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Vegetation composition, diversity, stand structure and carbon stock of a dry evergreen montane forest of Lendikinya forest reserve in Tanzania

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Abstract. *Mwaluseke ML, Mwakalukwa EE, Maliondo SMS. 2023. Vegetation composition, diversity, stand structure and carbon stock of a dry evergreen montane forest of Lendikinya forest reserve in Tanzania. Biodiversitas 24: 551-562.* There is limited information on woody plant diversity and vegetation patterns in African dry forests, particularly in East Africa, and hence increasing the interests in understanding species composition, diversity, and structural attributes of catchment forest reserves found in Tanzania. Moreover, tree species composition, species richness, and carbon stock are not well documented in most montane forests in the region, apart from Ethiopia. Their potential in terms of carbon storage is also important for understanding their productivity and the extent to which they can be used in mitigating the effects of climate change. This study assessed vegetation composition and diversity, stand structure and potential carbon stocks of Lendikinya Forest Reserve, a dry evergreen montane forest located in Monduli District in Tanzania. A total of 56 concentric circular plots with subplots of 2 m, 5 m, 10 m, 15 m and 20 m radii were used to collect woody species data on standing trees and stumps across the entire forest of 3,689 ha. A total of 79 species belonging to 36 families were identified. *Drypetes natalensis* (9.2%), *Diospyros abyssinica* (7.1%) and *Dombeya rotundifolia* (6.5%) were the most important species as per the Importance Value Index (IVI). The diversity indices have indicated the forest reserve to have a high diversity of woody species. Stand structure comprises 1,398 ± 679 stems ha^{-1}, basal area of 11.42 ± 5.41 $m^2ha^{-1}$and standing volume of 54.47 ± 24.1 m^3ha^{-1} while the mean carbon stocks were 16.04 ± 7.7 t C ha^{-1}. The alarming disturbances stress the urgent need for increased conservation efforts in order to protect the existing biodiversity and increase carbon storage and enhance water conservation in the reserve.

Keywords: Climate change, disturbance, diversity, evergreen, REDD+

INTRODUCTION

Tanzania is estimated to have about 48.1 million ha of forest area, or equating to 55% of the total land area of Tanzania mainland (MNRT 2015). Among various designations of forests in Tanzania, there are catchment forests with total extent of 995,300 ha which mostly occur in humid montane areas at intermediate to high elevations. These forests are established for the purposes of watershed management and gene pool conservation (URT 1998; Ashagre et al. 2014). In Tanzania, most of the catchment forests are located along the Eastern Arc Mountains which cover about 2% of Tanzania's total land area (Iddi 1998).

The establishment of new forest reserves in areas of high biodiversity value and critical watershed areas is advocated to ensure the conservation and preservation of forest biodiversity as well as the protection and maintenance of water sources and soil fertility (URT 1998; Nugroho et al. 2022). Across the world, forest designation similar to catchment forest reserves has been established in many countries using various terms, such as watershed protection forest in Indonesia (Santika et al. 2019). Proper management of watersheds in terms of wise use of soil, climate and vegetation within a given catchment area is important to maximize water storage capacity, minimize runoff and erosion, properly distribute water in time and space, maintain water quality and conserve soil (Ashagre et al. 2014; Nugroho et al. 2022).

Despite the importance of catchment forests in terms of biodiversity conservation, watershed management and climate regulation (Lopez-Toledo et al. 2012; Löf et al. 2019; Nepal 2021; Nugroho et al. 2022), they are facing serious anthropogenic threats to the extent of altering their functions (Achard et al. 2014; Mutiso et al. 2015). Increasing growth in the human population creates pressure that causes rapid deforestation and forest degradation in all types of forests (Green et al. 2013; Schaafsma et al. 2014; Majumdar and Datta 2015). Overall, such pressures are likely to cause large changes in the composition, diversity and structure of the woody species and, in the near future, may lead to the loss of habitat and some valuable plant and animal species (Richard et al. 2014; Gereau et al. 2016; Betts et al. 2017). Moreover, the effect of deforestation and forest degradation on these forests will lead to increased emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs), thus contributing to global warming and climate change problems (Houghton 2013; FAO 2020). Emissions from deforestation and forest degradation of tropical forests have been estimated to account for about 18-20% of the total global CO_2 emission (Houghton 2013; IPCC 2019; FAO 2020).

Tanzania is reported to lose about 372,816 ha of forest cover per year (MNRT 2015) and most recent estimates showed that the forest loss in the country reached about

469,420 ha per year (URT 2017). The high rate of deforestation in Tanzania implies that both forest resources and biodiversity in the country are under serious threat which also has consequence on the increased GHGs emission. Hence, the need to manage all forests more sustainably including the catchment forest reserves is emphasized. A better understanding of carbon stocks in these forests is important for estimating national carbon losses from deforestation and forest degradation (Willcock et al. 2014; Karki et al. 2017; Kendie et al. 2021).

