Scientific Reports in Life Sciences 3 (2): 15-31

DOI: http://doi.org/10.5281/zenodo.6840728

A report on vegetation types, species diversity, and distribution of Monduli mountains forest reserve in Monduli district, northern highlands of Tanzania

Canisius John Kayombo[1*], Godlisten Eden Koka[2], Gabriel Mwigune[3], Victor Sylvester[4] Kaaya[4]

[1]Forestry Training Institute-Olmotonyi, P. O. Box 943, Arusha-Tanzania TFSA Monduli District, Box 1, Monduli-Tanzania & Nationational Herbarium of Tanzania (NHT), P.O.Box 943, Arusha-Tanzania*
[2]TFSA Monduli District, P. O. Box 1, Monduli-Tanzania
[3]National Herbarium of Tanzania, P. O. Box 943, Arusha-Tanzania
[4]Forestry Training Institut-Olmotonyi, P. O. Box 943, Arusha-Tanzania

[*]Corresponding email: kayombo33@yahoo.co.uk

Received: 15 June 2022 / Revised: 10 July 2022 / Accepted: 15 July 2022/ Published online: 15 July 2022.

How to cite: Kayombo, C.J Koka, G.E., Mwigune . G., Kaaya, V.S (2022). A report on vegetation types, species diversity, and distribution of Monduli mountains forest reserve in Monduli district, northern highlands of Tanzania, Scientific Reports in Life Sciences 3(2), 15-31. **DOI:** http://doi.org/10.5281/zenodo.6840728

Abstract

The forest reserves are well managed when the available resources are known for their richness, diversity, abundance, distribution, and the encountered threats. This survey dealt with an assessment of threats endangering the plant species of Monduli Mountain Forest Reserve (MMFR) in Monduli District, northern highlands of Tanzania. Six (6) clusters of 10 plots measuring 20 m x 20 m each were established in MMFR making a total of 60 sample plots. The 20m x 20 m plots were established to determine the trees. Nested plots of 2 m x 5 m were established to determine the non-tree woody plants, and 1 m x 1 m quadrates were established to determine the herbaceous plants. Trees and non-tree woody plants were identified and counted for their number of individuals, while the herbaceous plants were determined for their number of occurrences in the sample plots. Threats endangering the plant species richness, diversity, and distribution of herbaceous plants were identified. The identified vegetation types were: (i) bushland (ii) montane forest (iii) dry riverine forest (iv) bamboo forest, (v) Plantation Forest pat, and (vi) wooded grassland. The plant species richness (S) was 308. Of those 144 were herbaceous plants, 84were trees, and 80 were non-tree woody plants. The calculated H' for trees and non-tree woody plants was>1.5 an implication of high diversity for such growth forms. Out of the 144 herbaceous plants, nine (9) of them were the most distributed, with an RF of 4.202 ± 2.521. 13 were moderately distributed with the RF of 2.353 ± 1.345, while the rest 122 species got an RF of < 1.345. This implied that most of the herbaceous plants were the least distributed in MMFR and hence were at risk of local extinction in case of any severe damage wherever they exist. The identified threats of MMFR were livestock grazing, encroachment on agriculture crop

farming, harvesting bamboos, logging for local honey bee hives, snaring for wild meat, wildfires firewood collection, and invasive plants including Datura stramonium, Nicotiana glauca, Senna didymobotrya and Caesalpinia decapetala MMFR is potential in terms of natural resources including flora on the valleys, spurs, mountains peaks and slopes. The vegetation types serve as homes for wildlife diversity. The most abundant and most distributed plants are more guaranteed of survival than the least abundant. The threats to plants are mostly man-made, that need to be controlled by conservation stakeholders. Education provision, restoration of degraded areas, and upgrading to a nature reserve is a panacea to sustainable conservation of MMFR.

Keywords: Diversity, Northern Highlands of Tanzania, Plant Species richness, Threats

Introduction

The forest reserves are well managed when the available resources are known for their richness, diversity, abundance, distribution, and the encountered threats. Protecting nature is a global concern (Ducarme et al., 2021). Tanzania, with an area of 945,000km^2 has a high diversity of plant species. There are over 9,000 species of higher plants in Tanzania, many of which are endemic, in the sense that they are only found in Tanzania (Ruffo et al., 2002). Monduli Mountain Forest Reserve (MMFR) harbors relatively high flora species diversity existing in the bushland, montane forest, wooded grassland, and bamboo forest. MMFR was gazetted as a Catchment Forest reserve under the Tanzania Forest Services Agency (TFS) in the Ministry of Natural Resources and Tourism (URT, 2016). The forest reserve was established in 1941. Administratively, the forest reserve is under the Tanzania Forest Service Agency (TFS) whereas, at the District level, it is under the District Forest Conservator. Below the District, there are forest rangers (URT, 2016). The previous agreement between the forest conservation authority and the surrounding villages offered specific rights and privileges including gathering and collecting dead firewood, medicinal plants, fodder, and vegetables; conducting ritual rites, beekeeping, and movement by using footpaths from one village to another. However, fodder gathering has a negative impact as it has led to collecting perennials instead of the allowed annual grasses, a situation that has led to the rejection of such an offer (URT, 2016). From time to time, illegal activities including logging for timber, local stinging bee hives, hunting for wild meat, cutting wild bamboos, encroachment, and livestock grazing have become severe, thus threatening the wild biodiversity (Guertin, 2003). Nevertheless, threats to the floristic richness, diversity, and distribution are continually taking place because of illegal activities.

There has been increased pressure on the forest reserve as a result of human population growth which has led to illegal tree cutting, grazing, and cultivation. Population pressure on the periphery of the forest reserve is high (Ndangalasi et al., 2007). The reserve is heavily grazed in some parts and is traditionally a dry season and dry year grazing ground for pastoralists. Boundary encroachment as an effort to increase home gardens is also a problem in the area (URT, 2016). Commercial wood extraction done in the *Juniperus*

procera, Olea capensis, Olea europaea, Albizia gummifera. The human disturbances are through firewood and medicinal plant collection (Wubetu et al., 2017). The area is known to have been used for tourist hunting activities since the year 1993. Tanzania is mostly nature bases, and hence biodiversity conservation is an important way of supporting tourism intervention (Gereta, 2010). As for now, MMFR is under TFS, conservation of resources is being emphasized ahus inviting biodiversity surveys to quantify the available resources.

The conservation of biodiversity protects water catchments, allowing water to be available for other uses including agriculture and hydropower generation (Gereta, 2010). The vegetation types of MMFR include wooded grassland, bushland, montane forest, riverine forest, bamboo forest, and a small patch of plantation forest in the Mwandete village area. A number of ecologists have been involved in the production of plant species checklists, while the individual plant species distribution remains inadequately studied (Gatti et al., 2022). The plants are well known as sources of food, fuel wood, building poles, furniture materials, regulation of climate, habitat for wildlife, livestock fodder, beautification of natural scenery, reduction of soil erosion, and windbreak. However, little is documented on the threats endangering the plant species richness, diversity, and distribution. This survey aimed to assess the threats endangering the woody plant species richness, diversity, and distribution of non-woody plants of MMFR in Monduli District, Northern Highlands of Tanzania.

Material and methods

Location of Monduli Mountains Forest Reserve (MMFR)

The MMFR is in Monduli District, Arusha Region, northern highlands of Tanzania. The forest reserve borders Mlimani, Musa, and Ngarashi villages in the south. On the west, it borders the Emeirete village. In the southeast, it borders Musa village. On the southwest, it borders the Ngarashi village (Figure 1). On the east, the forest borders Mwandeti village, while on the north it borders the Enguiki village (Figure 1). The MFR is located at 3° 14' – 3° 18’ S; 36° 24’ – 36˚ 31’ E in the Northern part of Tanzania in Monduli District which is about 42 km from the famous Arusha Municipality (URT, 2016). It is accessible from Monduli town to the North at Monduli Juu, southeast at Musa and to the East at Mwandeti via Kilima moto along Namanga – Arusha Road. The reserve covers Monduli Mountain at an altitude range of 1615m to 2660 m a.s.l (URT, 2016). The size of the forest is 8,900 with a total boundary length of 40km.

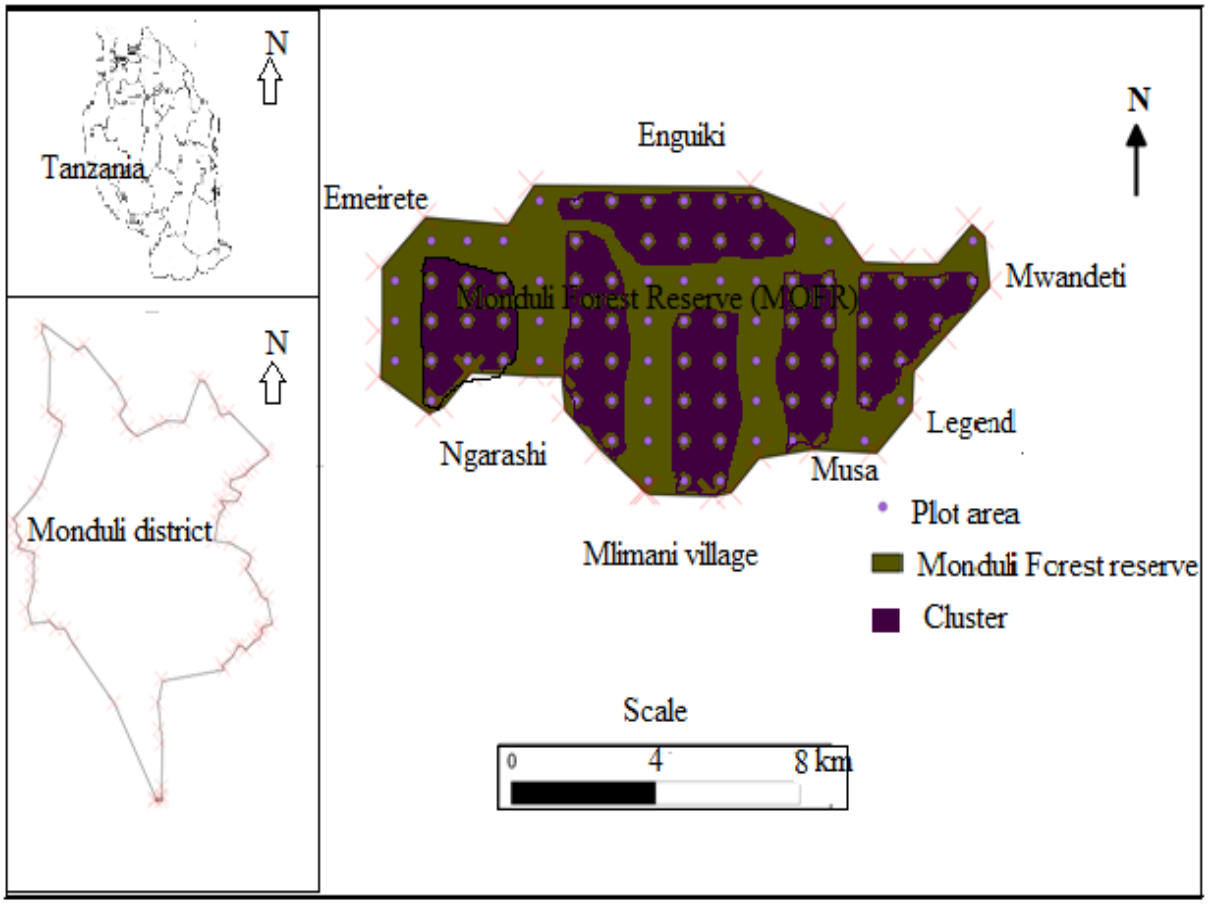

Figure 1. Location of Monduli Mountains Forest Reserve. (Source: Field Survey, 2022)

Climate and Vegetation Type

The MMFR receives oceanic rainfall with continental temperatures. The annual rainfall ranges from 750 – 1000 mm in the woodlands and 1200 – 1500mm in the forest (URT, 2016). The prevailing South winds during the rainy seasons bring moisture mainly to the South – Eastern parts of the mountain with the maximum rainfall between 800 and 900 mm. The side of the mountain opposite the prevailing wind receives less rain and the lands lying behind the leeward – side of the mountain is said to be in the rain shadow. The average temperature ranges from 11.5 ˚C (July) to 15.4 ˚C (Dec.) with the short and hot dry periods between January and March and long and cold dry periods between May and October (URT, 2016). There is a decrease of temperature with increasing elevation, which amounts to roughly 0.6 ˚C per 100m. Relative humidity naturally increases during the rain period. The vegetation types include the montane bushland, montane forest, woodland, and the bamboo forest (afro-alpine: dominated with *Synarundinaria alpina* mixed with *Afrocrania volkensii, Lepidotrichilia volkensii,* and *Hypericum revolutum.*

Topography and Hydrology

The MFR is hilly with abundant valleys. The forest reserve covers the top and slopes of Mount Monduli from an altitude of 1615 to 2660 m a.s.l. (URT, 2016) The deepest of them have a slope of 20 to 30 feet. Five of the biggest valleys are seasonal streams used by the communities for animal and domestic use. The rivers include Musa and Ngarashi discharging for Musa and Sinon-Ngarash respectively. These water sources are used to supply water to Monduli Township and villages adjacent to the forest and downstream. The highest rate of water flow from streams occurs between May and July while the minimum discharge is between September and October at the end of the dry season.

Geology and Soils

Monduli Forest Reserve (MFR) is located on basement rocks, which are overlain by materials that result from volcanic action. The dominant volcanic material found is a fine-grained and dark-colored rock called basalt. Upon weathering, basalt and associated rock types give a clay residue soil. The soils along the slopes of MFR are deep freely drained soils that have a depth of more than 45cm with good drainage and generally good agricultural potential. Three subgroups can be distinguished: Clay soils; deep, freely drained clays that have more than 35% clay. Their natural fertility status is moderate to high. Loamy soils; are deep, freely drained looming soils that have less than 35% clay. They are formed on plains and along slopes at the foot of escarpments and isolated hills of basement areas. Sandy soils; are deep, freely drained sandy soils that have more than 70% sand and less than 2% clay (URT, 2016). These soils mainly occur along active stream beds; near the base of granite outcrops and at the end of long foot slower were washed out erosion products accumulate.

Socio-Economic Activities of Local Community Bordering Monduli Natural Forest Reserve

The socio-economic activities of the bordering human communities include; livestock keeping (goats, sheep, donkeys, cows, poultry, pigs, and donkeys. While very few of them are employees of government and nongovernmental organizations including churches and the rare plantations.

Data Collection Method

The field surveys were carried out in January 2022. Ground search techniques were used to assess the flora. GPS was used to align the transect, mark the plot site, and position resources of amenity value, consultation, focus group discussion (FGDs), and field investigation, which involved identification and mapping of flora, fauna, and tourism attractions. Whittaker Nested Plot Method (Stohligren et al., 1995), whereby plots of 20m x 20 m were established at an interval of 1000m x 100 m. Whil, 2m x 5m nested plots were set to determine non-tree woody plants. All trees with a diameter at breast height of ≥ 5 cm were identified and counted for their number of individuals. The woody non-tree plants including lianas and shrubs were

identified and counted for their number of individuals. Herbaceous plants were identified within the 1 m x 1 m sub-plot and counted for their occurrence in sampled plots.

Data Analysis

Plant Species Richness (S) and Diversity

Plant species richness was determined by the total number of species identified from the sample plots. While diversity was obtained through the diversity index H' -∑pilnpi (Kent & Coker, 1992).

Plant Species Abundance and Distribution

1. Abundance

$$A = \frac{\sum ni}{NP};\ \text{and}\ RA = \frac{\sum ni}{NI} * 100\%\ (\text{Weiher and Keddy, 1999})$$

Where A=abundance; RA = relative abundance; NP = number of plots relative abundance; ni = total individuals of one species; NI = overall total of overall all species from the sample plots; 100% is a constant

2. Distribution

The distribution was determined by the frequency of a particular plant species. This is based on the total number of occurrences in the sample plots (60-plots). The relative frequency was used to determine the most, moderate, and least distributed plant taxon. Relative frequency shows the proportion of the total number of observations associated with each value or class of values (Mohr et al., 2021)

$RF = \frac{\sum nFi}{\sum NFI} * 100\%$ (Mohr et al., 2021).

Where; RF= relative frequency; nFi = total frequency of an individual species; NFI = an overall frequency of all plant species identified in the sample plots.

Determination of Illegal Activities

This was calculated based on the occurrence in the sample plots and from that the most common illegal activity was determined.

$DP = \frac{\sum Dni}{\sum DNI} * 100\%$; Where; DP = distribution percentage; Dni = number of plots of occurrence of one type of human activity; DNI = an overall occurrence of all human activities or in all sampled plots (60).

Results and discussion

Vegetation Types

The vegetation diversity contributes to species diversity in the ecosystem processes (Ruiz-Jaen & Aide, 2005). The identified vegetation types of Monduli Mountains Forest Reserve (MMFR) were wooded

grassland, bushland, woodland, montane forest, plantation forest, riverine forest, and bamboo forest. Each vegetation type was revealed to be unique in terms of the plant species composition and growth forms. Some species were specific to a certain vegetation type, while those found on different vegetation types differed in terms of abundance, and even sizes.

Wooded Grassland

This vegetation was identified at Mwandeti and Enguiki villages where the area was dominated by herbaceous plants with very scattered woody plants. The herbaceous plants were *Digiaria velutina, Kyllinga odorata, Sida massaica, Cynodon dactylon, Harpocarpha snowdenii, Hypoestes forskaoolii, Dactylectenium aegyptium,* while the woody plants were *Vachelia sieberiana, Buddleja salviifolia, senna didymobotrya, Scopia rhymniphylla,* and *Gymnospora accuminata.*

Bushland

The bush land is vegetation dominated with many shrubs which are woody plants with several stems that are shorter than the typical trees (Harris & Harris, 1997), with very scattered short trees. Bush land is dominated by woody cover of 3-7 m tall; grasses present but not important (Beentje et al., 1994). The identified plants in MMFR bush land were: *Rhus vulgaris, Lippia javanica, Toddalia asiatica, Hoslundia opposita, Psiadia punctulata, Buddleja salviifolia, Catha edulis,Crotalaria agatiflora, Hypericum revolutum, Maesa lanceolata, Ekebergia capensis, Deinbolia kilimandscharica, Senna didymobotrya, Vernonia myriantha, Clausena anisata, Turraea robusta, Calodendrum capensne, Dichrostcahys cinerea,* and *Nuxia congesta*.

Woodland

Woodland is an open stand of trees at least 8 m tall, with a canopy cover 40% or more (Beentje et al., 1994; GTZ, 2007). The woodland was dominated by *Rhus natalensis, Vangueria infausta, Vepris simplicifolia, Ehretia cymosa, Croton macrostachyus, Albizia schimperi, Vachelia sieberiana, Euclea divinorum,* and *Olea europaea*.

Montane Forest

Forest is a continuous stand of trees at least 10 m tall, with interlocking crowns, and the forest may be moist, dry forest, riverine forest, ground water (swamp forest), or rain forest (Beentje et al., 1994). The plant species that were identified in the montane forestincluded: *Albizia gummifera, Bersama abyssinica, Cussonia holstii, Deinbolia kilimandscharica, Euclea divinorum, Gymnosporia accuminata, Gymnosporia undata, Halleria lucida, Heteromorpha trifoliate, Juniperus procera, Olea capensis, Olea europaea, Kiggelaria africana, Crotalaria agatiflora, Ilex mitis, Vepris simplicifolia, Maesa lanceolata,*

Dombeya torrida, Cassipourea malosana, Casearia battiscombei, Dovyalis abyssinica, Xymalos monospora, Ekebergia capensis, Prunus africana, Fagaropsis angolensis, Angingeria adolfi-friederisii, Ficus thonningii, Ritchiea albersii.

Plantation Forest

Plantation forest also, known as forest plantation is a forest stand established by planting or/and seeding in the process of afforestation or reforestation(FAO, 2000). Forest plantation at Mwandeti village range was planted some years back to replace the severely degraded wooded grassland. The plantation forest that was observed at the Mwandeti village area was dominated with *Fraxinus angustifolia,* and *Grevillea robusta*. The vegetation is much degraded because of livestock grazing by the local communities from Mwandeti village.

Dry Riverine Forest

This is a forest that dominates at the river/stream sides (Kricher, 1998). The dominant trees were: *Dombeya torrida* (tree), *Xymalos monospora* (tree), and *Hyposetes aristata* (herb). Dry riverine forests are forests associated with rivers, usually on river flooding areas or along riversides.

Bamboo Forest

The bamboo forest vegetation was identified at the ridge tops and slopes and was occupied by *Synarundinaria alpina,* mixed with *Afrocrania volkensii, Hypericum revolutum,* and *Lepidotrichilia volkensii.*

There is a need to protect the diversified vegetation types to promote a functionally diverse plant community over the entire managed area rather than promoting high localized species diversity within a single vegetation type (White et al., 2004). The identified vegetation types at MMFR have an implication for high species diversity because of community diversity (Al-Aklabi et al., 2016).

Tree and Non-Tree Woody Plant Species Richness, Diversity Index, and Abundance

Plant species richness is the total number of species recorded in a given site (Wilson et al., 2012). In this study, a total of 308 plant species were identified at Monduli Mountains Forest Reserve (MMFR) (Table 1). Of those, 144 were herbaceous, 84 were trees, and 80 were non-tree woody plants (Table 1). The highest H' was determined in trees (4.033), while non-tree woody plants got the H' of 3.822. This implies that herbaceous species is the highest of all other growth forms. The H' of ≥1.5 for the trees and non-tree woody plants implies high species diversity (Table 1).

Table 1. Plant species richness (S) and diversity index for woody plants

Growth form	Richness (S)	Percentage (%)	H'
Trees	84	27.27	4.033
Non-tree woody plants	80	25.97	3.822
Herbaceous plants	144	46.76	-
Total	308	100	

Tree Species Richness (S), Diversity (H'), Abundance (A), and Relative Abundance (RA)

The tree species richness (S) was 84 with the H' of 4.033 (Table 1). The tree species with the highest abundance got a RA of ≤4.814 - ≥3.282 and IVI of ≤9.628 - ≥6.565. The most abundanttree species were: *Vepris simplicifolia, Vachelia sieberiana, Maesa lanceolata, Ekebergia capensis, Dombeya torrid, Nuxia congesta.* On the other hand, the moderately abundant trees got the RA of ≤3.064 - ≥1.641 with the IVI of ≤6.127 - ≥3.282. The identified trees in this category were: *Ritchiea albersii, Senna didymobotrya, Vernonia myriantha, Olea europaea, Mystroxylon aethiopcum, Lepidorichilia volkensii, Gymnosporia accuminata, Ficus thonningii, Fagaropsis angolensis, Euclea divinorum, Deinbolia kilimandscharica, Croton macrostachyus, Buddleja salviifolia, Bersama abyssinica, Albizia gummifera, Albizia schimperiana*. The most abundant plant species always have higher relative abundance, hence ensuring higher chances of survival in case of any threat than the least abundant (Vila-Ruiz et al., 2014).

Non-tree Woody Plant Species Richness (S), Diversity (H')), and Relative Abundance (RA)

A total of 80 non-tree woody plant species were identified at MMFR (Table 1). Some of the plants in this category were known to be the most abundant, while others were moderately abundant. Some of them were the least abundant. The most abundant non-tree woody plants got the RA of ≤8.594 - ≥3.614 with the IVI of ≤23.60 - ≥11.69. The identified plants this category were: -*Pavonia urens, Piper capense,* and *Synarundinaria alpina*. The moderately abundant non-tree woody plants got the RA of <3.614 - ≥1.205 with the IVI of <11.69 - ≥3.52). The moderately abundant non-tree woody plants were: *Pycnostachys meyeri, Psiadia punctulata, Urera hypselodendron, Solanum anguivi, Pterolobium stellatum, Vernonia brachycalyx, Phytolacca dodecandra, Obetia tenax, Mimulopsis solmsii, Lippia javanica, Leonotis nepetifolia, Lantana trifolia, Hibiscus vitifolius, Discopodium penninervium, Clutia abyssinica, Clerodendrum johnstonnii, Clematis simensis, Cannabis sativa, Bothriocline longipes,* and *Azima tetracantha.*

Herbaceous Plant Species Richness and Distribution

The herbaceous plant species richness (S) is the total number of species identified in the sample plots (Jia et al., 2011; Colville et al., 2020). The distribution reveals how a certain taxon is spread in the ecosystem

(Ricklefs & Bermingham, 2002). In this survey, the herbaceous plant species richness (S) was 144. Of those, nine (9) of them were the most distributed, with a relative frequency (RF) of 4.202 ± 2.521 making a total RF of 26.722.13 herbaceous species were moderately distributed with the RF of 2.353 ± 1.345 resulting in an overall total RF of 20.509 (Table 2), while the rest 122 species got the RF of < 1.345 summing up to 52.769. This implied that most of the herbaceous plants were the least distributed in MMFR and hence were at risk of local extinction in case of any severe damage wherever they exist. The least distributed plant taxa are at risk of disappearance whenever disturbances occur at their existence (Ringold et al., 2008).

Table 2. The most distributed herbaceous plants in Monduli Mountains Forest Reserve (MMFR)

	Botanica name	Family	F	RF
1	*Urtica massaica*	Urticaceae	25	4.202
2	*Achyranthes aspera*	Amaranthaceae	22	3.697
3	*Hypoestes forskaooli*	Acanthaceae	17	2.857
4	*Pteridium aquillinum*	Dennstidiaceae	17	2.857
5	*Stephania abyssinica*	Menispermaceae	17	2.857
6	*Justicia flava*	Acanthaceae	16	2.689
7	*Cynodon dactylon*	Poaceae	15	2.521
8	*Cyphostemma adenocaule*	Vitaceae	15	2.521
9	*Hypoestes aristata*	Acanthaceae	15	2.521
Total			159	26.722

The medium-distributed herbaceous plants were distributed in eight (8) to 14 plots (Table 6). The identified medium-distributed herbaceous plants were: *Momordica foetida, Scadoxus multiflora, Commelina benghalensis, Pteris catoptera, Asparagus racemosus, Pennisetum polystachyon, Cyathula polysephala, Desmodium repandum, Hydrocotyle sibthorpioides, Kyllinga odorata, Phaulopsis imbricate,* and *Zehneria scabra* (Table 3).

Table 3. The moderately distributed herbaceous plants in Monduli Forest Reserve

S/N	Botanical name	Family	F	RF
1	*Momordica foetida*	Cucurbitaceae	14	2.353
2	*Scadoxus multiflora*	Amarryllidaceae	12	2.017
3	*Commelina benghalensis*	Commelinaceae	11	1.849
4	*Pteris catoptera*	Pteridaceae	10	1.681
5	*Asparagus racemosus*	Asparagaceae	9	1.513
6	*Carduu nutans*	Asteraceae	9	1.513
7	*Pennisetum polystachyon*	Poaceae	9	1.513
8	*Cyathulla polysephala*	Amaranthaceae	8	1.345

S/N	Botanical name	Family	F	RF
9	*Desmodium repandum*	Fabaceae	8	1.345
10	*Hydrocotyle sibthorpioides*	Apiaceae	8	1.345
11	*Kyllinga odorata*	Cyperaceae	8	1.345
12	*Phaulopsis imbricate*	Acanthaceae	8	1.345
13	*Zehneria scabra*	Cucurbitaceae	8	1.345
Total			122	20.509

A total of 50 families of herbaceous plants were identified in Monduli Mountains Forest Reserve. Some of the families got the highest number of species, others were moderate in number, and the rest got the least number of species. The herbaceous plant family with the highest number of species was Asteraceae (20), while the moderate were Fabaceae (8), Poaceae (8), Solanaceae (8), Acanthaceae (7), Aspleniaceae (6), and Amaranthaceae (6), and the rest families got <6 species (Table 4). The plant family with the highest S is likely to survive even when some of the species are removed by human threats, while the least is always in a risk of local extinction.

Table 4. Herbaceous plant families with the highest and moderate number of species in Monduli Forest Reserve (MMFR)

S/N	Family	No. of species	Status in number of species
1	Asteraceae	20	Highest
2	Fabaceae	8	Moderate
3	Poaceae	8	Moderate
4	Solanaceae	8	Moderate
5	Acanthaceae	7	Moderate
6	Aspleniaceae	6	Moderate
7	Amaranthaceae	5	Moderate
8	Apiaceae	5	Moderate
9	Cyperaceae	5	Moderate
10	Urticaceae	5	Moderate

Plant Species Richness per Cluster

The clusters' results varied in terms of plant species richness. The vegetation clusters categorized based on vegetation strata or patterns differ in the species richness (Petersen et al., 2020). For herbaceous species richness (S), the Musa village cluster got the highest S (75), followed by Bomba la amaji (72), Enguiki (68), Mwandeti (46), Big game safaris (42), and Shimo la Maji got the least S (39) (Table5). The highest S was contributed by moderate human disturbances, and other conditions including soil moisture content even though this was not looked into in detail. The richness (S) variation was because of moderate disturbance as ecologically moderate disturbance encourages more regenerants while excessive disturbance led to local decline and extinction of some plant taxa (Thom and Seidl, 2016).

Table 5. Plant species richness (S) per cluster

Name of cluster	Richness (S)				Tree	Rank	Total	Rank
	HB	Rank	NT(S&WC)	Rank				
Big game safaris	42	5	27	5	31	3	100	4
Bomba la maji	72	2	44	1	52	1	168	1
Enguiki	68	3	41	2	31	3	140	2
Musa	75	1	30	3	31	3	136	3
Mwandeti	46	4	22	6	21	4	89	6
Shimo la tembo	39	6	30	4	40	2	109	5

Plant Species under IUCN Conservation Status and Tanzania National Reserve

Four tree species were known to be endangered, and national reserved (Table 6). *Osyris lanceolata* (Table 6) is endangered owing to overexploitation of its essential oil used in cosmetics and pharmaceutical industries (Antiego et al., 2019).*Prunus africana* is endangered Appendix II. *Juniperus procera* and Olea capensis are National Reserved Trees (NRT).

Table 6. IUCN conservation status and national reserved plants

Botanical name	Family	Growth form	E	NT	NRT
Juniperus procera	Cupressaceae	Tree			✓
Olea capensis	Oleaceae	Tree			✓
Osyris lanceolata	Santalaceae	Shrub/tree	✓		✓
Polystachya sp.	Orchidaceae	Epiphytic herb	✓		
Prunus africana	Rosaceae	Tree	✓		

Key: E=endangered; NT=near threatened; NRT=National Reserved Tree(s)

Threats Endangering Plant Species of Monduli Mountains Forest Reserve (MMFR)

Threats to natural resources are any factors that will potentially lead to the death of one or more biological species without offering the possibility of full recovery, hence calling for sustainable use of forest products, and even extraction of woody resources to reduce the threat severity to natural vegetation (Sosef et al. 2021). Threats such as deliberately done by human beings started by pastoralists and farmers to burn off dry grass wildfires can rapidly destroy huge areas of forest reserves (Nyongesa & Vacik, 2018). Fire is a particular threat during the dry season, and farmers often burn areas to promote new growth for their cattle, while many forests are burned to encourage the development of young/ tender leaves (Jones, 2021). The identified alarming threats at MMFR were human-caused (illegal) disturbances or activities. The recorded illegal activities at Monduli Mountains Forest Reserve(MMFR) were; livestock grazing, (cows, donkeys, and goats), logging for local beehives (Preferred: *Albizia gummifera*, and *Vepris simplicifolia*) firewood collection, collection of livestock fodder, cutting for poles, poaching for timber, hunting and catching wild animals, and harvesting the *Catha edulis* (Mrungi), wildfire set when grazing and roosting fresh maize, charcoal (but to a very small scale), and encroachment (Table 7).

Those human threats revealed noticeable damage to indigenous plant species. Most human activities conducted in natural forests involve the removal of natural vegetation communities and thus leading to the diminishing in richness, diversity, and distribution coverage (Chen et al. 2000). Only 5% of the sampled area represented the intact, three (3) plots), while the rest 95% represented 57 plots that were recorded to have been disturbed(Table 7). This meant that MMFR plant species richness, abundance, and distribution were severely threatened by illegal activities. Some plant taxa were damaged and even areas were replaced by invasive plants including *Datura stramonium*. Many lower plants and young trees were destroyed as the large trees were felled.

Table 7. Illegal activities occurrence and distribution percentage

Plot no	GR	FW	LBHV	CT	WF	ECR	Intact	FT	DBR	SN
60	53	11	2	3	4	1	3	29	1	2
100	88	18	3.33	5	7	1.7	5	48	1.7	3

***Key**:* GR=grazing; FW=firewood; LBHV=local beehive(s); CT=cutting; ECR=encroachment; FT=foot trail/track; DBR=debarking for rope; SN=snare(s)/snaring

Exotic and Invasive Plants

Natural forest resource management managers require an understanding of the presence of exotic and invasive plants and their suitable habitats so as to incorporate them into survey efforts to improve eradication efficiency (Jorgensen & Renz, 2021). Exotic plants are those introduced from abroad, while invasive plants are alien species that show a tendency to spread out of control (Langmaier & Lapin, 2020). The label "invasive" is generally reserved for plants that have been introduced from other regions and spread like wildfire in their new habitats (Rai & Singh, 2020). The exotic and invasive plants that have largely been influenced by human disturbances include *Caesalpinia decapetala* (Plate 8), *Datura stramonium, Senna didymobotrya, Nicotiana glauca, Withania somnifera* (Table8). The exotic plants always transform the natural scenery into the artificial state, while invasive plants are detrimental as they rapidly occupy areas and suppress the indigenous plants including palatable pastures for wildlife (Reichert et al., 2015).

Table 8. Exotic and invasive plants identified at MMFR

Botanical name	Family	Growth form	Exotic	Invasive
Caesalpinia decapetala	Fabaceae	Shrub/Wc	✓	✓
Datura stramonium	Solanaceae	Herb	✓	✓
Fraxinus angustifolia	Oleaceae	Tree	✓	
Grevillea robusta	Proteaceae	Tree	✓	
Senna didymobotrya	Fabaceae	Tree	✓	✓

Nicotiana glauca	Solanaceae	Shrub/Tree	✓
Withania somnifera	Solanaceae	Herb	✓

Conclusions

MMFR has a high diversity of plants embedded in the various vegetation types. The bushland, wooded grassland, woodland, and forest serve as habitats for wildlife, and storage of greenhouse gasses and hence contributing to the reduction of greenhouse gases in the atmosphere. The plant species diversity index of >1.5 for trees and none-tree woody plants had high diversity. The plants with higher relative RA and RF have more chances of continuous existence than the less abundant and distributed species. Threats caused by human activities such as livestock grazing, logging for local stinging honey beehives, encroachment, wildfires, and bamboo cutting for withes (building rods) threaten the richness, diversity, abundance, and distribution of biological species in the MMFR ecosystem.

Recommendations

Monduli Mountains Forest Reserve (MMFR) is potential in natural resources diversity that needs to be conserved for the benefit of the present and the future generation. The survey team recommends the following among others: upgrading the forest reserve into a nature reserve, educating to the local community on the value of conservation of natural resources, encouraging agroforestry at the local level, participatory forest management, revisiting boundaries together with village natural resources committees, and planting water friendly trees at degraded water catchment areas in Mwandeti and Musa villages, introduce modern beehives to the local community to reduce the rate of logging natural trees for local beehives, train local beekeepers on modern beekeeping (use of modern beehives), register the interested groups in honey beekeeping in the forest reserve, conservation education offering by TFS, conduct further research on bee fodder plants and suitable areas for beekeeping for proper land use suitability, and establish ranger posts at the selected sites in the forest reserve to serve the patrolling and extension staff.

Acknowledgment

The biodiversity survey of Monduli Mountains Forest Reserve (MMFR) has been done successfully as a result of the contribution and participation of many stakeholders from Monduli District including Jonas N. Nyange (Game Warden), forest assistants including Stephano Uronu, Kayani Laizer, and Timotheo Joseph (driver) from TFS-Monduli District offered material support. Ward and village leaders from bordering villages of Ngarashi, Mlimani, Musa, Mwandeti, Emeirete, and Enguiki provided material support during data collection. Gabriel Mwigune from the National Herbarium of Tanzania was involved in the collection of plant samples that were taken for identification and preservation at the herbarium cabinets in Arusha.

References

Al-Aklabi, A., Al-Khulaidi, A.W., Hussein, A., Al-sagheer, N. 2016. Main vegetation types and plant species diversity along an altitudinal gradient of Al Baha region, Saudi Arabia. *Saudi Journal of Biological Sciences, 23(6), 687-697.*

Andiego, K. P., Dangasuk, O. G., Odee, D. W., Omondi, F. S., Otieno, D. F., & Balozi, B. K. (2019). Genetic diversity of endangered sandalwood (Osyris lanceolata) populations in Kenya using ISSR molecular markers. *East African Agricultural and Forestry Journal*, *83*(2), 80-93.

Beentje, H., Adamson, J., & Bhanderi, D. (1994). *Kenya trees, shrubs, and lianas*. National Museums of Kenya.

Chen, G. X., Yu, K. W., Liao, L. P., & Xu, G. S. (2000). Effect of human activities on forest ecosystems: N cycle and soil fertility. *Nutrient Cycling in Agroecosystems*, *57*(1), 47-54.

Colville, J. F., Beale, C. M., Forest, F., Altwegg, R., Huntley, B., & Cowling, R. M. (2020). Plant richness, turnover, and evolutionary diversity track gradients of stability and ecological opportunity in a megadiversity center. *Proceedings of the National Academy of Sciences*, *117*(33), 20027-20037. https://doi.org/10.1073/pnas.1915646117.

Ducarme, F., Flipo, F., & Couvet, D. (2021). How the diversity of human concepts of nature affects conservation of biodiversity. *Conservation Biology*, *35*(3), 1019-1028. https://doi.org/10.1111/cobi.13639

FAO.(2000). *Forest plantations. Global Forest Resources Assessment. FRA*. Global Forest Resources Assessment/Food and Agriculture Organization of the United Nations (fao.org).

Gatti, R. C., Reich, P. B., Gamarra, J.G.P. & Lianey, J. (2022). The number of Trees on Earth. PNAS. *119 (6)* e2115329119. http://.doi.org.10.1073/pnas.2115329119

Gereta, E.J. 2010. The role of biodiversity conservation in the development of the tourism Industry in Tanzania. *Conservation of Natural Resources. Some Affairs & Asian Examples. Tapir Academic Press, Trondheim, Norway*.

GTZ. (2007). Eastern Africa Resource Base: GTZ Online Regional Energy Resource Base. Regional and Country Specific Energy Resource Database: II - Energy Resource.

Guertin, C. É. (2003). Illegal logging and illegal activities in the forestry sector: Overview and possible issues for the UNECE Timber Committee and FAO European Forestry Commission. *Quebec Wood Export Bureau*.http://unece.org/fileadmin//DAM/timber/docs
/tc-sessions/tc-61/presentations/guertin-paper.pdf.

Harris, J. G., & Harris, M. W. (1994). *Plant identification terminology: An illustrated glossary* (No. QK9 H37 2001). Utah: Spring Lake Publishing.

Jia, X., Shao, M., & Wei, X. (2011). Richness and composition of herbaceous species in restored shrubland and grassland ecosystems in the northern Loess Plateau of China. *Biodiversity and Conservation*, *20*(14), 3435-3452.

Jones, N. (2021). Bradfield Avenue, BRIDGEND, Mid-Glam CF31 4HL, United Kingdom

Jorgensen, N., & Renz, M. (2021). Assessing the performance and accuracy of invasive plant habitat suitability models in detecting new observations in Wisconsin. *Invasive Plant Science and Management*, 1-9.

Kent, M., & Coker, P. 1992. *Vegetation Description and Analysis: A Practical Approach (pp. 167-169).* New York: John Wiley and Sons.

Kricher, J. C. (1998). *A field guide to Eastern forests, North America* (Vol. 37). Houghton Mifflin Harcourt.

Langmaier, M., & Lapin, K. (2020). A systematic review of the impact of invasive alien plants on forest regeneration in European temperate forests. *Frontiers in Plant Science*, 1349.https://doi.org/10.3389/fpls.2020.524969.

Mohr, D.L., Wilson, W.J. & Freud, R.J. (2021). Statistics Methods. Fourth Edition, 747-754 pg.

Ndangalasi, H. J., Bitariho, R., & Dovie, D. B. (2007). Harvesting of non-timber forest products and implications for conservation in two montane forests of East Africa. *Biological Conservation*, *134*(2), 242-250.

Petersen, H., Jack, S. L., Hoffman, M. T., & Todd, S. W. (2020). Patterns of plant species richness and growth form diversity in critical habitats of the Nama-Karoo Biome, South Africa. *South African Journal of Botany*, *135*, 201-211.

Rai, P. K., & Singh, J. S. (2020). Invasive alien plant species: Their impact on environment, ecosystem services and human health. *Ecological indicators*, *111*, 106020. https://doi.org/10.1016/j.ecolind.2019.106020.

Reichert, B. L., Jean-Philippe, S. R., Oswalt, C., Franklin, J., & Radosevich, M. (2015). Woody vegetation and soil characteristics of residential forest patches and open spaces along an urban-to-rural gradient. *Open Journal of Forestry*, *5*(01), 90-104.

Ricklefs, R. E., & Bermingham, E. (2002). The concept of the taxon cycle in biogeography. *Global Ecology and Biogeography*, *11*(5), 353-361.https://doi.org/10.1046/j.1466-822x.2002.00300.x.

Ringold, P. L., Magee, T. K., & Peck, D. V. (2008). Twelve invasive plant taxa in US western riparian ecosystems. *Journal of the North American Benthological Society*, *27*(4), 949-966.

Ruffo, K. C., Birnie, A., & Tengnas, B.O. (2002). *Edible wild plants of Tanzania. Regional Land Management Unit (RELMA)*. Technical Handbook No. 27.

Ruiz-Jaén, M. C., & Aide, T. M. (2005). Vegetation structure, species diversity, and ecosystem processes as measures of restoration success. *Forest Ecology and Management*, *218*(1-3), 159-173.

Sosef, M.S.M., Gereau, R.E., Luke, W.R.Q., Ntore, S., Simo-Droissart, M., Stevart, T., & Tack, W. (2021). *Red List of the endemic and sub endemic trees of Centre Africa*. Democratic epublic of Congo-Rwanda-Burundi.

Stohlgren, T. J., Falkner, M. B., & Schell, L. D. (1995). A modified-Whittaker nested vegetation sampling method. *Vegetatio*, *117*(2), 113-121.

Thom, D., & Seidl, R. (2016). Natural disturbance impacts on ecosystem services and biodiversity in temperate and boreal forests. *Biological Reviews*, *91*(3), 760-781.

URT. (2016). Revised management plan for Monduli Forest Reserve. Monduli District, Arusha Region. Ministry of Natural Resources and Tourism, Tanzania Forest Service Agency (TFS), Tanzania.

Vila-Ruiz, C. P., Meléndez-Ackerman, E., Santiago-Bartolomei, R., Garcia-Montiel, D., Lastra, L., Figuerola, C. E., & Fumero-Caban, J. (2014). Plant species richness and abundance in residential yards across a tropical watershed: implications for urban sustainability. *Ecology and Society*, *19*(3). http://dx.doi.org/10/10.5751/ES-06164-190322

White, T. A., Barker, D. J., & Moore, K. J. (2004). Vegetation diversity, growth, quality and decomposition in managed grasslands. *Agriculture, Ecosystems & Environment*, *101*(1), 73-84.

Wilson, J. B., Peet, R. K., Dengler, J., & Pärtel, M. (2012). Plant species richness: the world records. *Journal of vegetation Science*, *23*(4), 796-802.https://doi.org/10.1111/j.1654-1103.2012.01400.x.

Wubetu, M., Abula, T., & Dejenu, G. (2017). Ethnopharmacologic survey of medicinal plants used to treat human diseases by traditional medical practitioners in Dega Damot district, Amhara, Northwestern Ethiopia. *BMC research notes*, *10* (1), 1-13.https://doi.org/10.1186/s13104-017-2482-3.