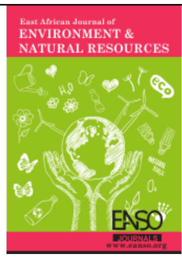

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*Original Article*

# Drivers of Anthropogenic Threats to Tree Species Volume, Diversity, and Plant Species Richness, Within the Vegetation Types of Mramba Forest Reserve in Mwanga District, Northern Tanzania

*Canisius John Kayombo[1*], Philipina F. Shayo[2], Grace A. Nchimbi[3] & Andambike T. Mgogo[4]*

[1] Tengeru Institute of Community Development, P. O. Box 1006, Arusha, Tanzania.
[2] Mbeya University of Science and Technology, P. O. Box 131, Mbeya, Tanzania.
[3] College of African Wildlife Management Mweka, P. O. Box 3031, Moshi, Tanzania.
[4] The University of Dar Es Salaam, P. O. Box 35169, Dar es Salaam, Tanzania.
[*] Correspondence ORCID ID; https://orcid.org/0000-0002-4177-0285; Email: kayombocanisiusjohn@gmail.com

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**Keywords**:

*Vegetation Types, Tree Volume, Diversity, Richness, Non-Tree Woody Plants, Non-Woody Plants, Anthropogenic Threats, Mramba Forest Reserve.*

**ABSTRACT**

Plant species evaluation is a panacea for a sustainable management plan of forest reserves. An assessment of anthropogenic threats to tree species volume, diversity, and plant species richness, at Mramba Forest Reserve was conducted in December 2022. Remote Sensing (RS) and Geographical Information System (GIS) were used to mark the plots together with the available shape files to produce the map of the study area. Plots of 20 m x 20 m were established, and trees with a diameter ≥ 5cm were measured at 1.3 m from ground level. 2 m x 5 m nested plots were set to determine woody non-trees, and 1 m x 1m sub-plots for determining the non-woody plants. Anthropogenic threats were recorded. The described vegetation types were; dry montane forest, shrubland with emergent trees, bushland, woodland, and wooded grassland. The calculated volume per diameter class was the highest in the fewer stems but with the largest trunk diameter. The diameter class of >50 cm got the largest volume (m3) of all (36,420 m3), followed by the diameter class of ≤30 -≥20 cm (11,617.14 m3), ≤40 - ≥31 cm (8,448.42), ≤20 - ≥11 cm (3,727.31 m3), ≤10 - ≥5 (659.617 m3). The woodland got the largest volume (44,450.85 m3) with 58 tree species, followed by dry montane forest (11,976.89 m3) with 29 tree species, bushland (6,430.64 m3) with 56 species, and wooded grassland got the least volume (153.99 m3) with 4 species. This implied that the difference in volume was contributed by the differences in the diameter sizes, heights, and the number of the measured tree stems. A total of 245 plant species were recorded, and of those 102 were trees with H' of 4.0318 implying high diversity tree diversity for MRAFR. The non-tree woody plants richness (S) was 70, and the non-woody plants richness (S) was 73. The recorded anthropogenic threats to the tree species volume, and plant S of MRAFR were; firewood collection, livestock grazing, charcoal making, poles and rods cutting. MFR comprises high plant taxa of different growth forms disturbed by anthropogenic activities, thus calling for further studies, regular

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patrols, alternative sources of energy provision, awareness creation and cons education to the community.

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## INTRODUCTION

It is known that forests cover 31% of the land area on our planet and they help people thrive and survive by, for example, purifying water and air and providing people with jobs; some 13.2 million people across the world have jobs in the forest sector and another 41 million have a job that is related to the sector (WWF, 2022). Forests are home to more than three-quarters of the world's life on land and play a critical role in mitigating climate change because they act as a carbon sink-soaking up carbon dioxide that would otherwise be free in the atmosphere and contribute to ongoing changes in climate patterns (WWF, 2022). Tanzania's Mainland has a land area of 88.6 million hectares, and as of the year 2010, 48.1 million ha were occupied by forests and woodlands representing 55% of the total land area. Approximately 93% of the total forest area is woodland and 7% is composed of mangroves, coastal forests, humid mountain forests, and plantations (MNRT, 2015). Surveys have estimated that an average of 10 million hectares in the world disappear each year regardless of the international efforts to remedy (FAO, 2017).

Tanzania is well known for its flora and fauna species diversity, of which among taxa are known to be endemic (Lovett and Pocs, 1993). A forest reserve is a forest area, either for the production of timber and other forest produce or for the protection of forests, and important water catchments, controlled under the Forests Ordinance and declared by the Minister. Tanzania has about 33.5 million hectares of forests and woodlands. Out of this total area, almost two-thirds consist of woodlands on public lands which lack proper management. Public lands are under enormous pressure from the expansion of agricultural activities, livestock grazing, fires and other anthropogenic activities. About 13 million hectares of this total forest area have been gazetted as forest reserves. Over 80,000 hectares of the gazetted area are under plantation forestry and about 1.6 million hectares are under water catchment management (URT, 1998). The

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forests offer habitat for wildlife, beekeeping, unique natural ecosystems and genetic resources. They are also an important economic base for the country's development.

Even though there are natural disturbances to biodiversity and abundance such as wild fauna grazing, anthropogenic disturbance has been known to generate a significant **loss of biodiversity** worldwide and grazing by domestic herbivores is a noticeable contributing disturbance (Mao et al., 2006). The biodiversity richness, distribution, and abundance changes are caused by excessive illegal hunting and habitat loss because of anthropogenic expansion with high demand for resources, illegal cutting of woody plants for timber, charcoal, building rods, poles and firewood (Doggart et al., 2008). In Tanzania, the biodiversity landscapes and ecosystems range from the rich marine life found in coral in the Indian Ocean to high mountains at the highest points (URT, 2014; URT, 2015). The Rift Valley and the Serengeti National Park are home to diverse and abundant plains, fauna, and mountainous forests scattered throughout the country containing fascinating forest fauna and flora (Murnyak and Kinsey, 2006). Some 25% of Tanzania is reserved for National Parks, and game-controlled areas and the rest are forest reserves, public land, settlement areas, and farms. In general, the natural resources proper management is a policy-based strategy. The first national forest policy was enacted in 1953 and was modified in 1963 with the aim of assessing the natural forest resources' sustainable utilization methods to satisfy the needs of the nation. The expansion of anthropogenic population and advancement of technology have set high pressure on natural forest resources exploitation for fuel wood, livestock grazing, encroachment for agricultural crops, and settlement (United Republic of Tanzania, 1998). In 1988, the Government of Tanzania initiated the preparation of the Tanzania Forestry Action Plan (TF AP), and it was completed and adopted by the Government in 1989 as a basis for the development of the forest sector (MNRT, 1998). There is a big challenge in managing the natural forest resources of Tanzania which are a national heritage for sustainable development to improve the environmental resources value, economic value, and social value (MNRT, 1998). In this case, the management plan has to be prepared after having assessed the available resources that can be marketed without excessive damage.