In addition, to the moist montane evergreen forests, there are a number of dry montane evergreen forests in different parts of the country. However, moist montane evergreen forests in East Africa are as well-documented as in Ethiopia (Asefa et al. 2020). Lendikinya Forest Reserve (LFR), a dry evergreen mountainous forest situated in the eastern part of Monduli District in Arusha Region, Tanzania, is one of the catchment forest reserves in the country which was established since 1969 (Meindertsma and Kessler 1997). LFR, like any other forests, has been frequently subjected to uncontrolled tree cutting for commercial use and faces forest encroachment due to agricultural activities (UNDP 2003). Excessive tree cutting and encroachment for agriculture is suspected to have caused massive degradation of species composition, diversity, and forest structure. For successful management of this forest, more precise data in terms of species composition, diversity and structural attributes are required. Nevertheless, maintaining ecological equilibrium including biodiversity conservation and meeting the requirements of the forest-adjacent communities in terms of provisioning various ecosystem services such as water resources, requires deliberate efforts to manage the existing natural forests sustainably (Erenso et al. 2014). Thus, biomass and carbon stock are key indicators that can assist in assessing the productivity and biological and economic attributes of the forest. Regarding the potential for reduced emissions from deforestation and forest degradation, plus forest conservation, sustainable forest management, and enhancement (REDD+) implementation, LFR lacks baseline data on carbon storage as an indicator of forest ecosystem functioning, productivity, and requirements for climate change mitigation options (Jacobs et al. 2015).

Therefore, in order to aid preparation of strategies for successful management of the forest reserve, this study was intended to provide baseline data on species composition, diversity and structural attributes and carbon storage potential of a relatively disturbed Lendikinya Forest Reserve found in Monduli District in Tanzania. Specifically, the study aimed to: i) determine species composition and diversity of all woody trees and shrubs found in reserve, ii) determine the stocking rate (standing and removed stem density and, basal area) of trees and shrubs with diameter $\geq$ 5 cm in reserve, and iii) estimate carbon stocks of the reserve.

MATERIALS AND METHODS

Study area

Lendikinya Forest Reserve (LFR) with a total area of 3,689 ha, is a dry evergreen mountainous forest that is situated in the eastern part of Monduli District located in the Arusha Region, Tanzania (Figure 1). Monduli District lies between latitudes 2º and 4º S and longitude 36º and 37º E. The District is generally semi-arid with an average rainfall ranging between 400 and 900 mm per annum while the average temperature ranges from 11.5ºC (July) to 29ºC (December). For the lower altitudes in May, humidity during the night reaches 100%. LFR has been managed for watershed protection by the Monduli District Council since 1969 (Meindertsma and Kessler 1997). Vegetation found in Monduli District, including LFR is mostly referred to as upland dry evergreen forests, which occur from about 1200 m above sea level altitude upwards with rainfall not well distributed (Lovett and Pocs 1993; Holmes 1995). Specifically, the forest type in LFR is a dry montane forest of arid and semi-arid land protruding in high mountains (UNDP 2003). Common tree species found in these areas resemble those found on the drier parts of the western and northern slopes of the Usambara, Kilimanjaro and Meru mountains, also forming major portions of the Pare and Mporoto mountains. Examples of common genera include *Prunus*, *Teclea*, *Rapanea*, *Olea*, *Juniperus*, *Cassipourea*, *Cordia*, *Fagaropsis*, *Croton*, *Ekebergia* and *Rawsonia* (Lovett and Pocs 1993; Holmes 1995). LFR borders four villages, namely Lashaine, Monduli Juu, Alkatani, and Lendikinya. The economic activities of the people of the area depend on livestock, agro-pastoralism, and tourism. LFR like any other forest, has been frequently subjected to uncontrolled tree cutting for commercial use and faces encroachment due to agricultural activities (UNDP 2003). Excessive tree cutting and encroachment for agriculture are suspected of having caused massive degradation of species composition, diversity, and forest structure. The woodland harbour big game species such as *Loxodonta africana* (Elephants), *Giraffa camelopardalis* (Giraffe), *Syncerus caffer* (Buffaloes) and a variety of birds and insects.

Data collection

The field survey was conducted in May-June 2014 and involved the establishment of 56 concentric circular sample plots with subplots with a radius of 2 m, 5 m, 10 m, 15 m and 20 m located systematically across the entire forest of 3,689 ha (Figure 1). The first plot in the first transect was established at half of the inter-plot distance (i.e. 250 m) while for the successive plots, the inter-plot distance of 500 m was maintained. The following parameters were recorded within each of the 56 plots: within the 2 m radius, all trees and shrubs with diameter at breast height (Dbh) <5 cm were identified and counted, within 5 m radius, all trees and shrubs with Dbh ≥5 - <10 cm were identified and measured for Dbh, within 10 m radius all trees and shrubs with Dbh ≥ 10 - <20 cm were identified and measured for Dbh, within 15 m radius all trees and shrubs with Dbh ