain of 11% in close forest area from the year 2019 after being upgraded to a nature reserve. Generally, these results show that MNFR has recovered from the previous disturbances and the quality of the forests has increased. Efforts to continue protecting the forest against any further disturbances to uphold the current healthier status of the forest are recommended.

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INTRODUCTION

Healthier forest ecosystems provide a large number of ecological services to humankind (Mori *et al.,* 2017). These services range from watershed management (Hermansen *et al.*, 1985), biodiversity conservation (Lausch *et al.,* 2018), soil erosion control (Ajijah *et al.,* 2022) and climate amelioration (Artaxo *et al.,* 2022). These services are not only of local importance but also of global importance (Lei *et al.,* 2023). Monitoring the state of forest health over time is vital in order to identify likely challenges which can affect the capacity of the forest to offer the expected ecosystem services. The information is important for conservators and managers to plan for strategies to address the identified challenges so as to enhance and protect the quality of the forests.

Tanzania encompasses various terrestrial and complex drainage systems with a diverse range of biodiversity and unique habitats that offer a variety of ecosystem services to human livelihood (URT, 2022). Kilombero Valley floodplain located in Kilombero District is one of the important drainage ecosystems which is known for maintaining a wetland with international importance under the IUCN category (IUCN, 2020). The wetland is among the main sources of annual runoff to the largest and most complex river basin in East Africa (Rufiji River Basin). It contributes about 60% of annual runoff to the newly constructed Julius Nyerere Hydropower dam (JNHP). Thus, the effort to conserve this catchment is important because it has national importance.

Magombera Nature Forest Reserve (MNFR) is among of many catchment forest reserves found in Tanzania (Marshall, 2008). MNFR is a lowland tropical forest located within the Kilombero landscape. MNFR was declared a Nature Forest Reserve in January, 2019 due to its ecological and water catchment potentials (Mahulu *et al*., 2019). Despite its importance, the forest suffered uncontrolled human activities from the 1970s until 2019 when it was upgraded to the status of Nature Forest Reserve (Mahulu *et al*., 2019). It is believed that those anthropogenic activities affected the forest ecosystem structure and functioning directly or indirectly, resulting in biodiversity loss, habitat deterioration and fragmentation (Rija, 2022). However, no studies have ever been conducted to ascertain the extent to which MNFR has recovered from the previous disturbances. Monitoring the state of ecosystem health over time is vital to ensure that the successful conservation of important habitats for other species has been achieved. We have hypothesized that the current healthier status of MNFR is much better than it was in 2018 before being upgraded to the status of Nature Forest Reserve in 2019.

The general objective of this study was therefore to assess the extent of forest recovery from the previous disturbances in the Magombera Nature Forest Reserve (MNFR) located in Kilombero District, Morogoro region, Tanzania. Specifically, the study aimed to assess the current status of; i) woody species diversity and regeneration in MNFR, ii) soil quality (texture, bulk density, pH and soil organic carbon) in MNFR, and iii) vegetation cover in comparison with the previous cover before it was upgraded to nature forest

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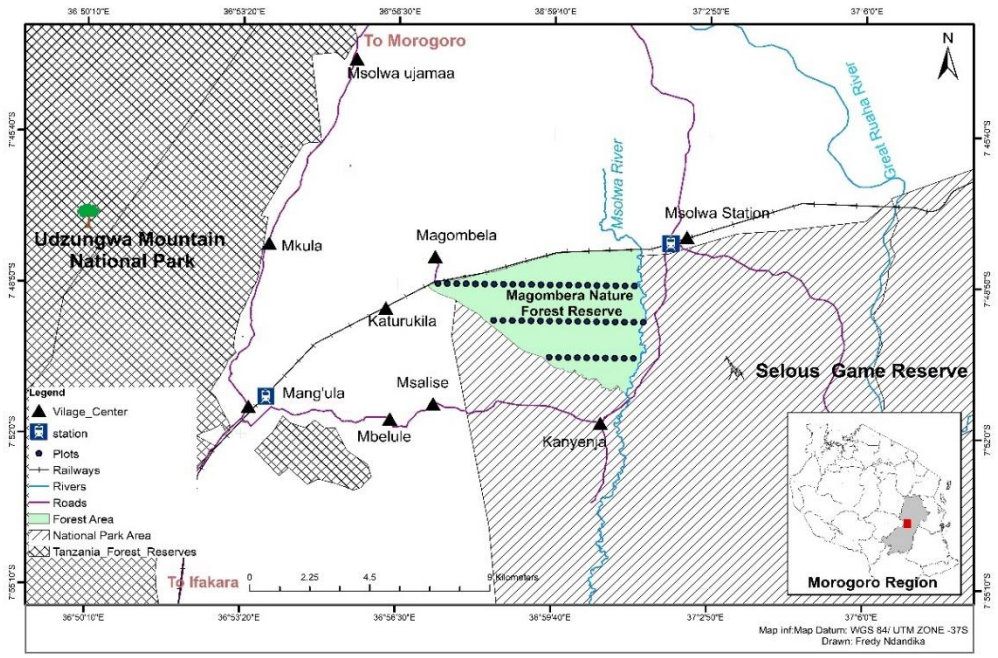
reserve in 2019. The findings from this study will be helpful in the formulation of better conservation strategies for MNFR.

MATERIALS AND METHODS

Description of Study Area

Magombera Nature Forest Reserve (MNFR) is a lowland tropical forest located at latitude 07°46'40" - 07°52'0" S and longitude 36°57'30" - 37°01'30" E in Kilombero District, Morogoro region, Tanzania (Fig. 1). MNFR is sandwiched between the Udzungwa Mountain National Park and Selous game reserve. The forest lies around 270 m above sea level with a distance of 6 km from Udzungwa Mountain National Park to the west and buffered with the Selous game reserve to the east (Mahulu *et al.*, 2019). The topography of the forest is characterized by a slightly flat terrain landscape. The climate is of high humidity, with an average annual rainfall of 1,500 mm per year and an average temperature of 32°C. The area is characterized by binomial rainfall distribution whereas the short rain occurs between October to December while the long rain starts from February to early May. It is characterized by mixed vegetation types namely the closed forest, woodland, grassland and riparian vegetation whereas the woodland is found to be the dominant vegetation type. It consists of a mixed soil of Karoo sandstone from the Msolwa floodplain and alluvial deposits from the Udzungwa Mountains. MNFR is surrounded by four (4) villages. Among the major agricultural crops cultivated around the reserve are sugar cane, paddy/rice, cassava and maize.

Figure 1: Map of Study Location and Layout of Observation Plot in the MNFR



Sampling Design and Data Collection

Sampling Design

A systematic sampling design was employed to capture spatial variability, ensure consistency in sampling and reduce the likelihood of bias during the collection of both vegetation and soil data in the study area. A total of 49 concentric sample plots of 0.071 ha were laid systematically at a regular interval in three transects across the entire reserve of 2,623 ha. The distance between transects was 700m and between plots was 350m. For the purpose of avoiding edge effects of the

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related disturbances, plots were placed 70 m away from the forest margin during sampling (Yigeremu & Woldearegay, 2022).

Data Collection

The field survey for collecting biophysical and soil data was conducted in December 2023 with a total of 49 concentric plots of 0.071 ha laid systematically in three transects across the entire forest of 2,623 ha (Fig. 1). From each plot the following parameters for biophysical data were measured; within 2m radius, all seedlings with <1cm diameter were counted, identified and recorded; Within 5m radius, all saplings with ≥ 1cm DBH but < 5m diameter were identified, measured, and recorded; Within 10m radius, all young trees with ≥5cm DBH and < 20cm were identified, measured and recorded; and Within 15m radius, all adult trees with DBH ≥20 was identified, measured and recorded. Other life forms such as herbs, climbers, lianas, sedges and grasses were identified, counted and recorded within a 2m radius. Other information recorded include elevation, slope, plot coordinates and type of disturbances. Plot coordinates and elevation were recorded using GPS (Garmin 76CSx), tree height was measured using a Suunto hypsometer and the diameter at breast height (DBH) of trees was measured using Caliper.

Soil samples were collected from 24 plots systematically with an interval of one plot to a depth of 0 – 15 cm and 15 – 30 cm in each plot where the land use changes expected to occur. In grassland areas, soil samples were collected after clearing the surface litter (Bhowmik *et al.*, 2019). A total of 48 composite soil samples from 24 plots were collected into plastic bags after being thoroughly homogenized. Then, 200g of sub-sample from the 24 pooled samples was taken, air dried and sieved to pass through 2 mm mesh sieves before analysis. Moreover, 24 undisturbed soil samples were collected from each plot using a 5 cm long by 5 cm diameter cylindrical metal core sampler to determine bulk density. The core sampler was tapped slightly with a hammer until the top of the soil core was about 0.5 cm beneath the soil surface. The soil around the holder was excavated, the soil sample core taken out, and excess soil cut off with a soil knife.

Landsat satellite images of 2016, 2019 and 2022 covering the study area were obtained from the United States Geological Survey (USGS), the Data Interface from the Global Visualization Viewer (GloVis) at http://glovis.usgs.gov. Remote sensed data from Landsat imageries were pre-processed by using three programs, QGIS, ArcGIS and ERDAS Imagine 2015 software. The Landsat imageries Layers were then selected, stacked and transformed using the UTM projection, zone 36 south with Clarke 1880 spheroid and Arc 1960 Tanzania. An area of interest (AOI) was selected based on a study area. The AOI used to shape files to subset the three Landsat imageries of 2016, 2019 and 2022. All Landsat imaginaries were enhanced to produce high-resolution imageries (Wu et al., 2017).

Landsat imageries were processed (classified) through classification schemes which contained taxonomically correct definitions of classes' information that were organized according to logical criteria in order to generate land cover change types and were analyzed to determine changes that have taken place within the study area between 2016, 2019 and 2022. An ERDAS image processing system was used for all image data processing. The unsupervised image classification (ISODATA) was used for all images followed by supervised classification to generalize the land cover types.

Data Analysis

The collected data were analyzed for species richness, diversity, Importance value index, stand structure (stem density, basal area, diameter distribution), regeneration, soil quality (texture, pH and Organic matter content), and changes in vegetation cover before and after gazettement to a nature forest reserve in 2019. Species richness was determined as the total number of species in a given area. Species diversity was determined using the Shannon – Wiener Diversity Index (H') with a formula: $H' = \sum_{i=1}^{s} \text{Pi} * \text{In Pi}$ whereas; s = the number of species, Pi = the importance value

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of a species as a proportion of all species, In = the natural logarithm. The stem density of woody species was computed as the average number of individual woody species per plot divided by the area of such plot measured (Kayombo *et al.*, 2022). Basal area was computed by dividing the area covered by the woody species in a plot with the plot size ($G= \pi d^2 / 4$), where d is the diameter at breast height (Lyimo & Shaaban, 2015). The Importance Value Index (IVI) was computed as the sum of relative stem density and relative basal area expressed in percentage (Mwakalukwa *et al.*, 2023). All analyses were carried out in Microsoft Excel spreadsheets (Mwaluseke *et al.*, 2023).

Analysis of Soil samples entails to determination of key indicators of soil health namely soil bulk density, soil texture, soil pH and soil organic carbon (Nunes *et al.*, 2021). In the laboratory, soil bulk density (BD) was determined by taking the ratio of oven-dry weight and volume of a core of the soil sample. Soil textural classes were determined by using the hydrometer method (Huluka & Miller, 2014). Three hydrometer readings were taken to determine the particle size distribution which was used to measure the percentage of soil particles (sand, silt and clay) in suspension at different times and temperatures. Soil pH was determined by using a pH meter in an air-dry soil sample mixed with 0.01M of $CaCl_2$ at a 2:5:1 ratio. Soil Organic Carbon (SOC) was determined using the wet oxidation method (Nelson & Sommers, 1996) by heating samples with a mixture of sulfuric acid and 10ml of dichromate then with iron II solution to obtain the amount of organic carbon.

The study categorized vegetation cover changes into four classes such as dense forest, less dense forest, grassland and bare land. The dense forest is described as woody vegetation with mature stands of greater than six meters tall with a crown cover of more than 30%, the less dense forest consists of patches with trees of more than six meters tall with a crown cover of less than 30% while the bare land described as an area with no dominant vegetation cover (Ojoyi *et al.*, 2016). Its analysis was employed by downloading satellite imageries from the year 2016 to 2022 with a spatial resolution of 10m from the United States Geographical Survey (USGS) website and classified using a supervised classification with a Gaussian maximum likelihood classifier (Wu *et al.*, 2017). The analyses were aided by the training data that was collected from the field.

The quality of a supervised classification depends on the quality of the training sites (Perumal & Bhaskaran, 2010). The vegetation cover changes in the study area were categorized into four classes such as closed forest, open forest, grassland and bare land. Classes were recorded in ERDAS Imagine, and then areas for each land cover category were calculated and interpreted for the respective years. Assessment of the land cover changes was done by comparing maps of spatially the same at three different times (T1, T2 and T3) such that 2016, 2019 and 2022 for this case.

RESULTS

Woody Species Richness, Diversity and Regeneration Status in MNFR

Species Richness

A total of 352 individual plant species (102 adult trees and shrubs, 110 regenerant trees and shrubs and 140 other growth forms) belonging to 109 plant families were found in the MNFR (Appendix 1-3). Trees were leading for having 170 species (48.3%) followed by herbs 63 species (17.9%), grasses 43 species (12.2%), shrubs 42 species (11.9%), climbers 15 species (4.3%), sedges 14 species (4%), and lianas 5 species (1.4%).

In the category of adult trees and shrubs with (DBH>1cm), the most frequent species was *Isoberlinia scheffleri* (Harms) Greenway (7%), *Ochna macrocalyx* Oliv. (5.7%), *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon (5.2%), *Bryophyllum suarezense* (H.Perrier) A.Berger (4.8%) and *Antidesma venosum* E.Mey. ex Tul. (3.5%).

For regenerants (DBH<1cm), the most frequent species was *Aerangis thomsonii (Rolfe) Schltr. (8.8%), Rauvolfia tetraphylla L. (6.8%), Mallotus oppositifolius (Geiseler) Müll.Arg. (5.8%) and*

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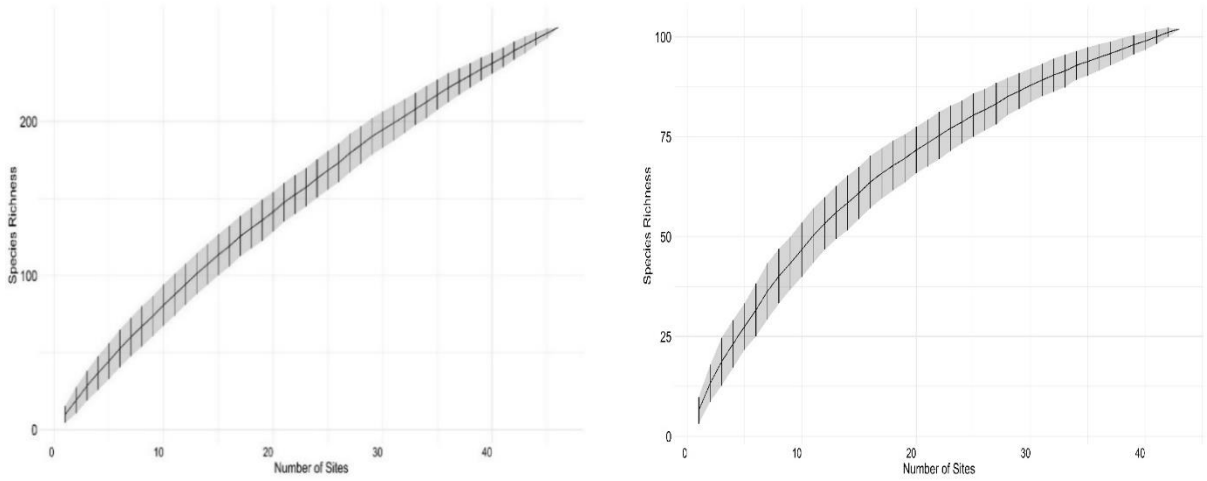
Casearia battiscombei R.E.Fr. (4.4%). Likewise, the most dominant families for regenerant trees and shrubs were Fabaceae (18.2%), Rubiaceae (10.8%) and Malvaceae (10%) (Appendix 2).

Based on other growth forms, the most frequent species were *Commelina africana L.* (18%) and *Arthraxon hispidus* (Thunb.) Makino (17%) for herbs; *Panicum maximum* Jacq. (28%) and *Hyparrhenia filipendula* (Hochst.) Stapf (19%) for grasses; *Kyllinga pumila* Steud. (23%) and *Cyperus papyrus* L. (21%) for climbers; *Landolphia kirkii* Dyer ex Hook.f. (42%) and *Cyphostemma serpens* (Hochst. ex A.Rich.) Desc. (7%) for sedges; and *Entada rheedei* Spreng. (47%) and *Aristolochia elegans* Mast. (18%) for lianas (Appendix 3).

The adult and regenerant tree and shrub species richness showed to be increased proportionally with the slight increase in the number of plots (figure 2 A & B).

Figure 2: Adult (A) and Regenerant (B) Species Accumulation Curve in MNFR, Tanzania



A B

Species Diversity

The Shannon – Weiner diversity indices for trees, shrubs and other growth forms in MNFR are indicated in Table 1. The most frequent species for adult trees and shrubs (DBH>1cm) were *Isoberlinia scheffleri* (Harms) Greenway *(7%), Ochna macrocalyx* Oliv. *(5.7%), Diplorhynchus condylocarpon* (Müll.Arg.) Pichon *(5.2%), Bryophyllum suarezense* (H. Perrier) A. Berger *(4.8%) and Antidesma venosum* E. Mey. ex Tul. *(3.5%).* The Important Value Index (IVI) indicated that, *Bryophyllum suarezense* (H. Perrier) A. Berger, *Crossopteryx febrifuga* (Afzel. ex G.Don) Benth., *Isoberlinia scheffleri* (Harms) Greenway, *Diplorhynchus condylocarpon* (Müll.Arg.) *Pichon and Ochna macrocalyx* Oliv. were the most important species for adult trees and shrubs in the forest (Appendix 1).

Table 1: Diversity Status of the Identified Life Forms in MNFR

SN	Life forms	Shannon value (H')
1	Trees	4.09
2	Shrubs	3.99
3	Herbs	3.12
4	Grasses	2.56
5	Sedges	2.15
6	Climbers	2.12
7	Lianas	1.37

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Forest Structure

The total mean stem density for trees and shrubs (DBH>1cm) was 525 ± 321 stemsha^{-1} with *Mallotus oppositifolius* (Geiseler) Müll.Arg. contributing the most to the total stems ha^{-1} (10.5%) followed by *Sericanthe odoratissima* (K.Schum.) Robbr. (6.2%), *Antidesma venosum* E. Mey. ex Tul. (5.7%), *Isoberlinia scheffleri* (Harms) Greenway (4.9%) and *Ochna macrocalyx* Oliv. (4.5%) (Appendix 1). Whereas the total mean basal area for trees and shrubs (DBH>1cm) was 15.49±8.69 m^2ha^{-1} with *Bryophyllum suarezense* (H. Perrier) A. Berger contributing the most to the total basal area (15%) and *Isoberlinia scheffleri* (Harms) Greenway (13%) (Appendix 1). The distribution of stem density and basal area per diameter classes are indicated in Figures 3 and 4 respectively.

Figure 3: Diameter Distribution of Stem Density per Hectare for Adult Trees and Shrubs (DBH>1cm) in MNFR

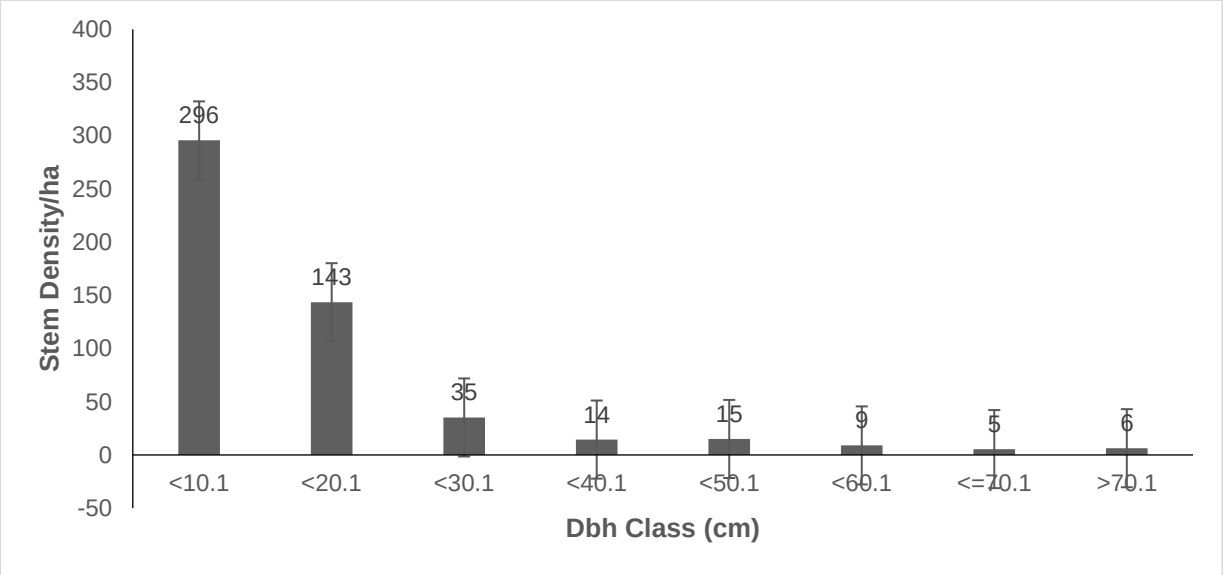
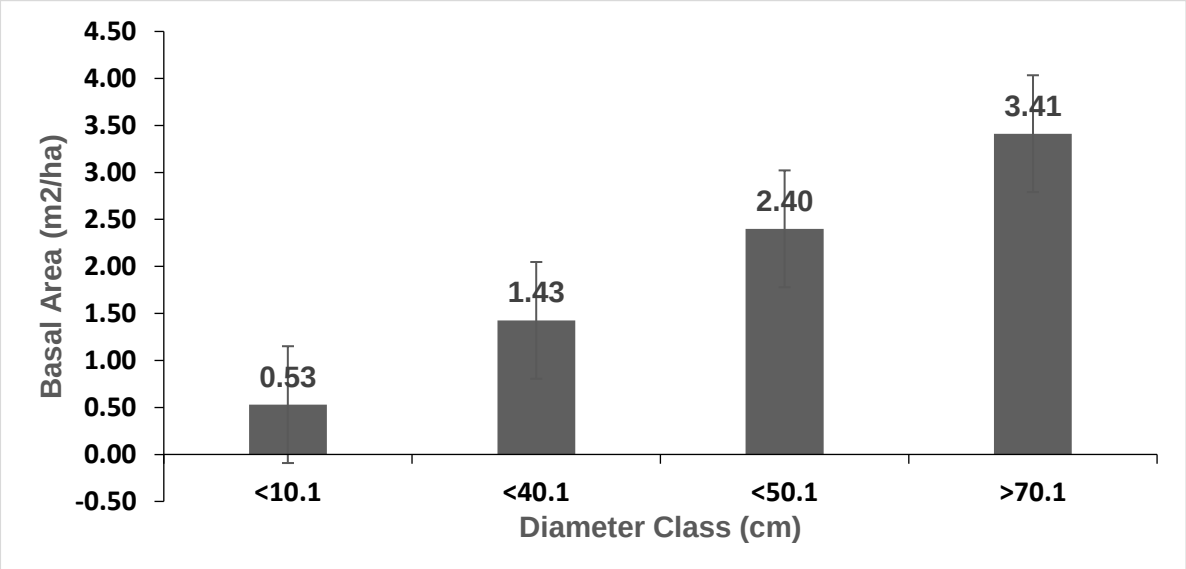


Figure 4: Diameter Distribution of Basal Area per Hectare for Adult Trees and Shrubs (DBH>1cm) in MNFR.



Soil Quality in MNFR

The soil texture of MNFR was Sandy Clay Loam, with 58% sand, 13% silt, and 29% clay. The bulk

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density soil was 1.59 g/cm^3 and its pH was 4.6, which is highly acidic soil. Soil organic carbon was found to be 4.5% (Table 2).

Table 2: Results of Chemical and Physical Properties of Soil in MNFR

Soil Parameter	Soil Depth		Mean	*SD
	0-15 cm	15-30 cm		
Soil texture	Sandy Clay Loam	Sandy Clay Loam		
Soil pH	4.6	4.56	4.58	0.44
Soil Organic Carbon	1.18	0.71	0.95	0.37
Bulk Density (g/cm^3)	1.61	1.56	1.59	0.14

*SD = Standard Deviation, p<0.005

Changes in Vegetation Cover Before and After Upgrading to Nature Forest Reserve in 2019.

The study results showed a significant vegetation change during the study period such that there was a significant increase in closed forest area by 17.82% from the year 2019 to 2022 and a sharp decrease in bare land area by 11.26% from the year 2019 to 2022. However, the dynamic vegetation trends were observed in grassland and open forest areas (Table 3).

Table 3: Vegetation Cover Change From 2016 to 2022 in MNFR

Class Name	The year 2016		The year 2019		Year 2022	
	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)
Grass Land	200.43	7.64	138.06	5.26	205.92	7.85
Open Forest	858.15	32.71	907.38	34.59	667.8	25.46
Bare Land	292.05	11.13	317.52	12.10	21.96	0.84
Close Forest	1272.69	48.51	1260.36	48.04	1727.64	65.86

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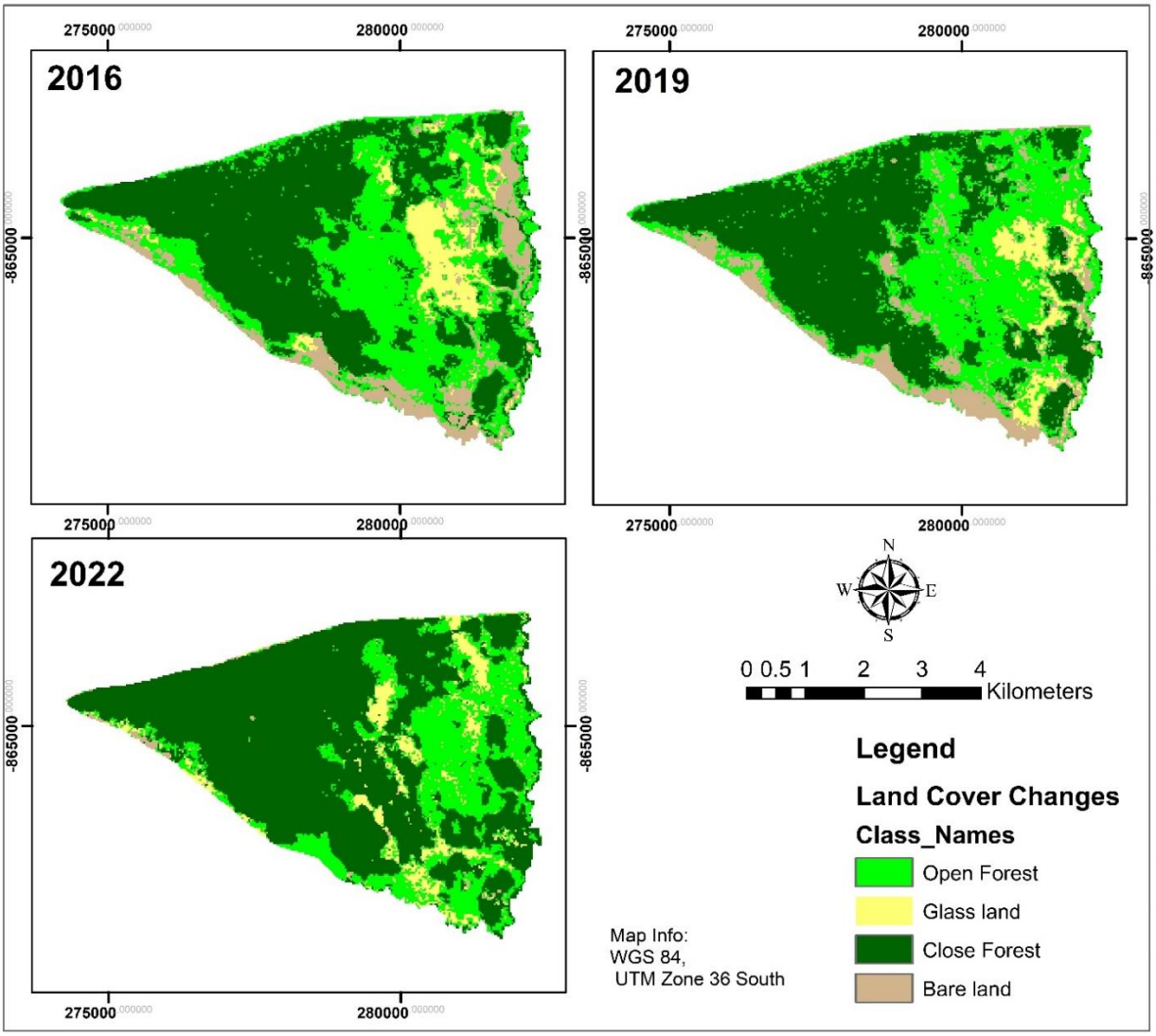
Figure 5. Trend of Vegetation Cover Change Over Time.



DISCUSSION

Woody Species Diversity and Regeneration in MNFR

Species Richness

The species richness of 102 adult trees and shrubs, 110 regenerant trees and shrubs and 140 other growth forms (herbs, grasses, climbers, sedges, lianas) reported in this study relatively correspond with other studies in tropical forests. For instance, Kacholi *et al.* (2015) found a total of 101 tree species in Uluguru mountain forests whereas a total of 146 species from tropical evergreen forests of North East India reported by Tynsong *et al.*, (2022). The most dominant species in this study (Appendix 1&2) were found to be relatively higher compared to the previous study as reported by Rodgers *et al.*, (1979) and Vollesen (1980) as cited in Marshall (2008) such that the dominant species like *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon, *Bryophyllum suarezense* (H.Perrier) A.Berger, *Antidesma venosum* E.Mey. ex Tul. and *Mallotus oppositifolius* (Geiseler) Müll.Arg. was not a dominant species before. However, *Isoberlinia scheffleri* (Harms) Greenway and *Ochna macrocalyx* Oliv. were listed as dominant species too in the previous study (Marshall, 2008) indicating a high rate of forest recovery and a healthier ecosystem. The existence of resilient to environmentally stressed species such as *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon, *Bryophyllum suarezense* (H. Perrier) A. Berger, *Antidesma venosum* E. Mey. ex Tul. and *Mallotus oppositifolius* (Geiseler) Müll.Arg. as a dominant species implying the stability of the

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forest ecosystem (Trumbore *et al.,* 2015). Furthermore, the presence of species under the Fabaceae and Malvaceae families influence the act of ecosystem engineers that increase soil fertility through a symbiotic and mutualistic relationship with other organisms in the ecosystem and facilitating proper understory development (Tilney *et al.,* 2012).

Species richness for other growth forms consists of 40% of the total number of species in the forest. This extent of other growth forms positively affects the ecosystem structure and function by influencing stand development, fire behaviour, improving soil properties and providing habitats for various wildlife species (Perring *et al.,* 2024). However, the existence of the other growth forms indicates that the forest might have been disturbed by anthropogenic activities.

Species Diversity

The most diverse forests happen in lowland tropical areas with a proper distribution of rainfall (Gentry, 1992). The diversity indices for trees and shrubs in MNFR corresponded with the recommended range of not exceeding 5 (Buzas & Hayek, 2011). It is relatively correlated with those recorded in Uluguru Forests (H=4.03) and Udzungwa Mountain National Park (H=4.31) (Lovett *et al.,* 2006; Kacholi *et al.,* 2015). The higher diversity indices in MNFR reflect the resilience and recovery of the ecosystem (Bentsi *et al.,* 2022). Generally, the study showed a high diversification of floristic species that influence the proper functioning and recovery of MNFR (Sanjaya *et al.,* 2022).

Forest Structure

The mean stem density for VIII class trees was three times more than that reported by Huang *et al.,* (2003) from Tanzanian tropical forests. This indicates the forest being more vigorous ensuring its stability (Poorter *et al.,* 2021). Trees and shrubs of class I & II have higher stem density constituting 84% of stand density compared with the other class. This indicates that the regeneration status is higher. The diameter distribution of the trees and shrubs characterizes the general pattern of normal stand structure such that, the majority of the trees and shrubs species have a larger number of individuals at the lower DBH class and regularly decrease in number towards the higher DBH classes (Mwakalukwa *et al.,* 2023). Such an inverted J-shaped distribution pattern indicates a stable and significant increase in forest recovery after being disturbed (Tebabal *et al.,* 2024).

Soil Quality in MNFR

The association between soil properties and species richness is still debatable. Different studies found that good forest soil may be rich in species and have a great influence on the diversification of vegetation type (Gentry, 1992; Sellan *et al.,* 2019). The soil properties found in MNFR such as sand clay loam indicate a moderate water-holding capacity which is suitable for plant growth by promoting healthy root development. A lower bulk density that indicates Moderate soil compaction that may be caused by prior deforestation, heavy rainfall or other natural processes influences the promotion of better soil drainage, proper aeration, high water retention and ability to hold moisture and nutrients that support healthy plant growth (Trumbore *et al.,* 2015). The forest has an acidic soil with a pH of 4.58 that may be caused by high rate of organic matter decomposition or human activities like sugar cane plantation where the application of chemical fertilizer is high and industrial pollution from nearby industry (ILLOVO Sugar Company) affecting nutrient availability and microbial activities (Lolila *et al.,* 2023). The acidic soil found by Lolila *et al.* (2023) in East Usambara Forests that influences species composition and distribution corresponds with the acidic soil of pH 4.58 in MNFR. Soil organic carbon of MNFR is relatively low which may be caused by poor soil cover, monocropping and excessive use of chemical fertilizer may be among of factors for low soil organic carbon. Therefore, the forest recovery of the study area is significantly influenced by soil pH, soil organic carbon and sand similarly as in other tropical forests like East Usambara Forest (Lolila *et al.* 2023; Trumbore *et al.,* 2015; Tilney *et al.,* 2012).

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Changes in Vegetation Cover Before and After Upgrading to Nature Forest Reserve in 2019.

The forest cover which is still relatively extensive consisting of four identified vegetation cover classes, provides a fundamental basis for demonstrative and inclusive conservation interventions of the forest. The study revealed a steady increase in areas covered by close forest from 2019 to 2022 indicating a rapid recovery of the forest (Shapiro *et al.*, 2021; Ojoyi *et al.*, 2016). The increased area of the close forest increases the capacity of the forest to support biodiversity and ecosystem services. (Shapiro *et al.*, 2021). It was found that the dynamic vegetation trends in grassland and open forest areas credited to the landscape pattern of the two sandwiched protected areas of Selous Game Reserve and Udzungwa Mountain National Park (Munishi *et al.*, 2010; Burges *et al.*, 2002).

CONCLUSION AND RECOMMENDATION

Conclusion

The forest was rich and diverse in plant species similar to other tropical forests. The good regeneration status ensures resilience of the forest from natural and anthropogenic disturbances allowing suitable ecological flow within the forest and between the Udzungwa Mountain National Park and the Selous Game Reserve. The soil of MNFR had a better quality that provided a good habitat for microorganism activities contributing to ecosystem functions. The changes in vegetation cover improved yearly as intensive conservation interventions were taken assuring a healthy ecosystem.

Recommendation

In order to continue protecting the threatened tropical species, a clear and rational conservation plan and interventions are highly recommended to limit its loss ensuring the existence of wildlife corridor and ecosystem stability. However, further studies should be conducted to assess the impact of sugarcane cultivation in relation to forest water reservoirs and drainage systems.

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Appendix 1: Checklist of Tree and Shrub Species (>1cm DBH) Identified in the Magombera Nature Forest Reserve (MNFR), Tanzania. Note: Importance Value Index = IVI, SE = Standard error of the mean (mean ± SE), plot size = 15m radius.

SN	*Botanical name*	Family name	Life form/Habit	Frequency (%)	H`	Density (stems/ha)	Basal area (m2/ha)	IVI
1	*Agauria salicifolia (Lam.) Oliv.*	Ericaceae	Shrub/tree	1	0.01	3	0	0.4
2	*Albizia petersiana (Bolle) Oliv.*	Fabaceae	Shrub/tree	1	0.01	0	0	0.9
3	*Annona senegalensis Pers.*	Annonaceae	Shrub/tree	22	0.1	17±12	0.2±0.1	8.1
4	*Annona stenophylla Engl. & Diels*	Annonaceae	Sub Shrub/Shrub	1	0.01	0	0	0.5
5	*Anthocleista grandiflora Gilg*	Gentianaceae	Tree	10	0.06	5±3	0.3±0.2	4.0
6	*Antidesma venosum E.Mey. ex Tul.*	Phyllanthaceae	Shrub/tree	26	0.12	32±18	0.2±0.1	8.2
7	*Aoranthe penduliflora (K.Schum.) Somers*	Rubiaceae	Shrub	10	0.06	11±8	0.1	2.6
8	*Borassus aethiopum Mart.*	Arecaceae	Tree	13	0.07	4±2	0.8±0.3	10.1
9	*Brachystegia boehmii Taub.*	Fabaceae	Tree	3	0.02	1	0.1±0.1	0.9
10	*Brachystegia floribunda Benth.*	Fabaceae	Tree	7	0.04	3±1	0.2±0.1	4.5
11	*Brachystegia spiciformis Benth.*	Fabaceae	Tree	9	0.05	2	0.3±0.2	3.4
12	*Bridelia micrantha (Hochst.) Baill.*	Phyllanthaceae	Tree	8	0.05	4±2	0.1±0.1	2.9
13	*Bryophyllum suarezense (H.Perrier) A.Berger*	Crassulaceae	subshrub	35	0.14	13±4	2.3±0.6	17.9
14	*Burttdavya nyasica Hoyle*	Rubiaceae	Tree	3	0.02	2±1	0.1±0.1	2.6
15	*Canthium captum Bullock*	Rubiaceae	Shrub/tree	10	0.06	18±12	0	2.5
16	*Casearia battiscombei R.E.Fr.*	Salicaceae	Tree	13	0.07	11±9	0.3±0.2	2.9
17	*Cassia abbreviata Oliv.*	Fabaceae	Shrub/tree	1	0.01	1	0	0.6
18	*Cassipourea gummiflua Tul.*	Rhizophoraceae	Tree	7	0.04	3±2	0.2±0.1	1.3
19	*Catunaregam spinosa (Thunb.) Tirveng.*	Rubiaceae	Shrub/tree	11	0.06	6±4	0.1±0.1	4.3
20	*Celtis africana Burm.f.*	Cannabaceae	Tree	1	0.01	0	0	0.4
21	*Coffea pseudozanguebariae Bridson*	Rubiaceae	Shrub/tree	8	0.05	5	0	0.8
22	*Cola microcarpa Brenan*	Malvaceae	Tree	1	0.01	0	0.1±0.1	0.7
23	*Combretum collinum Fresen.*	Combretaceae	Shrub/tree	1	0.01	1	0	0.8
24	*Combretum molle R.Br. ex G.Don*	Combretaceae	Shrub/tree	10	0.06	4±1	0.2±0.1	9.0
25	*Commiphora swynnertonii Burtt*	Burseraceae	Shrub/tree	2	0.02	1	0	0.7

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SN	*Botanical name*	Family name	Life form/Habit	Frequency (%)	H`	Density (stems/ha)	Basal area (m2/ha)	IVI
26	*Commiphora zimmermannii Engl.*	Burseraceae	Tree	1	0.01	1	0	0.6
27	*Cordia africana Lam.*	Boraginaceae	Shrub/tree	1	0.01	0	0.1±0.1	1.0
28	*Cordia sinensis Lam.*	Boraginaceae	Shrub/tree	1	0.01	1	0	0.4
29	*Cordyla africana Lour.*	Fabaceae	Tree	2	0.02	1	0.2±0.2	2.0
30	*Craterispermum schweinfurthii Hiern*	Rubiaceae	Shrub/tree	1	0.01	1	0	0.7
31	*Crossopteryx febrifuga (Afzel. ex G.Don) Benth.*	Rubiaceae	Shrub/tree	23	0.11	13±4	0.4±0.3	13.8
32	*Dalbergia boehmii Taub.*	Fabaceae	Shrub/tree	2	0.02	1	0	1.2
33	*Dalbergia melanoxylon Guill. & Perr.*	Fabaceae	Shrub/tree	12	0.07	17±14	0	3.5
34	*Dialium holtzii Harms*	Fabaceae	Tree	5	0.03	11±8	0.1±0.1	2.0
35	*Diospyros fischeri Gürke*	Ebenaceae	Shrub/tree	4	0.03	2±1	0.1±0.1	1.7
36	*Diospyros kabuyeana F.White*	Ebenaceae	Tree	24	0.11	23±9	0.3±0.1	8.5
37	*Diospyros mespiliformis Hochst. ex A.DC.*	Ebenaceae	Tree	4	0.03	2±1	0.2±0.1	2.7
38	*Diospyros mollis Griff.*	Ebenaceae	Shrub/tree	4	0.03	2	0	2.0
39	*Diospyros squarrosa Klotzsch*	Ebenaceae	Shrub/tree	1	0.01	0	0.1±0.1	0.5
40	*Diospyros zombensis (B.L.Burtt) F.White*	Ebenaceae	Shrub/tree	5	0.03	2±1	0.1	1.2
41	*Diplorhynchus condylocarpon (Müll.Arg.) Pichon*	Apocynaceae	Shrub/tree	38	0.15	24±9	0.3±0.1	12.4
42	*Dombeya rotundifolia (Hochst.) Planch.*	Malvaceae	Shrub/tree	1	0.01	0	0	0.7
43	*Dracaena mannii Baker*	Asparagaceae	Shrub/tree	4	0.03	5±4	0	1.7
44	*Drypetes gerrardii Hutch.*	Putranjivaceae	Tree	3	0.02	6±5	0	1.9
45	*Drypetes usambarica (Pax) Hutch.*	Putranjivaceae	Tree	2	0.02	1	0	1.1
46	*Elaeodendron buchananii (Loes.) Loes.*	Celastraceae	Tree	1	0.01	3±2	0	0.4
47	*Erythrophleum suaveolens (Guill. & Perr.) Brenan*	Fabaceae	Tree	6	0.04	2	0.5±0.3	4.0
48	*Eugenia capensis (Eckl. & Zeyh.) Harv.*	Myrtaceae	Shrub/tree	15	0.08	9±8	0.1±0.1	1.9
49	*Garcinia kingaensis Engl.*	Clusiaceae	Tree	4	0.03	2±1	0	0.9
50	*Grewia bicolor Juss.*	Malvaceae	Shrub/tree	2	0.02	1	0	1.5
51	*Hyphaene petersiana Klotzsch ex Mart.*	Arecaceae	Tree	1	0.01	0	0	1.7

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SN	*Botanical name*	Family name	Life form/Habit	Frequency (%)	H`	Density (stems/ha)	Basal area (m2/ha)	IVI
52	*Isoberlinia scheffleri (Harms) Greenway*	Fabaceae	Tree	53	0.19	27±13	2±0.8	13.3
53	*Julbernardia globiflora (Benth.) Troupin*	Fabaceae	Shrub/tree	4	0.03	2±1	0.1±0.1	1.5
54	*Kigelia africana (Lam.) Benth.*	Bignoniaceae	Tree	5	0.03	3±1	0.1±0.1	1.7
55	*Lannea stuhlmannii (Engl.) Eyles*	Anacardiaceae	Shrub/tree	3	0.02	2±1	0.1	3.9
56	*Leptactina platyphylla (Hiern) Wernham*	Rubiaceae	Shrub/tree	1	0.01	0	0	0.4
57	*Lettowianthus stellatus Diels*	Annonaceae	Tree	9	0.05	3±1	0.3±0.2	2.7
58	*Maerua kirkii (Oliv.) F.White*	Capparaceae	Shrub/tree	1	0.01	0	0	0.6
59	*Mallotus oppositifolius (Geiseler) Müll.Arg.*	Euphorbiaceae	Shrub/tree	25	0.11	55±29	0	7.2
60	*Manilkara sansibarensis (Engl.) Dubard*	Sapotaceae	Shrub/tree	1	0.01	1	0	0.6
61	*Margaritaria discoidea (Baill.) G.L.Webster*	Phyllanthaceae	Shrub/tree	16	0.08	10±7	0.1±0.1	3.7
62	*Markhamia lutea (Benth.) K.Schum.*	Bignoniaceae	Tree	21	0.1	11±8	0.4±0.3	4.6
63	*Markhamia obtusifolia (Baker) Sprague*	Bignoniaceae	Tree	9	0.05	5±2	0.1	6.5
64	*Milicia excelsa (Welw.) C.C.Berg*	Moraceae	Tree	2	0.02	1	0.1±0.1	1.0
65	*Ochna holstii Engl.*	Ochnaceae	Tree	5	0.03	4±3	01	1.9
66	*Ochna holtzii Gilg*	Ochnaceae	Shrub/tree	1	0.01	0	0	0.6
67	*Ochna macrocalyx Oliv.*	Ochnaceae	Shrub	42	0.16	25±8	0.5±0.2	12.5
68	*Ochna schweinfurthiana F.Hoffm.*	Ochnaceae	Shrub/tree	1	0.01	0	0	0.6
69	*Parkeria Hook.*	Pteridaceae	Tree	1	0.01	0	0.4±0.4	1.3
70	*Pericopsis angolensis (Baker) Meeuwen*	Fabaceae	Tree	2	0.02	0	0.1	1.1
71	*Philenoptera bussei (Harms) Schrire*	Fabaceae	Tree	5	0.03	2	0.2±0.1	2.9
72	*Philenoptera violacea (Klotzsch) Schrire*	Fabaceae	Tree	1	0.01	0	0	0.5
73	*Phoenix canariensis H.Wildpret*	Arecaceae	Tree	1	0.01	0	0	0.6
74	*Piliostigma thonningii (Schumach.) Milne-Redh.*	Fabaceae	Shrub/tree	2	0.02	0	0.1±0.1	1.8
75	*Pseudolachnostylis maprouneifolia Pax*	Phyllanthaceae	Shrub/tree	15	0.08	5±2	0.4±0.2	10.6
76	*Pteleopsis myrtifolia (M.A.Lawson) Engl. & Diels*	Combretaceae	Shrub/tree	24	0.11	8±3	0.6±0.2	9.7
77	*Pterocarpus angolensis DC.*	Fabaceae	Shrub/tree	2	0.02	0	0	0.8
78	*Rauvolfia caffra Sond.*	Apocynaceae	Tree	4	0.03	2±1	0	1.9
79	*Rawsonia lucida Harv. & Sond.*	Achariaceae	Tree	1	0.01	0	0	0.6

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SN	*Botanical name*	Family name	Life form/Habit	Frequency (%)	H`	Density (stems/ha)	Basal area (m2/ha)	IVI
80	*Rothmannia manganjae (Hiern) Keay*	Rubiaceae	Shrub/tree	2	0.02	5±5	0	0.5
81	*Sclerocarya birrea (A.Rich.) Hochst.*	Anacardiaceae	Tree	2	0.02	1±1	0	3.5
82	*Sericanthe odoratissima (K.Schum.) Robbr.*	Rubiaceae	Shrub/tree	14	0.08	28±16	0	4.2
83	*Shirakiopsis elliptica (Hochst.) Esser*	Euphorbiaceae	Tree	2	0.02	1±1	0	0.8
84	*Sorindeia madagascariensis (Spreng.) DC.*	Anacardiaceae	Tree	1	0.01	0	0.1±0.1	0.5
85	*Synsepalum cerasiferum (Welw.) T.D.Penn.*	Sapotaceae	Tree	5	0.03	2±1	0.3±0.2	1.9
86	*Syzygium owariense (P.Beauv.) Benth.*	Myrtaceae	Tree	1	0.01	0	0	0.6
87	*Tabernaemontana elegans Stapf*	Apocynaceae	Shrub/tree	3	0.02	1	0	1.6
88	*Tabernaemontana pachysiphon Stapf*	Apocynaceae	Shrub/tree	15	0.08	8±4	0.1	3.7
89	*Tabernaemontana rauvolfiae A.DC.*	Apocynaceae	Shrub/tree	1	0.01	0	0	0.4
90	*Tabernaemontana ventricosa Hochst. ex A.DC.*	Apocynaceae	Tree	9	0.05	9±8	0.1±0.1	1.3
91	*Tapura fischeri Engl.*	Dichapetalaceae	Shrub/tree	9	0.05	4±2	0.1	3.4
92	*Terminalia mollis M.A.Lawson*	Combretaceae	Tree	1	0.01	0	0	0.7
93	*Terminalia sambesiaca Engl. & Diels*	Combretaceae	Tree	1	0.01	0	0	0.7
94	*Treculia africana Decne. ex Trécul*	Moraceae	Tree	5	0.03	2±1	0.2±0.1	2.3
95	*Uapaca nitida Müll.Arg.*	Phyllanthaceae	Shrub/tree	1	0.01	0	0	0.5
96	*Vachellia robusta (Burch.) Kyal. & Boatwr.*	Fabaceae	Tree	2	0.02	0	0.1±0.1	2.4
97	*Vangueria infausta Burch.*	Rubiaceae	Shrub/tree	3	0.02	2±2	0	1.0
98	*Vitex doniana Sweet*	Lamiaceae	Shrub/tree	7	0.04	3±1	0.2±0.1	9.7
99	*Vitex fischeri Gürke*	Lamiaceae	Shrub/tree	1	0.01	0	0	0.4
100	*Vitex mombassae Vatke*	Lamiaceae	Shrub/tree	1	0.01	0	0	0.6
101	*Ximenia caffra Sond.*	Olacaceae	Shrub/tree	2	0.02	1±1	0	0.7
102	*Xylopia aethiopica (Dunal) A.Rich.*	Annonaceae	Tree	7	0.04	3±1	0.4±0.3	3.7
	Total			**733**	**3.99**	**525±321**	**16±9**	**300**

Appendix 2: Checklist of Regenerants (<1cm DBH) Identified in Magombera NFR. Note: Shannon Wiener diversity Index (H')

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S/N	**Botanical name**	**Plant Family**	**Life form**	**Frequency**	**H`**	**Stem density/ha**
1	*Achyranthes aspera L.*	Amaranthaceae	Shrub	19	0.07	309±216
2	*Aerangis thomsonii (Rolfe) Schltr.*	Orchidaceae	Shrub	100	0.21	1624±1624
3	*Aeschynomene pubescens Vahl ex DC.*	Fabaceae	Shrub	5	0.02	81±81
4	*Aeschynomene schimperi Hochst. ex A.Rich.*	Fabaceae	Shrub	33	0.10	535±414
5	*Aganope stuhlmannii (Taub.) Adema*	Fabaceae	Tree	3	0.02	48±49
6	*Agathisanthemum bojeri Klotzsch*	Rubiaceae	Shrub	6	0.03	97±97
7	*Allophylus africanus P.Beauv.*	Sapindaceae	Shrub/tree	8	0.03	129±91
8	*Annona senegalensis Pers.*	Annonaceae	Shrub/tree	2	0.01	32±33
9	*Antiaris toxicaria (J.F.Gmel.) Lesch.*	Moraceae	Tree	5	0.02	81±67
10	*Aoranthe penduliflora (K.Schum.) Somers*	Rubiaceae	Shrub	1	0.01	16±16
11	*Asparagus flagellaris (Kunth) Baker*	Asparagaceae	Shrub	4	0.02	64±64
12	*Breynia disticha J.R.Forst. & G.Forst.*	Phyllanthaceae	Shrub/tree	7	0.03	113±113
13	*Bridelia micrantha (Hochst.) Baill.*	Phyllanthaceae	Tree	3	0.02	48±48
14	*Canthium angustifolium Roxb.*	Rubiaceae	Shrub/tree	5	0.02	81±81
15	*Canthium parviflorum Bartl. ex DC.*	Rubiaceae	Shrub/tree	2	0.01	32±32
16	*Casearia battiscombei R.E.Fr.*	Salicaceae	Tree	50	0.14	812±812
17	*Casearia parvifolia Willd.*	Salicaceae	Shrub/tree	1	0.01	16±16
18	*Catunaregam spinosa (Thunb.) Tirveng.*	Rubiaceae	Shrub/tree	1	0.01	16±16
19	*Cestrum aurantiacum Lindl.*	Solanaceae	Shrub/tree	2	0.01	32±32
20	*Coffea pseudozanguebariae Bridson*	Rubiaceae	Shrub/tree	4	0.02	64±64
21	*Combretum molle R.Br. ex G.Don*	Combretaceae	Shrub/tree	2	0.01	32±32
22	*Combretum mossambicense (Klotzsch) Engl.*	Combretaceae	Shrub/tree	28	0.09	454±195
23	*Conostomium kenyense Bremek.*	Rubiaceae	Shrub	2	0.01	32±32
24	*Crotalaria pallida Aiton*	Fabaceae	Shrub	10	0.04	162±162
25	*Croton scheffleri Pax*	Euphorbiaceae	Tree	8	0.03	129±129
26	*Cyathula cylindrica Moq.*	Amaranthaceae	Shrub	30	0.10	487±487
27	*Dalbergia fischeri Taub.*	Fabaceae	Shrub/tree	3	0.02	48±48
28	*Dalbergia melanoxylon Guill. & Perr.*	Fabaceae	Shrub/tree	20	0.07	324±192
29	*Deinbollia borbonica Scheff.*	Sapindaceae	Shrub/tree	8	0.03	129±93
30	*Desmodium repandum (Vahl) Poir.*	Fabaceae	Shrub	5	0.02	81±81

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S/N	Botanical name	Plant Family	Life form	Frequency	H`	Stem density/ha
31	*Dialium guineense Willd.*	Fabaceae	Shrub/tree	3	0.02	48±48
32	*Dialium holtzii Harms*	Fabaceae	Tree	25	0.08	406±172
33	*Diospyros fischeri Gürke*	Ebenaceae	Tree	10	0.04	162±83
34	*Diospyros kabuyeana F.White*	Ebenaceae	Tree	12	0.05	194±112
35	*Diospyros mespiliformis Hochst. ex A.DC.*	Ebenaceae	Tree	2	0.01	32±32
36	*Diospyros mollis Griff.*	Ebenaceae	Tree	7	0.03	113±65
37	*Diospyros montana Roxb.*	Ebenaceae	Tree	4	0.02	64±64
38	*Diospyros zombensis (B.L.Burtt) F.White*	Ebenaceae	Shrub/tree	2	0.01	32±32
39	*Diplorhynchus condylocarpon (Müll.Arg.) Pichon*	Apocynaceae	Shrub/tree	15	0.06	243±139
40	*Dolichos luticola Verdc.*	Fabaceae	Shrub	3	0.02	48±48
41	*Ecbolium revolutum (Lindau) C.B.Clarke*	Acanthaceae	Shrub	3	0.02	48±48
42	*Englerophytum natalense (Sond.) T.D.Penn.*	Sapotaceae	Tree	11	0.04	178±90
43	*Eriosema psoraleoides (Lam.) G.Don*	Fabaceae	Shrub	7	0.03	113±86
44	*Erythrina schliebenii Harms*	Fabaceae	Tree	2	0.01	32±32
45	*Erythrophleum micranthum Harms ex Craib*	Fabaceae	Tree	12	0.05	194±126
46	*Erythrophleum suaveolens (Guill. & Perr.) Brenan*	Fabaceae	Tree	20	0.07	324±148
47	*Eupatorium adenophorum Spreng.*	Asteraceae	Shrub	1	0.01	16±16
48	*Flueggea virosa (Roxb. ex Willd.) Royle*	Phyllanthaceae	Shrub/tree	3	0.02	48±48
49	*Garcinia buchananii Baker*	Clusiaceae	Shrub/tree	2	0.01	32±32
50	*Garcinia kingaensis Engl.*	Clusiaceae	Tree	9	0.04	146±108
51	*Gardenia taitensis DC.*	Rubiaceae	Shrub/tree	11	0.04	178±178
52	*Glossocardia bosvallia (L.f.) DC.*	Asteraceae	Shrub	3	0.02	48±48
53	*Gmelina macrophylla K.Schum.*	Lamiaceae	Tree	2	0.01	32±32
54	*Grewia bicolor Juss.*	Malvaceae	Shrub/tree	25	0.08	406±264
55	*Grewia conocarpa K.Schum.*	Malvaceae	Shrub/tree	3	0.02	48±48
56	*Harrisonia abyssinica Oliv.*	Rutaceae	Shrub/tree	14	0.05	227±111
57	*Hermannia exappendiculata (Mast.) K.Schum. ex Engl.*	Malvaceae	Shrub	2	0.01	32±32
58	*Hibiscus flavifolius Ulbr.*	Malvaceae	Shrub	5	0.02	81±81
59	*Hymenocardia ulmoides Oliv.*	Phyllanthaceae	Shrub/tree	3	0.02	48±48
60	*Hypericum revolutum Vahl*	Hypericaceae	Shrub/tree	3	0.02	48±48

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S/N	Botanical name	Plant Family	Life form	Frequency	H`	Stem density/ha
61	*Indigofera australis Willd.*	Fabaceae	Tree	2	0.01	32±32
62	*Isoberlinia scheffleri (Harms) Greenway*	Fabaceae	Tree	15	0.06	243±150
63	*Lettowianthus stellatus Diels*	Annonaceae	Tree	3	0.02	48±48
64	*Majidea zanguebarica Kirk ex Oliv.*	Sapindaceae	Shrub/tree	35	0.11	568±568
65	*Mallotus oppositifolius (Geiseler) Müll.Arg.*	Euphorbiaceae	Shrub/tree	66	0.17	1071±543
66	*Mallotus philippensis (Lam.) Müll.Arg.*	Euphorbiaceae	Shrub/tree	10	0.04	162±162
67	*Margaritaria discoidea (Baill.) G.L.Webster*	Phyllanthaceae	Shrub/tree	13	0.05	211±211
68	*Markhamia lutea (Benth.) K.Schum.*	Bignoniaceae	Tree	13	0.05	211±158
69	*Markhamia obtusifolia (Baker) Sprague*	Bignoniaceae	Tree	14	0.05	227±141
70	*Monodora grandidieri Baill.*	Annonaceae	Shrub/tree	6	0.03	97±97
71	*Monodora junodii Engl. & Diels*	Annonaceae	Shrub/tree	2	0.01	32±32
72	*Monodora minor Engl. & Diels*	Annonaceae	Shrub/tree	8	0.03	129±129
73	*Monodora myristica (Gaertn.) Dunal*	Annonaceae	Tree	15	0.06	243±243
74	*Ochna holtzii Gilg*	Ochnaceae	Shrub/tree	6	0.03	97±72
75	*Ochna macrocalyx Oliv.*	Ochnaceae	Shrub	33	0.10	535±396
76	*Oxyanthus speciosus DC.*	Rubiaceae	Shrub/tree	1	0.01	16±16
77	*Parkia filicoidea Welw. ex Oliv.*	Fabaceae	Tree	5	0.02	81±81
78	*Pavonia propinqua Garcke*	Malvaceae	Shrub	1	0.01	16±16
79	*Pentas parvifolia f. intermedia Verdc.*	Rubiaceae	Shrub	4	0.02	64±64
80	*Philenoptera bussei (Harms) Schrire*	Fabaceae	Tree	2	0.01	32±32
81	*Philenoptera laxiflora (Guill. & Perr.) Roberty*	Fabaceae	Tree	12	0.05	194±194
82	*Phyllanthus nigrescens (Blanco) Müll.Arg.*	Phyllanthaceae	Shrub	3	0.02	48±48
83	*Plumbago auriculata Lam.*	Plumbaginaceae	Shrub	13	0.05	211±211
84	*Plumbago zeylanica L.*	Plumbaginaceae	Shrub	11	0.04	178±125
85	*Polyalthia verdcourtii Vollesen*	Annonaceae	Tree	5	0.02	81±81
86	*Rauvolfia serpentina (L.) Benth. ex Kurz*	Apocynaceae	Shrub	4	0.02	64±64
87	*Rauvolfia tetraphylla L.*	Apocynaceae	Shrub	78	0.18	1266±1141
88	*Rauvolfia volkensii (K.Schum.) Stapf*	Apocynaceae	Tree	2	0.01	32±32
89	*Rothmannia longiflora Salisb.*	Rubiaceae	Shrub/tree	2	0.01	32±32
90	*Rytigynia kigeziensis Verdc.*	Rubiaceae	Shrub/tree	4	0.02	64±64

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S/N	**Botanical name**	**Plant Family**	**Life form**	**Frequency**	**H`**	**Stem density/ha**
91	*Sapium sebiferum (L.) Dum.Cours.*	Euphorbiaceae	Tree	6	0.03	97±72
92	*Sericanthe odoratissima (K.Schum.) Robbr.*	Rubiaceae	Shrub/tree	22	0.08	357±162
93	*Sida ovata Forssk.*	Malvaceae	Shrub	2	0.01	32±32
94	*Sorindeia madagascariensis (Spreng.) DC.*	Anacardiaceae	Tree	19	0.07	308±192
95	*Suregada zanzibariensis Baill.*	Euphorbiaceae	Shrub	4	0.02	64±45
96	*Synsepalum cerasiferum (Welw.) T.D.Penn.*	Sapotaceae	Tree	22	0.08	357±196
97	*Tabernaemontana elegans Stapf*	Apocynaceae	Shrub/tree	3	0.02	48±48
98	*Tabernaemontana pachysiphon Stapf*	Apocynaceae	Shrub/tree	10	0.04	162±92
99	*Tabernaemontana ventricosa Hochst. ex A.DC.*	Apocynaceae	Tree	4	0.02	64±45
100	*Tarenna pavettoides (Harv.) Sim*	Rubiaceae	Shrub	3	0.02	48±48
101	*Triaspis niedenzuiana Engl.*	Malpighiaceae	Shrub	2	0.01	32±32
102	*Triumfetta brachyceras K.Schum.*	Malvaceae	Shrub	7	0.03	113±113
103	*Triumfetta flavescens Hochst. ex A.Rich.*	Malvaceae	Shrub	6	0.03	97±72
104	*Triumfetta rhomboidea Jacq.*	Malvaceae	Shrub	6	0.03	97±59
105	*Triumfetta tomentosa Bojer*	Malvaceae	Shrub	3	0.02	48±48
106	*Vachellia nilotica (L.) P.J.H.Hurter & Mabb.*	Fabaceae	Shrub/tree	3	0.02	48±48
107	*Vitex fischeri Gürke*	Lamiaceae	Shrub/tree	3	0.02	48±48
108	*Waltheria indica L.*	Malvaceae	Shrub	2	0.01	32±32
109	*Xylopia aethiopica (Dunal) A.Rich.*	Annonaceae	Tree	19	0.07	308±146
110	*Xylotheca tettensis (Klotzsch) Gilg*	Achariaceae	Shrub/tree	4	0.02	64±45
Grand total				**1139**	**4.09**	**18497±14646**

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Appendix 3: Checklist of Other Life Forms Identified in Magombera NFR

SN	*Botanical name*	Family	Life form	Frequency	H`	Stem density
1	*Alternanthera sessilis (L.) DC.*	Amaranthaceae	Herb	10	0.05	162±162
2	*Ammannia latifolia L.*	Lythraceae	Herb	6	0.04	97±97
3	*Aneilema acuminatum R.Br.*	Commelinaceae	Herb	1	0.01	16±16
4	*Aneilema aequinoctiale (P.Beauv.) G.Don*	Commelinaceae	Herb	7	0.04	113±113
5	*Aneilema lanceolatum Benth.*	Commelinaceae	Herb	10	0.05	162±162
6	*Aneilema pedunculosum C.B.Clarke*	Commelinaceae	Herb	13	0.07	211±168
7	*Arachnorchis viriosa R.J.Bates*	Orchidaceae	Herb	4	0.03	64±64
8	*Argemone mexicana L.*	Papaveraceae	Herb	1	0.01	16±16
9	*Arisaema mildbraedii Engl.*	Araceae	Herb	4	0.03	64±64
10	*Arthraxon hispidus (Thunb.) Makino*	Poaceae	Herb	141	0.30	2289±1180
11	*Barleria argentea Balf.f.*	Acanthaceae	Herb	5	0.03	81±81
12	*Chlorophytum macrophyllum (A.Rich.) Asch.*	Asparagaceae	Herb	2	0.01	32±32
13	*Commelina africana L.*	Commelinaceae	Herb	146	0.31	2371±1110
14	*Commelina albescens Hassk.*	Commelinaceae	Herb	5	0.03	81±81
15	*Commelina benghalensis Forssk.*	Commelinaceae	Herb	47	0.16	763±391
16	*Commelina forskailii Hochst. ex C.B.Clarke*	Commelinaceae	Herb	3	0.02	48±48
17	*Commelina latifolia Hochst. ex A.Rich.*	Commelinaceae	Herb	5	0.03	81±81
18	*Costus spectabilis (Fenzl) K.Schum.*	Costaceae	Herb	10	0.05	162±162
19	*Crabbea reticulata C.B.Clarke*	Acanthaceae	Herb	4	0.03	64±64
20	*Craterostigma plantagineum Hochst.*	Linderniaceae	Herb	2	0.01	32±32
21	*Craterostigma pumilum Hochst.*	Linderniaceae	Herb	1	0.01	16±16
22	*Crossandra friesiorum Mildbr.*	Acanthaceae	Herb	20	0.09	324±255
23	*Crotalaria pycnostachya Benth.*	Fabaceae	Herb	13	0.07	211±211
24	*Crotalaria zanzibarica Benth.*	Fabaceae	Herb	3	0.02	48±48
25	*Cucumis anguria L.*	Cucurbitaceae	Herb	1	0.01	16±16
26	*Cyathula orthacantha (Hochst. ex Asch.) Schinz*	Amaranthaceae	Herb	7	0.04	113±113
27	*Cyathula polycephala Baker*	Amaranthaceae	Herb	70	0.21	1136±1136
28	*Cycnium ajugifolium Engl.*	Orobanchaceae	Herb	13	0.07	211±168
29	*Dissotis senegambiensis Triana*	Melastomataceae	Herb	1	0.01	16±16

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SN	*Botanical name*	Family	Life form	Frequency	H`	Stem density
30	*Farsetia stenoptera Hochst.*	Brassicaceae	Herb	2	0.01	32±32
31	*Floscopa glomerata (Willd. ex Schult. & Schult.f.) Hassk.*	Commelinaceae	Herb	3	0.02	48±48
32	*Gomphocarpus kaessneri (N.E.Br.) Goyder & Nicholas*	Apocynaceae	Herb	2	0.01	32±32
33	*Hibiscus acetosella Welw. ex Hiern*	Malvaceae	Herb	5	0.03	81±81
34	*Hypoestes aristata (Vahl) Sol. ex Roem. & Schult.*	Acanthaceae	Herb	2	0.01	32±32
35	*Hypoxis obtusa Burch. ex Ker Gawl.*	Hypoxidaceae	Herb	2	0.01	32±32
36	*Ipomoea aquatica Forssk.*	Convolvulaceae	Herb	3	0.02	48±48
37	*Ipomoea blepharophylla Hallier f.*	Convolvulaceae	Herb	6	0.04	97±97
38	*Ipomoea garckeana Vatke*	Convolvulaceae	Herb	2	0.01	32±32
39	*Justicia betonica L.*	Acanthaceae	Herb	10	0.05	162±162
40	*Justicia calyculata Deflers*	Acanthaceae	Herb	10	0.05	162±162
41	*Justicia matammensis (Schweinf.) Oliv.*	Acanthaceae	Herb	4	0.03	64±64
42	*Lobelia baumannii Engl.*	Campanulaceae	herb	15	0.07	243±243
43	*Maerua subcordata (Gilg) DeWolf*	Capparaceae	Herb	2	0.01	32±32
44	*Mollugo nudicaulis Lam.*	Molluginaceae	Herb	3	0.02	48±48
45	*Momordica boivinii Baill.*	Cucurbitaceae	Herb	5	0.03	81±57
46	*Momordica foetida Schumach.*	Cucurbitaceae	Herb	3	0.02	48±48
47	*Mucuna quadrialata Baker*	Fabaceae	Herb	2	0.01	32±32
48	*Murdannia simplex (Vahl) Brenan*	Commelinaceae	Herb	5	0.03	81±81
49	*Nephthytis afzelii Schott*	Araceae	Herb	3	0.02	48±48
50	*Persicaria maculosa Gray*	Polygonaceae	Herb	1	0.01	16±16
51	*Polygonum divaricatum Poir.*	Polygonaceae	Herb	10	0.05	162±162
52	*Polygonum salicifolium Schur*	Polygonaceae	Herb	40	0.15	649±649
53	*Reichardia tingitana (L.) Roth*	Asteraceae	Herb	3	0.02	48±48
54	*Rutheopsis herbanica (Bolle) A.Hansen & G.Kunkel*	Apiaceae	Herb	3	0.02	48±48
55	*Scadoxus multiflorus (Martyn) Raf.*	Amaryllidaceae	Herb	1	0.01	16±16
56	*Sicyos edulis Jacq.*	Cucurbitaceae	Herb	3	0.02	48±48
57	*Siphonochilus aethiopicus (Schweinf.) B.L.Burtt*	Zingiberaceae	Herb	29	0.12	470±337
58	*Striga asiatica (L.) Kuntze*	Orobanchaceae	Herb	3	0.02	48±48
59	*Tacca chantrieri André*	Dioscoreaceae	Herb	3	0.02	48±48