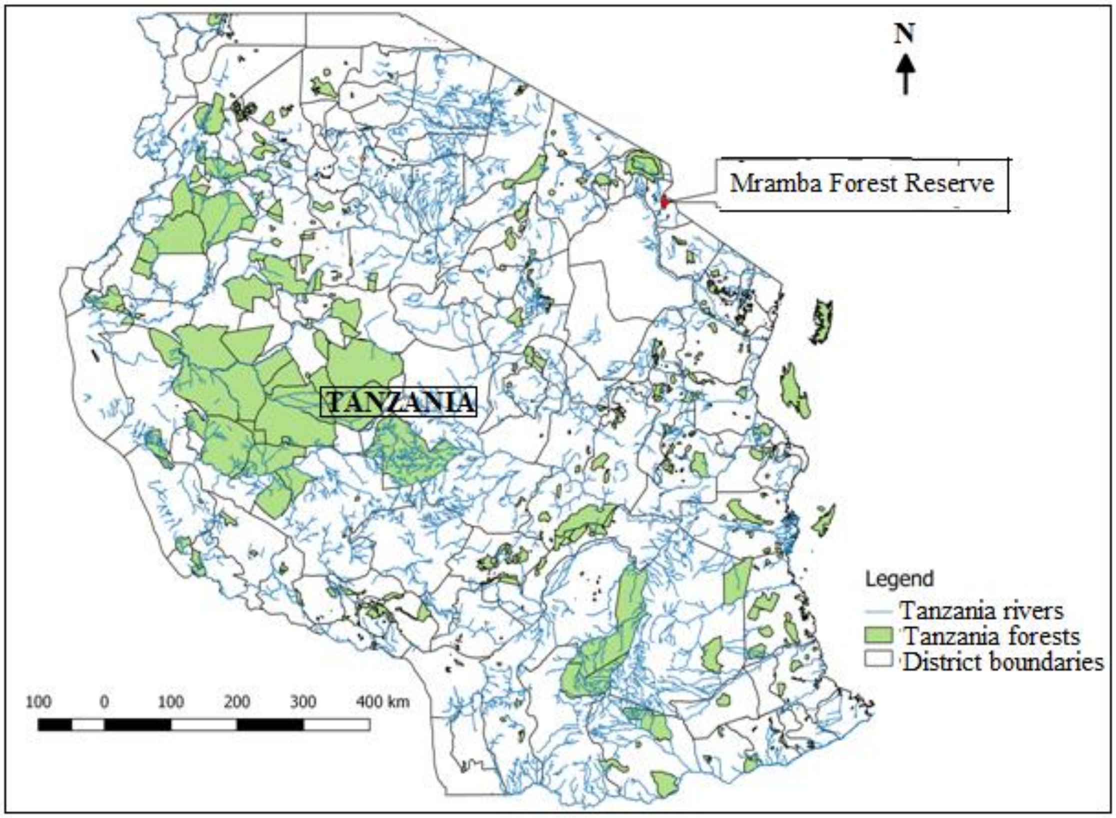
Mramba Forest Reserve is a protected area that misses adequate information on the biological diversity, composition, and recreational resources. Mramba Forest Reserve is on the slopes of the West Pare Mountains just north of the anthropogenic settlement. The community needs natural forest resources for household uses and income generation. The needs are: charcoal, firewood, bush meat, poles, livestock fodder, crop farming land, and settlement. Mramba Forest Reserve, apart from being known to be a home for fairly high floristic and fauna species diversity and high scenic value, lacks adequate information on the natural biodiversity resources. This investigation intended to assess the anthropogenic activities endangering tree volume, diversity and plant species richness of Mramba Forest Reserve (MRAFR) in Mwanga District

## METHODOLOGY

### Study Site Description

The study was conducted at Mramba Forest Reserve (MRAFR) in Mwanga district. The Mramba Forest Reserve with an area of 3355 Ha is situated at 3°23'S 36°47'E (Doggart et al., 2008). The reserve is accessed from the Kifaru village road junction of Same to Moshi or through Mwanga town centre through the mountains to Mandaka, and Lambo, or to Mwai, and or Kivisini. The reserve covers the west Pare slopes facing west, on rock outcrop (Doddart et al. 2008) (Figure 1). The MRAFR, lies at an altitude of 760 – 1,700 m a.s.l (Lovet and Pocs, 1993), however, during this study the recorded altitude ranged from 715 to 1,700 for some areas. The MRAFR borders Mandaka village on the south, southwest, and west, Lambo village on the southeast, while Mwai and Visini villages border the forest reserve on the east (Figure 2). The northeast, north to north-west borders Kifaru village. It also borders Kisangiro on the west (Figure 2).

**Figure 1: Map of Tanzania Showing the Study Location**




The climate of the area is characterized by oceanic rainfall with oceanic temperatures. The rainfall ranges from 700 – 1400 mm per annum with a mist effect at higher altitudes (Lovett and Pocs, 1993). The dry season extends between June and October. Temperatures vary from $25^0$C in March to $16^0$C minimum in July. The vegetation is dry montane open bushland occurring on rock outcrops. The MRAFR vegetation on spurs and small valleys offers attractive scenic views to the community. Ecologically the vegetation cover minimizes erosion during heavy rains, regulates rainfall, habitat for wildlife and many plant taxa.

### Sampling Method

Mramba Forest Reserve was classified into two (2) major categories of transects (clusters), namely the valley transects, and spur tops transects. Whittaker Nested Plot Method (Stohlgren *et al*., 1995) was applied, whereby plots of 10m x 20 m were established. 2m x 5m nested plots were set to determine shrubs, saplings, and poles (Figure 2). 1m x 1m nested plots were established to determine tree seedlings and herbaceous plants (Figure 2). All trees with a diameter at breast height of ≥ 5 cm were identified and measured at 1.3m from the ground. Woody non-tree plants including lianas and shrubs were identified and counted for their number of individuals. The trees were classified for their stages (seedlings, saplings, and poles). Herbaceous plants were identified and estimated for percentage cover within a 1 m x 1 m sub-plot. The observed anthropogenic activities were identified and recorded.

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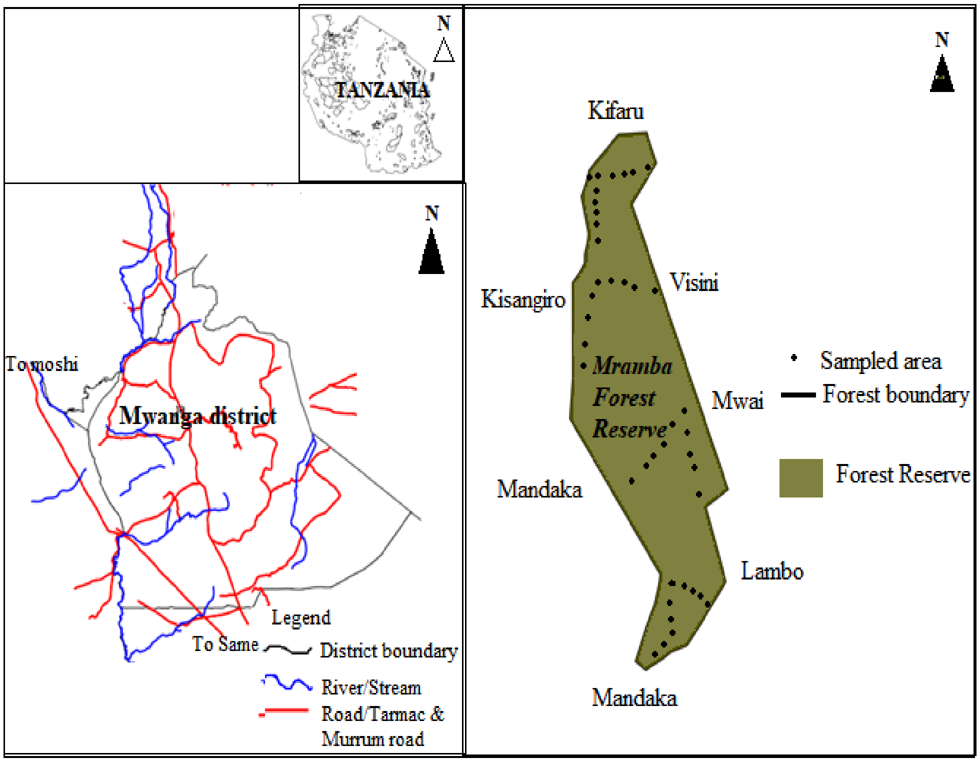
**Figure 2: Mramba Forest Reserve Sampled Area**




## Data Analysis

Quantification of vegetation indices

(i) Tree volume

All trees with a dbh ≥5cm measured and recorded within 10 m x 20 m plots were calculated for their volume through:

- $V = \frac{\Pi D^2}{4(100cm)} \, x \, h(m)$ (Lefsky & McHale, 2008); where π=3.14; D=diameter; 4=constant; cm = centimeter; h = height; m = meter

(ii) Plant Diversity Indices

- Shannon Wiener Diversity (H') and Simpson Indices

H' = -Σpilnpi; and index of dominance (ID) = $pi^2$ (Kent and Coker, 1992). Where; H' = Shannon Wiener diversity index; C or ID = index of dominance; pi = Simpson's index.

## RESULTS AND DISCUSSION

### Vegetation Types and Community Composition of Mramba Forest Reserve (MRAFR)

***Vegetation Types***

The vegetation types influence the soil formation and availability of different plant species (Arenberg and Arai, 2019). During this survey, the following vegetation types were described based on the physiognomic characteristics**.** Those vegetation types were: dry montane forest, bushland, shrubland, wooded grassland, and woodland.

***a. Dry montane forest***

Dry montane forest (Plate 2) was occupied by *Croton megalocarpus*, *Afrocarpus falcatus*, *Mimusops kummel*, *Chaetacme aristata*, *Albizia gummifera*, *Obetia radula*, *Vepris simplicifolia*, *Erythroxyllum emarginatum*, *Apodytes dimidiata*, *Clausena*, *anisata*, and *Gymnosporia accuminata.*

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**Plate 1: Dry Montane Forest**

***b. Bushland***

The identified plant species in bushland (Plate 2) were *Dodonaea viscosa*, *Hoslundia opposita, Microglossa pyrifolia, Pterlobium stellatum, Toddalia asiatica, Cadaba farinosa, Cissus quadrangularis*, *Duosperma crenatum*, *Euphorbia serlina*, *Grewia similis*, *Hibiscus aponeurus*, *Ipomoea kituiensis*, *Plectranthus*, with emergent trees of *Croton macrostachyus, Ochna holstii, Vepris simplicfolia, Adansonia digitata, Calotropsis procera, Cordia monoica, Delonix elata, Elaeodendron buchanannii, Euphorbia quenquecostata, Euphorbia tirucali, Ficus ovata, Haplocoelum foliosum, Hymenodictyon parvifolium, Maerua angolensis, Maerua parvifolia, Ormocarpum kirkii, Sesamotnamnus busseanus, Sterculia stenocarpa.*

**Plate 2: Bushland of Mramba Forest Reserve**

***c. Wooded grassland***

The wooded grassland was recorded on rock sheets, where herbaceous plants with scattered woody plants were found (Plate 3). The identified non-woody plants were: *Rycherytrum repens, Kleinia abyssinica, Commelina benghalensis, Hypoestes*

 

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*forskah* mixed with woody plants of *Trimeria grandifolia, Solanecio mannii, Vernonia lasiopus, Eucalyptus robusta, Ficus ingens, Obetia radula,* and *Aloe volkensii,*

**Plate 3: Wooded Grassland on Rock Sheet**

***d. Woodland***

The woodland was dominated by: *Terminalia kilimandscharica, Lannea schweinfurthii, Croton dichogamus, Commiphora coarulea, Ehretia bakeri, Sterculia stenocarpa, Ficus ovata, Vachelia nilotica, Sessamothamnus busseanus, Dombeya kirkii, Dalbergia arbutifolia, Cordia monoica, Commiphora africana, Hymenodicton parvifolia,* and *Adansonia digitata.*

**Forest Stand Parameters for Mramba Forest Reserve MRAFR)**

***Forest Stocking p and Volume per Diameter Class***

Tree volume is an important parameter in forest management that is used to estimate the merchantable size of trees (Mauya et al., 2014). During this survey, the largest volume was revealed in the diameter class of > 50 apart from the smallest number of the measured stems (Table 1). The tree species with the lowest diameter, apart from the highest number of stems (stocks) captured the lowest volume of all other classes. This implied that the trees with the largest size diameter contribute more to the volume than the smallest diameter trees (Table 1).

 

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**Table 1: Tree Species Volume per Diameter Class**

| DBH-class (cm) | Stockings | Volume (m^3) | Mean volume (m^3) |
|---|---|---|---|
| ≤10 - ≥5 | 271 | 659.617 | 2.43 |
| ≤20 - ≥11 | 182 | 3,727.31 | 20.479 |
| ≤30 - ≥21 | 143 | 11,617.14 | 81.252 |
| ≤40 - ≥31 | 45 | 8,448.42 | 187.742 |
| ≤50 - ≥41 | 8 | 2,636.78 | 329.597 |
| >50 | 8 | 36,420 | 4,552.44 |
| | 657 | 63,508.779 | 5,173.94 |

## Plant Species Richness, Diversity, Relative Abundance, and Distribution

### *Plant Species Richness per Growth Form*

During this survey, a total of 247 plant species were recorded including trees (103), non-tree woody plants (70), and non-woody (herbaceous) plants (74) (Table 2).

**Table 2: Plant Species Richness (S) of Mramba Forest Reserve per Growth Form**

| Growth form | Richness (S) |
|---|---|
| Trees | 103 |
| Non-woody (herbaceous) plants | 74 |
| Non-tree woody plants | 70 |
| **Total** | **247** |

### *Tree Species Richness per Vegetation Type*

The woodland got the highest richness of all other vegetation types, followed by bushland (67 from 15 plots), dry montane forest (29 from 9 plots), and wooded grassland from 1 plot). The highest mean species richness for vegetation types was recorded in the thicket land, followed by shrubland and bushland, and woodland was ranked the least (Table 3).

**Table 3: Tree Species Richness per Plot per Vegetation Type**

| Vegetation type | Total plots | Richness (S) | Mean richness (MS) |
|---|---|---|---|
| Woodland | 15 | 58 | 3.9 |
| Bushland | 15 | 67 | 4.5 |
| Dry montane forest | 9 | 29 | 3.2 |
| Wooded grassland | 1 | 4 | 4 |
| **Total plots** | **40** | | |

### Tree Species Diversity and Dominance Index, and Relative Abundance (RA)

The calculated H' from the 102 tree species (Table 4) was 4.0318, with a Simpson index of 0.02716 and a reciprocal of 3.69. These values revealed high diversity, as high diversity H' value is 1.5 and above, but not beyond 5, while the Simpson value ranges from 0 to 1(Kent and Coker, 1992). Seven tree species were revealed to be the most dominant and abundant (Table 4). Relative abundance (RA) is the percentage composition of an organism of a particular kind relative to the total number of

 

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organisms in a specified area (Webb, 1974). Simpson index can be applied to determine the species dominance (Ezulike et al., 2019). Those most dominant trees got the $pi^2$ 0.00511 to ≥ 0.00151, with a relative density (RD) of 7.1540 - ≥ 3.8880. Eight (8) tree species were categorized as the medium dominant according to this survey. The rest 90 tree species got a $pi^2$ of <0.00029 and were considered the least dominant and abundant (Table 4).

**Table 4: Tree Species Richness (S), Diversity Index, Dominance Index, Abundance, and Relative Abundance (RA)**

| S/n | Botanical name | Author | Ind. | H' | pi^2 | A | RA |
|---|---|---|---|---|---|---|---|
| 1 | *Adansonia digitata* L. | L. | 8 | 0.0546 | 0.0001548 | 0.2 | 1.244 |
| 2 | *Albizia gummifera* | (J.F.Gmel.) C.A.Sm. | 17 | 0.0960 | 0.0006990 | 0.425 | 2.644 |
| 3 | *Albizia anthelmintica* | (Sch.) W.F.Wight | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 4 | *Albizia petersiana* | (Bolle)Oliv. | 16 | 0.0919 | 0.0006192 | 0.4 | 2.488 |
| 5 | *Aloe volkensii* | Engl. | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 6 | *Apodytes dimidiata* | E.Mey. Ex Arn | 7 | 0.0492 | 0.0001185 | 0.175 | 1.089 |
| 7 | *Borassus aethiopicum* | Mart | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 8 | *Boscia salicifolia* | Oliv. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 9 | *Boswelia neglecta* | S. Moore | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 10 | *Brachylaena huillensis* | O.Hoffm | 26 | 0.1297 | 0.0016350 | 0.65 | 4.044 |
| 11 | *Bridelia micrantha* | (Hochst.)Baill | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 12 | *Cadaba farinosa* | Forssk | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 13 | *Calotropsis procera* | (Ait.) W.T.Ait. | 4 | 0.0316 | 0.0000387 | 0.1 | 0.622 |
| 14 | *Celtis africana* | Burm.f. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 15 | *Chaetacme aristata* | Planch. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 16 | *Clausena anisata* | **(Willd.) Hook.f. ex Benth.** | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 17 | *Combretum molle* | R. Br. ex G. Don | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 18 | *Commiphora africana* | (A. Rich.) Engl. | 9 | 0.0598 | 0.0001959 | 0.225 | 1.399 |
| 19 | *Commiphora coarulea* | Burtt | 25 | 0.1263 | 0.0015117 | 0.625 | 3.888 |
| 20 | *Commiphora mossambicensis* | (Oliv.)Engl | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 21 | *Commiphora schimperi* | (O.Berg) Engl. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 22 | *Commiphora mollis* | (Oliv.)Engl | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 23 | *Cordia africana* | Lam | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 24 | *Cordia monoica* | Roxb | 13 | 0.0789 | 0.0004088 | 0.325 | 2.022 |
| 25 | *Cordia sinensis* | Lam | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 26 | *Croton dichogamus* | Pax | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 27 | *Croton megalocarpus* | Hutch. | 7 | 0.0492 | 0.0001185 | 0.175 | 1.087 |
| 28 | *Croton sylivaticus* | Hochst. | 11 | 0.0696 | 0.0002927 | 0.275 | 1.711 |
| 29 | *Cussonia holstii* | Harms ex Engl. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 30 | *Cussonia spicata* | Thunb. | 5 | 0.0378 | 0.0000605 | 0.125 | 0.778 |
| 31 | *Dalbergia arbutifolia* | Baker | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |

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| S/n | Botanical name | Author | Ind. | H' | pi^2 | A | RA |
|---|---|---|---|---|---|---|---|
| 32 | *Delonix elata* | (L.) Gamble | 10 | 0.0648 | 0.0002419 | 0.25 | 1.555 |
| 33 | *Dodonaea viscosa* | Jacq. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 34 | *Dombeya kirkii* | Mast. | 11 | 0.0696 | 0.0002927 | 0.275 | 1.711 |
| 35 | *Ehretia bakeri* | Britt. | 6 | 0.0436 | 0.0000871 | 0.15 | 0.933 |
| 36 | *Ehretia cymosa* | Thonn. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 37 | *Ekebergia capensis* | Sparm | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 38 | *Elaeodendron buchananii* | (Loes)Loes | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 39 | *Erythrina burttii* | Baker f. | 5 | 0.0378 | 0.0000605 | 0.125 | 0.778 |
| 40 | *Erythrococca fischeri* | Pax | 4 | 0.0316 | 0.0000387 | 0.1 | 0.622 |
| 41 | *Erythroxyllum emarginatum* | Thonn | 5 | 0.0378 | 0.0000605 | 0.125 | 0.778 |
| 42 | *Eucalyptus grandis* | Hill ex Maid. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 43 | *Euclea divinorum* | Hiern. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 44 | *Euphorbia bussei* | Pax | 9 | 0.0598 | 0.0001959 | 0.225 | 1.399 |
| 45 | *Euphorbia candelabrum* | Trémaux ex Kotschy | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 46 | *Euphorbia quenquecostata* | Volkens | 36 | 0.1614 | 0.0031346 | 0.9 | 5.599 |
| 47 | *Euphorbia tirucali* | L. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 48 | *Faurea saligna* | Harvey | 5 | 0.0378 | 0.0000605 | 0.125 | 0.778 |
| 49 | *Ficus ingens* | (Miq.)Miq. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 50 | *Ficus ovata* | Vahl. | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 51 | *Ficus thonningii* | Blume | 5 | 0.0378 | 0.0000605 | 0.125 | 0.778 |
| 52 | *Ficus tirucali* | L. | 4 | 0.0316 | 0.0000387 | 0.1 | 0.622 |
| 53 | *Grewia bicolor* | Juss. | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 54 | *Grewia tembensis* | Fresen | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 55 | *Grewia villosa* | Willd. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 56 | *Gymnosporia accuminata* | (L.f.)SzySzy | 7 | 0.0492 | 0.0001185 | 0.175 | 1.089 |
| 57 | *Haplocoelum foliosum* | (Hiern.)Bullock | 13 | 0.0789 | 0.0004088 | 0.325 | 2.022 |
| 58 | *Hymenodictyon parvifolia* | Oliv. | 17 | 0.0960 | 0.0006990 | 0.425 | 2.6439 |
| 59 | *Lannea schimperi* | (Hochst. ex A.Rich.) Engl. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 60 | *Lannea schweinfurthiii* | (Engl.)Engl. | 7 | 0.0492 | 0.0001185 | 0.175 | 1.089 |
| 61 | *Ludia mauritiana* | J.F.Gmel | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 62 | *Maerua angolensis* | DC. | 5 | 0.0378 | 0.0000605 | 0.125 | 0.778 |
| 63 | *Maerua parvifolia* | Pax | 8 | 0.0546 | 0.0001548 | 0.2 | 1.244 |
| 64 | *Manilkara mochsia* | (Baker) Dubard | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 65 | *Markhamia lutea* | (Benth.)K.Sch. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 66 | *Milletia dura* | Dunn. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 67 | *Mimusops kummel* | Bruce ex A.DC. | 36 | 0.1614 | 0.0031346 | 0.9 | 5.599 |
| 68 | *Mystroxylom aethiopicum* | (Thunnb.)Loes | 6 | 0.0436 | 0.0000871 | 0.15 | 0.933 |

 

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| S/n | Botanical name | Author | Ind. | H' | pi^2 | A | RA |
|---|---|---|---|---|---|---|---|
| 69 | *Obetia radula* | (Baker) Baker ex B.D.Jacks. | 6 | 0.0436 | 0.0000871 | 0.15 | 0.933 |
| 70 | *Ochna holstii* | Engl. | 26 | 0.1297 | 0.0016350 | 0.65 | 4.044 |
| 71 | *Olea europaea* | L. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 72 | *Oncoba spinosa* | Forssk. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 73 | *Ormocarpum kirkii* | S.Moore | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 74 | *Osyris lanceolata* | Hochst. & Steud. ex A. DC | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 75 | *Ozoroa insigns* | Delile | 6 | 0.0436 | 0.0000871 | 0.15 | 0.933 |
| 76 | *Pappea capensis* | Eckl. & Zeyh. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 77 | *Pittosporum viridiflorum* | Sims | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 78 | *Pleorostylia africana* | Loes | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 79 | *Afrocarpus falcatus* | (Thunb.) C.N.Page | 9 | 0.0598 | 0.0001959 | 0.225 | 1.399 |
| 80 | *Premna resinosa* | (Hochst.) Schauer | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 81 | *Rawsonia lucida* | Harv. & Sond | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 82 | *Searsia longipes* | (Engl.)Maffet. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 83 | *Searsia natalensis* | (Bernh. ex Krauss) F.A.Barkley | 14 | 0.0833 | 0.0004741 | 0.35 | 2.177 |
| 85 | *Solanum schummanianum* | Dammer | 9 | 0.0598 | 0.0001959 | 0.225 | 1.399 |
| 86 | *Steganotaenia araliacea* | Hochst. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 87 | *Sterculia stenocarpa* | H. J.P.Winkl. | 46 | 0.1887 | 0.0051179 | 1.15 | 7.154 |
| 88 | *Strychnos mitis* | S.Moore | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 89 | *Synadenium grantii* | Hook.f. | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 90 | *Tarenna graveolens* | (S.Moore)Bremek | 7 | 0.0492 | 0.0001185 | 0.175 | 1.089 |
| 91 | *Terminalia kilimandscharica* | Engl. | 14 | 0.0833 | 0.0004741 | 0.35 | 2.177 |
| 92 | *Trichocladus ellipticus* | Eckl. & Zeyh. | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 93 | *Trilepesium madagascariensis* | DC. | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 94 | *Vachelia nigrescens* | Oliv. | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| 95 | *Vachelia nilotica* | (L.) P.J.H.Hurter & Mabb. | 14 | 0.0833 | 0.0004741 | 0.35 | 2.177 |
| 96 | *Vachelia tortilis* | (Forssk.) Galasso & Banfi | 5 | 0.0378 | 0.0000605 | 0.125 | 0.778 |
| 97 | *Vangueria infausta* | Burch | 4 | 0.0316 | 0.0000387 | 0.1 | 0.622 |
| 98 | *Vangueria madagascariensis* | J.F.Gmelin | 1 | 0.0101 | 0.0000024 | 0.025 | 0.156 |
| 99 | *Vepris glomerata* | (F.Hoffm.)Engl. | 3 | 0.0281 | 0.00000121 | 0.075 | 0.466 |
| 100 | *Vepris simplicifolia* | (Engl.) Mziray | 34 | 0.1554 | 0.0027960 | 0.85 | 5.288 |
| 101 | *Ximenia caffra* | Sond. | 2 | 0.0180 | 0.0000097 | 0.05 | 0.311 |
| 102 | *Ziziphus mucronata* | Willd. | 3 | 0.0250 | 0.0000218 | 0.075 | 0.467 |
| | **Total** | | **643** | **4.0318** | **0.0271690** | **16.075** | **100** |

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The medium dominant tree species had the $pi^2$ of 0.00279 to ≥0.00029, with the RD of 5.2877 to ≥1.7107 (Table 5).

**Table 5: Most and Medium Dominant and Abundant Tree Species of Mramba Forest Reserve**

| S/N | Botanical name | Ind. | H' | Pi² | A | RA |
|---|---|---|---|---|---|---|
| | **Most dominant, and abundant** | | | | | |
| 1 | *Sterculia stenocarpa* | 46 | 0.1887 | 0.00511 | 1.15 | 7.15 |
| 2 | *Mimusops kummel* | 36 | 0.1614 | 0.00313 | 0.9 | 5.59 |
| 3 | *Euphorbia quenquecostata* | 36 | 0.1614 | 0.00313 | 0.9 | 5.59 |
| 4 | *Vepris simplicifolia* | 34 | 0.1554 | 0.00279 | 0.85 | 5.28 |
| 5 | *Ochna holstii* | 26 | 0.1297 | 0.00163 | 0.65 | 4.04 |
| 6 | *Brachylaena huillensis* | 26 | 0.1297 | 0.00163 | 0.65 | 4.04 |
| 7 | *Commiphora coarulea* | 25 | 0.1263 | 0.00151 | 0.625 | 3.88 |
| | **Medium dominant and abundant** | | | | | |
| | | | **H'** | **Pi²** | **A** | **RA** |
| 1 | *Hymenodictyon parvifolia* | 17 | 0.0960 | 0.00069 | 0.425 | 2.6439 |
| 2 | *Albizi gummifera* | 17 | 0.0960 | 0.00069 | 0.425 | 2.6439 |
| 3 | *Vachelia nilotica* | 14 | 0.0833 | 0.00047 | 0.35 | 2.1773 |
| 4 | *Terminalia kilimandscharica* | 14 | 0.0833 | 0.00047 | 0.35 | 2.1773 |
| 5 | *Searsia natalensis* | 14 | 0.0833 | 0.00047 | 0.35 | 2.1773 |
| 6 | *Haplocoelum foliosum* | 13 | 0.0789 | 0.00040 | 0.325 | 2.0218 |
| 7 | *Cordia monoica* | 13 | 0.0789 | 0.00040 | 0.325 | 2.0218 |
| 8 | *Croton sylivaticus* | 11 | 0.0696 | 0.00029 | 0.275 | 1.7107 |

*Key: ind=individual(s); H'=Shannon wiener diversity index; $pi^2$=Simpson index; D=density' RD=relative density; A=abundance; RA=relative abundance; IVI=importance value index.*

**Non-Tree Woody Plant Species Richness and Distribution**

Woody plants are plants that have hard stems (thus the term, "woody") and that have buds that survive above ground in winter, and the best-known examples are trees and shrubs (bushes) (Beaulifueu, 2020) and woody climbers or vines. During this survey, a total of 70 non-tree woody plants were recorded. Only one (1) of them was known to be the most distributed, with an RF of 7.729 (Table 6). The rest 69 species got an RF < 7.729. This implies that the area is occupied by plants whose distribution is almost limited to small areas.

**Table 6: Non-tree Woody Plant Species Richness and Distribution**

| S/n | Botanical Name | Author | F | RF |
|---|---|---|---|---|
| 1 | *Abrus schimperi* | Wall. ex Wight & Arn | 1 | 0.48 |
| 2 | *Abutilon longicuspe* | Hochst. ex A.Rich. | 2 | 0.97 |
| 3 | *Abutilon mauritianum* | (Jacq.) Sweet | 1 | 0.48 |
| 4 | *Acalypha fruticosa* | Forssk | 16 | 7.73 |
| 5 | *Adenia gummifera* | (Harv.) Harms | 1 | 0.48 |
| 6 | *Adenium obesium* | (Forssk.)Roem | 3 | 1.45 |

 

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| S/n | Botanical Name | Author | F | RF |
|---|---|---|---|---|
| 7 | *Anisotes pubinervis* | (T.Anders.) Heine | 1 | 0.48 |
| 8 | *Aspilia mossambicensis* | (Oliv.) Willd. | 2 | 0.97 |
| 9 | *Blephariospermum zanguebaricum* | Oliv. & Hiern. | 3 | 1.45 |
| 10 | *Cadaba farinosa* | Forssk | 1 | 0.48 |
| 11 | *Caesalpinia volkensii* | Harms. | 2 | 0.97 |
| 12 | *Capparis tomentosa* | Lam. | 1 | 0.48 |
| 13 | *Carissa edulis* | Vahl. | 3 | 1.45 |
| 14 | *Cissus quadrangularis* | L. | 6 | 2.89 |
| 15 | Cissus rotundifolia | Lam | 2 | 0.97 |
| 16 | *Clematis simensis* | Fresen | 1 | 0.48 |
| 17 | *Clutia abyssinica* | Jaub & Spach. | 1 | 0.48 |
| 18 | *Combretum pentagonum* | M. A. Lawson | 1 | 0.48 |
| 19 | *Crotalaria axillaris* | Aiton | 2 | 0.97 |
| 20 | *Dalbergia lactea* | Vatke | 1 | 0.48 |
| 21 | *Duosperma crenatum* | (Lindau) P.G.Mey. | 6 | 2.89 |
| 22 | *Euphorbia engleri* | Pax | 3 | 1.45 |
| 23 | *Euphorbia scarlatina* | T. Carter | 6 | 2.89 |
| 24 | *Flabellaria paniculata* | Cav. | 9 | 4.35 |
| 25 | *Flueggea virosa* | (Roxb. Ex Willd.)Royle | 1 | 0.48 |
| 26 | *Gnidia kraussiana* | Meisn | 3 | 1.45 |
| 27 | *Grewia forbersii* | Harv. Ex Mast. | 1 | 0.48 |
| 28 | *Grewia similis* | K. Schum. | 4 | 1.93 |
| 29 | *Helinus mystacinus* | (Aiton) E.Mey. ex Steud | 1 | 0.48 |
| 30 | *Heteromorpha arborescens* | (Spreng.) Cham. & Schltdl. | 1 | 0.48 |
| 31 | *Hibiscus aponeurus* | Sprague & Hutch. | 9 | 4.35 |
| 32 | *Hibiscus calyohhyllus* | Cav. | 1 | 0.48 |
| 33 | *Hibiscus fuscus* | Garke | 1 | 0.48 |
| 34 | *Hoslundia opposita* | Vahl. | 5 | 2.42 |
| 35 | *Indigofera arrecta* | Hochst. Ex A.Rich | 4 | 1.93 |
| 36 | *Ipomoea kituiensis* | Vatke | 5 | 2.42 |
| 37 | *Landolfia buchananii* | (Hallier f.) Stapf | 1 | 0.48 |
| 38 | *Lantana camara* | L. | 5 | 2.42 |
| 39 | *Lippia japonica* | (Burm.f.) Spreng | 1 | 0.48 |
| 40 | *Maerua triphylla* | A.Rich | 3 | 1.45 |
| 41 | *Microglossa pyrifolia* | (Lam.) Kuntze | 3 | 1.45 |
| 42 | *Monanthotaxis buchananii* | (Engl.) Verdc | 2 | 0.97 |
| 43 | *Monanthotaxis schweinfurthii* | (Engl. & Diels) Verdc. | 5 | 2.42 |
| 44 | *Ochna schweinfurthii* | F. Hoffm | 2 | 0.97 |
| 45 | *Ocimum obovatum* | E. Mey ex Benth | 1 | 0.48 |
| 46 | *Opilia amentacea* | Roxb. | 3 | 1.45 |

 

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| S/n | Botanical Name | Author | F | RF |
|---|---|---|---|---|
| 47 | *Paederia pospischilii* | K.Schum. | 4 | 1.93 |
| 48 | *Phyllanthus ovalifolia* | Forssk. | 4 | 1.93 |
| 49 | *Phyllanthus reticulatus* | Poir. | 1 | 0.48 |
| 50 | *Plectranthus barbatus* | Andrews | 4 | 1.93 |
| 51 | *Prisiadia punctulata* | Vatke | 3 | 1.45 |
| 52 | *Pterolobium stellatum* | (Forssk.) Brenan | 6 | 2.89 |
| 53 | *Pyrenacantha malvifolia* | Engl. | 3 | 1.45 |
| 54 | *Rhoicissus tridentata* | (L.f.) Wild & R.B.Drumm. | 1 | 0.48 |
| 55 | *Rothecca myricoides* | (Hochst.) D.A. Steane & Mabb. | 3 | 1.45 |
| 56 | *Oxyanthus speciosus* | DC | 1 | 0.48 |
| 57 | *Salacia madagascariensis* | (Lam.) DC | 5 | 2.42 |
| 58 | *Senecio hadiensis* | Forssk | 1 | 0.48 |
| 59 | *Solanum anguivi* | Lam. | 4 | 1.93 |
| 60 | *Thunbergia holstii* | Lindau | 1 | 0.48 |
| 61 | *Thilachium africanum* | Lour | 1 | 0.48 |
| 62 | *Tiliacora funifera* | Oliv. | 1 | 0.48 |
| 63 | *Tinnea aethiopica* | Kotschy ex Hook.f. | 3 | 1.45 |
| 64 | *Toddalia asiatica* | (L.) Lam | 4 | 1.93 |
| 65 | *Senegalia brevispica* | (Harms) Seigler & Ebinger | 2 | 0.97 |
| 66 | *Vernonia brachycalyx* | N. Hoffm | 1 | 0.48 |
| 67 | *Vernonia cinerascens* | Sch.Bip | 1 | 0.48 |
| 68 | *Vernonia galamensis* | (Cass.) Less | 1 | 0.48 |
| 69 | *Vernonia lasiopus* | O. Hoffm. H. Rob | 8 | 3.87 |
| 70 | *Vitex strickeri* | Vatke & Hildebrandt | 7 | 3.38 |
| | **Total** | | **207** | **100.0** |

**Non-woody (herbaceous) Plant Species Richness and Distribution**

Non-wood life form has a significant contribution to vascular plant species richness in the tropics (Linares-Palomino et al., 2009). Non-woody plants which are also, called herbaceous plants or herbs are **plants with relatively soft stems and short-lived shoot systems, and most herbaceous angiosperms lack vascular cambium (**Beaulieu, 2020)**.** During this survey, a total of 73 non-woody plants were recorded (Table 7). The herbaceous plant with the highest relative frequency (RF) was treated as the most distributed taxon. RF shows the extension of resources in a given ecosystem (Loeble, 2012).

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**Table 7: Non-woody (Herbaceous) Plant Species Richness (S), and Relative Frequency (RF)**

| S/n | Botanical Name | | Family | F | RF |
|---|---|---|---|---|---|
| 1 | *Abrus precatorius* | L. | Fabaceae | 1 | 0.54 |
| 2 | *Abutilon grandifolium* | (Willd.) Sweet | Malvaceae | 3 | 1.61 |
| 3 | *Acalypha volkensii* | Pax | Euphorbiaceae | 4 | 2.15 |
| 4 | *Achyranthes aspera* | L. | Amaranthaceae | 4 | 2.15 |
| 5 | *Actinopteris semiflabellata* | Pic. Serm | Pteridaceae | 7 | 3.76 |
| 6 | *Aloe secundiflora* | Engl. | Asphodalaceae | 1 | 0.54 |
| 7 | *Asparagus africanus* | Lam. | Asparagaceae | 11 | 5.91 |
| 8 | *Asparagus flaggelaris* | (Kunth) Baker | Asparagaceae | 3 | 1.61 |
| 9 | *Asparagus racemosus* | Willd. | Asparagaceae | 2 | 1.08 |
| 10 | *Asparagus setaceus* | (Kunth.)Jessop. | Asparagaceae | 4 | 2.15 |
| 11 | *Asplenium sandersonii* | Hook | Aspleniaceae | 3 | 1.61 |
| 12 | *Asplenium strangeanum* | Pic.Serm | Aspleniaceae | 1 | 0.54 |
| 13 | *Asplenium stuhlmanii* | Hieron. | Aspleniaceae | 1 | 0.54 |
| 14 | *Barleria acanthoides* | Vahl. | Acanthaceae | 1 | 0.54 |
| 15 | *Barleria ventricosa* | Hochst. ex Nees | Acanthaceae | 5 | 2.69 |
| 16 | *Boerhavia coccinea* | Mill. | Nyctaginaceae | 2 | 1.08 |
| 17 | *Celosia trigyna* | L. | Amaranthaceae | 1 | 0.54 |
| 18 | *Cheilanthus calomelanos* | C.Pres | Pteridaceae | 1 | 0.54 |
| 19 | *Cheillanthes viridis* | (Forssk.) SW | Pteridaceae | 4 | 2.15 |
| 20 | *Cissampelos pareira* | L. | Menispermaceae | 1 | 0.54 |
| 21 | *Cissus rotundifolia* | Lam. | Vitaceae | 5 | 2.69 |
| 22 | *Cleome hirta* | (Klotzsch) Oliv. | Capparaceae | 2 | 1.08 |
| 23 | *Coccinia adoense* | (A.Rich.) Cogn. | Cucurbitaceae | 1 | 0.54 |
| 24 | *Commelina africana* | L. | Commelinaceae | 1 | 0.54 |
| 25 | *Commelina benghalensis* | L. | Commelinaceae | 6 | 3.23 |
| 26 | *Commicarpus plumbagineus* | (Cav.) Standl. | Nyctaginaceae | 1 | 0.54 |
| 27 | *Corchorus olitorius* | L. | Tiliaceae | 2 | 1.08 |
| 28 | *Crabbea velutina* | S.Moore | Acanthaceae | 1 | 0.54 |
| 29 | *Cyathula cylindrica* | Moq. | Amaranthaceae | 6 | 3.23 |
| 30 | *Cyphostemma adenocaule* | (St. ex A.Rich.) Desc. ex W. & R.B.D. | Vitaceae | 4 | 2.15 |
| 31 | *Digitaria velutina* | (Forssk.) P.Beauv. | Poaceae | 1 | 0.54 |
| 32 | *Euphorbia prostrata* | Aiton | Euphorbiaceae | 1 | 0.54 |
| 33 | *Flemingia grahamiana* | Wight & Arn | Fabaceae | 1 | 0.54 |
| 34 | *Gynandropsis gynandra* | L. | Capparaceae | 1 | 0.54 |
| 35 | *Helichryssum foetidum* | (L.)Moench | Asteraceae | 1 | 0.54 |
| 36 | *Heliotropium steudineri* | Vatke | Boraginaceae | 1 | 0.54 |
| 37 | *Hypoestes forskaolii* | (Vahl.)R.Br | Acanthaceae | 2 | 1.08 |
| 38 | *Indigofera hirsuta* | L. | Fabaceae | 1 | 0.54 |

 

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| S/n | Botanical Name | | Family | F | RF |
|---|---|---|---|---|---|
| 39 | *Issoglossa laxa* | Oliv. | Acanthaceae | 1 | 0.54 |
| 40 | *Jasminum fluminense* | Vell. | Oleaceae | 1 | 0.54 |
| 41 | *Justicia betonica* | L. | Acanthaceae | 1 | 0.54 |
| 42 | *Justicia flava* | (Vahl) Vahl | Acanthaceae | 4 | 2.15 |
| 43 | *Kalanchoe densiflora* | Rolfe | Crassulaceae | 2 | 1.08 |
| 44 | *Kleinia abyssinica* | (A.Rich.) A.Berger | Asteraceae | 2 | 1.08 |
| 45 | *Kyllinga brevifolia* | Rottb. | Cyperaceae | 1 | 0.54 |
| 46 | *Melhania velutina* | Forssk. | Malvaceae | 4 | 2.15 |
| 47 | *Melochia corchorifolia* | L. | Malvaceae | 1 | 0.54 |
| 48 | *Momordica rostrata* | Zimm. | Cucurbitaceae | 2 | 1.08 |
| 49 | *Murdania simplex* | (Vahl.)Brenan | Commelinaceae | 1 | 0.54 |
| 50 | *Panicum trichocladum* | Hack. ex K.Schum. | Poaceae | 2 | 1.08 |
| 51 | *Pentas lanceolata* | (Fossk.)Deflers | Rubiaceae | 1 | 0.54 |
| 52 | *Phyllanthus reticulatus* | Poir | Phyllanthaceae | 1 | 0.54 |
| 53 | *Plectranthus* sp. | | Lamiaceae | 1 | 0.54 |
| 54 | *Portulaca oleraceae* | L. | Portulacaceae | 3 | 1.61 |
| 55 | **Pilosellodes hirsuta** | (Forssk.) C.Jeffrey ex Cufod | Asteraceae | 1 | 0.54 |
| 56 | *Pteridium aquillinum* | L.Kuhn | Dennstidiaceae | 1 | 0.54 |
| 57 | *Ruellia megachlamys* | S.Moore | Acanthaceae | 7 | 3.76 |
| 58 | *Ryncherytrum repens* | (Willd.) C.E.Hubb. | Poaceae | 2 | 1.08 |
| 59 | *Sansevieria robusta* | N.E.Br. | Sansevieriaceae | 3 | 1.61 |
| 60 | *Sansevieria suffruticosa* | N.E.Br. | Sansevieriaceae | 2 | 1.08 |
| 61 | *Scadoxus multiflora* | (Martyn) Raf. | Amarryllidaceae | 1 | 0.54 |
| 62 | *Scleria bulbifera* | Hochst. ex A.Rich. | Cyperaceae | 2 | 1.08 |
| 63 | *Secamone punctulata* | Decne | Apocynaceae | 5 | 2.69 |
| 64 | *Senecio syringifolia* | O.Hoffm | Asteraceae | 2 | 1.08 |
| 65 | *Senna obtusifolia* | (L.) H.S.Irwin & Barneby | Fabaceae | 1 | 0.54 |
| 66 | *Setaria megaphylla* | (Steud.) T.Durand & Schinz | Poaceae | 16 | 8.60 |
| 67 | *Sida acuta* | Burm.f. | Malvaceae | 1 | 0.54 |
| 68 | *Smilax anceps* | Willd. | Smilacaceae | 1 | 0.54 |
| 69 | *Solanum campylacanthum* | Hochst. ex A.Rich. | Solanaceae | 2 | 1.08 |
| 70 | *Stephania abyssinica* | (Quart.-Dill. & A.Rich.) Walp. | Menispermaceae | 1 | 0.54 |
| 71 | *Tephrosia villosa* | (L.) Pers | Fabaceae | 5 | 2.69 |
| 72 | *Tragia brevipes* | Pax | Euphorbiaceae | 4 | 2.15 |
| 73 | *Tribulus terrestris* | L. | Zygophyllaceae | 3 | 1.61 |
| | **Total** | | | **186** | **100** |

 

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The calculated highest RF ranged from 8.60 ≤ - ≥ 5.91, and only two (2) species fell under this category. The medium frequency got an RF of ≤ 3.76 - ≥ 2.69, and only eight (8) species were treated under this group (Table 6). The rest 64 species got an RF ≤ 2.69, which implies that most herbaceous plant species were the least distributed in the sampled plots (Table 8). The low RF of any given plant species increases the chances of decline and even extinction in case of any disturbance in a particular area of their existence (Di et al., 2018).

**Table 8: Relative Frequency of the Most and Medium Distributed Herbaceous Plants in MRAFR**

| Botanical Name | Family | F | RF |
|---|---|---|---|
| *Setaria megaphylla* | Poaceae | 16 | 8.60 |
| *Asparagus africanus* | Asparagaceae | 11 | 5.91 |
| *Actinopteris semiflabellata* | Pteridaceae | 7 | 3.76 |
| *Ruellia megachlamys* | Acanthaceae | 7 | 3.76 |
| *Commelina benghalensis* | Commelinaceae | 6 | 3.23 |
| *Cyathula cylindrica* | Amaranthaceae | 6 | 3.23 |
| *Barleria ventricosa* | Acanthaceae | 5 | 2.69 |
| *Cissus rotundifolia* | Vitaceae | 5 | 2.69 |
| *Secamone punctulata* | Apocynaceae | 5 | 2.69 |
| *Tephrosia villosa* | Fabaceae | 5 | 2.69 |

*Key: F=frequency; RF=relative frequency*

**International Union of Conservation of Nature (IUCN) Status and Tanzania National Reserved Trees Recorded at Mramba Forest Reserve**

The identified National Reserved Trees were: *Afrocarpus falcatus.* The plant species under IUCN status was *Brachylaena huillensis* as near threatened taxon (NT) (Table 9).

**Table 9: IUCN Status and Tanzania National Reserved Plants of Mramba Forest Reserve**

| Botanical name | Family | IUCN status | Tanzania National Reserved |
|---|---|---|---|
| *Afrocarpus falcatus* | Podocarpaceae | - | ✓ |
| *Brachyllaena huillensis* | Asteraceae | LR/NT | ✓ |
| **Total** | | **1** | **1** |

**Anthropogenic Threats to Tree Volume, Diversity, and Plant Species Richness, Within the Vegetation Types of Mramba Forest Reserve**

Forests around the world are under threat, jeopardizing these benefits, manifesting themselves in the form of deforestation and forest degradation (WWF, 2022). Anthropogenic activities threats are human-induced disturbances to the natural ecosystem (Battisti et al., 2016). The identified anthropogenic threats to natural resources were; livestock grazing, pole cutting, logging for timber, charcoal, wildfires, wildlife hunting, and snaring (Table 10).

 

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**Table 10: Recorded Anthropogenic Disturbances at Mramba Forest Reserve**

| Type of disturbance | Remarks | Preferred species |
|---|---|---|
| Livestock grazing | Very common during the dry season | Grasses & some tree leaves |
| Pole cutting | Used for local house construction | *Tarenna pavettoides* |
| Logging for timber | Not very severe, but signs recorded | *Cordia africana*, *Albizia gummifera*, *A. petersi*ana |
| Charcoal | Illegally done for sale | *Albizia petersiana* |
| Wildfires | Recorded at Lambo village side<br>Not very common, but when done it invites massive invasive alien trees *Eucalyptus grandis* and *E. robusta.* | |
| Wildlife hunting | Known to be for home consumption | |
| Snaring | Recorded at Lambo village | |
| Introduction of invasive Alien plants | The planted *Eucalyptus robusta* at the boundary | |

Poaching for charcoal, poles and timber damages trees and the lower plants as the trees are felled. Snaring damages both flora (Tenzini & Hasenauer, 2016; Komolafe & Ige, 2022). The used materials for snaring are always poles cut in the natural forests (Brezzi et al., 2017). There are also, small rods that are used to support the set pole to catch the targeted wild fauna (small mammals). The catching of wild fauna decreases the richness, and abundance (Wong and Krishnasamy, 2019). Invasive alien (foreign/unfamiliar) plants including *Eucalyptus grandis* invade the areas covered by natural vegetation, a situation that leads to the decline of native plant species richness, abundance, and distribution (Rai & Singh, 2020). The invasive alien tree species *E. grandis* was planted to mark the boundary; however, it has become a very big challenge to the natural plant species, it is spreading vigorously overwhelming the indigenous vegetation species. This was noticeable at the Lambo village boundary. The nearby border planted *E. grandis* by local people distribute the seeds to the natural forest. The invasive plants also, alter the natural scenery into unimpressively looking scenery.

### Drivers of Anthropogenic Threats to Mramba Forest Reserve

The relatively large-scale anthropogenic disturbances in natural vegetation across major regions have been caused by various activities such as urbanization (Forbes et al., 2001). The drivers of anthropogenic threats to natural forest resources in Mramba Forest Reserve include; the expansion of the anthropogenic population with high demand for resources, technological advances whereby the local community need natural forest resources to improve their homesteads furniture and house, shortage of employment opportunities persuade local community members to jump into natural forest resources, inadequate or lack of alternative income generating projects done in the natural forest such as ecotourism. The drivers to threats of natural resources such as high demand for fuelwood, settlement, arable land, construction materials and grazing land destroy the biodiversity habitats. Settlement expansion stimulates urbanization that also advances the urban forests (Reichert et al., 2015), which include mostly exotics that are known to be invasive leading to damage and degradation of natural vegetation and species composition (Clusella-Trullas & Garcia, 2017).

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusion

Tree species volume helps to predict the merchanable size of trees, and the amount of biomass in the ecosystem. The fewer measured stems but with the largest total volume ($m^3$) were

 

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contributed by the larger diameter sizes and even height which are the parameters of volume. On the other hand, the volume estimates help to improve the value of forests. The diameter class >50 got a volume of 36,420 $m^3$, while the rest got less than this amount. Also, the mean volume was led by the class of >50 (Table 1). The plant species richness for trees was 103, non-woody plants (74), and the non-tree woody plants got 70 (Table 6). The total plant species richness of 247 for MRAFR implies how potential of the reserve in terms of plant diversity. The plant species richness per vegetation type was led by woodland (S=58), even though the mean species was led by bushland (MS=4.5 ), followed by wooded grasslands (MS=4), woodland (MS=3.9), and dry montane was ranked the least with a mean richness of 3.2 (Table 3). The anthropogenic disturbances including collection of livestock fodder, livestock grazing, logging (for timber, charcoal), and cutting for poles and rods have an influence on tree seedlings, saplings, and poles (Table 10). Anthropogenic activities aiming at timber extraction will always focus on the larger sizes of trunks. The tree seedlings are usually more prone to damage when disturbed, thus affecting the future growth stages. The introduced exotic tree species *Eucalyptus grandis* and *E. robusta* to mark the forest reserve's boundary hinder the growth of native taxa and change the scenic value of the indigenous vegetation as they are self-spreading into the meant to be protected forest.

**Recommendations**

Mramba Forest Reserve lies in the Northern Pare Mountains in the eastern arc mountains of Tanzania, an area with high biological diversity inadequately surveyed. Being under the Tanzania Forest Service Agency (TFS), Mramba Forest Reserve is advantaged in terms of qualifying for a more sustainable conservation regime to satisfy the needs of the present generation without jeopardizing the needs of the future generation. The survey team, among others we have set the following recommendations:-

- Further research of biodiversity in the area. The area is composed of many montane undulating hills with steep slopes and impassable bushlands that hinder easy movement to get to most of the areas to capture the existing resources.
- Upgrade the forest reserve to a nature reserve. Mramba Forest Reserve is endowed with valuable nature resources that can be marketed such as vegetation zones, a variety of flowering plant species, fauna species, valleys and mountain ridges appropriate as viewpoints to various lower locations.
- Construct ranger posts at Mramba Forest Reserve instead of staff having to travel every day from and to Mwanga which is over 30 km away.
- Education and awareness creation on the non-woody income generation interventions including tourism, and beekeeping that can also be marketed to tourists
- More attractions have to be surveyed, recorded, and mapped to improve information on the forest.
- Plans to eradicate the *Eucalyptus grandis* should be made because those invasive plants are growing faster and vigorously transforming the natural scenery.
- Camping sites have to be identified and documented. These sites will attract tourists who will be happy to stay in the field for enjoyment, while also will automatically terrify the poachers
- Construct hostels that will accommodate various stakeholders wanting to spend their nights near and in the area, but not happy staying in tents.

 

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- Regular patrols should be conducted, short of that natural forest resources will keep on declining due to anthropogenic activities.
- Local communities should be involved in most stages of forest management and benefit sharing.

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