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SN	*Botanical name*	Family	Life form	Frequency	H`	Stem density
60	*Tacca integrifolia Ker Gawl.*	Dioscoreaceae	Herb	3	0.02	48±48
61	*Thunbergia alata Bojer ex Sims*	Acanthaceae	Herb	10	0.05	162±162
62	*Triumfetta pentandra A.Rich.*	Malvaceae	Herb	7	0.04	113±113
63	*Vigna pubescens R.Wilczek*	Fabaceae	Herb	54	0.18	876±812
	Subtotal			**814**	**3.12**	**13219±10102**
64	*Brachiaria lachnantha (Hochst.) Stapf*	Poaceae	Grass	28	0.05	454±380
65	*Brachiaria ramosa (L.) Stapf*	Poaceae	Grass	2	0.01	32±32
66	*Cenchrus ciliaris L.*	Poaceae	Grass	25	0.05	406±406
67	*Cenchrus massaicus (Stapf) Morrone*	Poaceae	Grass	59	0.09	958±561
68	*Cenchrus purpureus (Schumach.) Morrone*	Poaceae	Grass	12	0.03	194±138
69	*Corchorus capsularis L.*	Malvaceae	Grass	4	0.01	64±64
70	*Cynodon dactylon (L.) Pers.*	Poaceae	Grass	7	0.02	113±113
71	*Cyperus difformis L.*	Cyperaceae	Grass	3	0.01	48±36
72	*Cyperus exaltatus Retz.*	Cyperaceae	Grass	21	0.04	341±341
73	*Cyperus kilimandscharicus Kük.*	Cyperaceae	Grass	3	0.01	48±48
74	*Cyperus schimperianus Steud.*	Cyperaceae	Grass	2	0.01	32±32
75	*Dactyloctenium aegyptium (L.) Willd.*	Poaceae	Grass	4	0.01	64±64
76	*Dactyloctenium giganteum B.S.Fisher & Schweick.*	Poaceae	Grass	3	0.01	48±48
77	*Digitaria eriantha Steud.*	Poaceae	Grass	3	0.01	48±48
78	*Eleusine africana Kenn. -O'Byrne*	Poaceae	Grass	2	0.01	32±32
79	*Eragrostis minor Host*	Poaceae	Grass	12	0.03	194±194
80	*Eragrostis racemosa (Thunb.) Steud.*	Poaceae	Grass	18	0.04	292±189
81	*Gladiolus natalensis Reinw. ex Hook.*	Iridaceae	Grass	13	0.03	211±211
82	*Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.*	Poaceae	Grass	20	0.04	324±324
83	*Hyparrhenia filipendula (Hochst.) Stapf*	Poaceae	Grass	458	0.31	7438±2314
84	*Hyparrhenia hirta (L.) Stapf*	Poaceae	Grass	168	0.18	2728±989
85	*Imperata cylindrica (L.) Raeusch*	Poaceae	Grass	101	0.13	1640±794
86	*Microstegium vimineum (Trin.) A.Camus*	Poaceae	Grass	155	0.17	2517±1034
87	*Mimosa pudica L.*	Fabaceae	Grass	8	0.02	129±129
88	*Oplismenus hirtellus (L.) P.Beauv.*	Poaceae	Grass	30	0.05	487±487

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SN	***Botanical name***	Family	Life form	Frequency	H`	Stem density
89	*Oplismenus undulatifolius (Ard.) P.Beauv.*	Poaceae	Grass	30	0.05	487±487
90	*Panicum maximum Jacq.*	Poaceae	Grass	717	0.36	11644±2411
91	*Panicum repens L.*	Poaceae	Grass	20	0.04	324±324
92	*Panicum vaginatum (Sw.) Godr.*	Poaceae	Grass	54	0.08	714±649
93	*Panicum virgatum Roxb. ex Steud.*	Poaceae	Grass	10	0.02	324±227
94	*Paspalum dilatatum Poir.*	Poaceae	Grass	1	0.00	16±16
95	*Phalaris arundinacea L.*	Poaceae	Grass	284	0.25	4612±2034
96	*Phragmites australis (Cav.) Trin. ex Steud.*	Poaceae	Grass	28	0.05	454±407
97	*Rhynchospora corymbosa (L.) Britton*	Cyperaceae	Grass	11	0.02	178±178
98	*Setaria pumila (Poir.) Roem. & Schult.*	Poaceae	Grass	20	0.04	324±324
99	*Sorghum halepense (L.) Pers.*	Poaceae	Grass	12	0.03	194±164
100	*Sporobolus indicus (L.) R.Br.*	Poaceae	Grass	10	0.02	162±162
101	*Tragus racemosus (L.) All.*	Poaceae	Grass	5	0.01	81±57
102	*Typha latifolia L.*	Typhaceae	Grass	23	0.04	373±327
103	*Urochloa brizantha (A.Rich.) R.D.Webster*	Poaceae	Grass	8	0.02	129±129
104	*Urochloa mosambicensis (Hack.) Dandy*	Poaceae	Grass	10	0.02	162±162
105	*Urochloa mutica (Forssk.) T.Q.Nguyen*	Poaceae	Grass	50	0.08	812±666
106	*Urochloa panicoides P.Beauv.*	Poaceae	Grass	80	0.11	1299±737
	Subtotal			**2534**	**2.56**	**41153±18492**
107	*Carex acutiformis Ehrh.*	Cyperaceae	Serge	10	0.11	162±98
108	*Cyperus alopecuroides Rottb.*	Cyperaceae	Serge	5	0.07	81±81
109	*Cyperus alterniflorus R.Br.*	Cyperaceae	Serge	10	0.11	162±162
110	*Cyperus articulatus L.*	Cyperaceae	Serge	2	0.03	33±33
111	*Cyperus esculentus L.*	Cyperaceae	Serge	39	0.26	633±312
112	*Cyperus javanicus Houtt.*	Cyperaceae	Serge	7	0.09	114±113
113	*Cyperus longus L.*	Cyperaceae	Serge	10	0.11	162±162
114	*Cyperus papyrus L.*	Cyperaceae	Serge	65	0.33	1055±694
115	*Cyperus rotundus L.*	Cyperaceae	Serge	58	0.31	941±689
116	*Kyllinga bulbosa Steud.*	Cyperaceae	Serge	10	0.11	162±162
117	*Kyllinga odorata Kunth*	Cyperaceae	Serge	9	0.10	146±94

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SN	***Botanical name***	**Family**	**Life form**	**Frequency**	**H`**	**Stem density**
118	*Kyllinga polyphylla Willd. ex Kunth*	Cyperaceae	Serge	5	0.07	81±81
119	*Kyllinga pumila Steud.*	Cyperaceae	Serge	70	0.34	1136±1136
120	*Phyllanthus amarus Schumach. & Thonn.*	Phyllanthaceae	Serge	11	0.12	178±101
	Subtotal			**311**	**2.15**	**5051±3923**
121	*Ampelocissus africana (Lour.) Merr.*	Vitaceae	Climber	3	0.12	49±49
122	*Canarina eminii Asch. & Schweinf.*	Campanulaceae	Climber	2	0.09	32±32
123	*Cissus quadrangularis L.*	Vitaceae	Climber	1	0.05	16±16
124	*Cyphostemma adenocaule (Steud. ex A.Rich.) Desc. ex Wild & R.B.Drumm.*	Vitaceae	Climber	3	0.12	49±49
125	*Cyphostemma nieriense (T.C.E.Fr.) Desc.*	Vitaceae	Climber	3	0.12	49±49
126	*Cyphostemma nodiglandulosum (T.C.E.Fr.) Desc.*	Vitaceae	Climber	4	0.14	65±45
127	*Cyphostemma orondo (Gilg & M.Brandt) Desc.*	Vitaceae	Climber	4	0.14	65±45
128	*Cyphostemma serpens (Hochst. ex A.Rich.) Desc.*	Vitaceae	Climber	6	0.19	97±59
129	*Landolphia kirkii Dyer ex Hook.f.*	Apocynaceae	Climber	37	0.36	601±569
130	*Leptadenia lanceolata (Poir.) Goyder*	Apocynaceae	Climber	4	0.14	65±65
131	*Ophrestia hedysaroides (Willd.) Verdc.*	Fabaceae	Climber	2	0.09	32±32
132	*Rourea orientalis Baill.*	Connaraceae	Climber	6	0.19	97±68
133	*Tragia impedita Prain*	Euphorbiaceae	Climber	3	0.12	48±48
134	*Tragia insuavis Prain*	Euphorbiaceae	Climber	3	0.12	48±48
135	*Volkameria inermis L.*	Lamiaceae	Climber	3	0.12	48±48
	Subtotal			**84**	**2.12**	**1364±1226**
136	*Aristolochia elegans Mast.*	Aristolochiaceae	liana	7	0.31	113±86
137	*Cissampelos pareira L.*	Menispermaceae	liana	7	0.31	113±113
138	*Entada phaseoloides (L.) Merr.*	Fabaceae	liana	4	0.24	64±51
139	*Entada rheedei Spreng.*	Fabaceae	liana	18	0.35	292±151
140	*Landolphia myrtifolia (Poir.) Markgr.*	Apocynaceae	liana	2	0.15	32±32
	Subtotal			**38**	**1.37**	**617±435**
	Grand Total			**3781**		**61404±34179**

Note: Shannon Wiener diversity Index (H'), **Other growth forms = herbs, grasses, serge, climbers and lianas*

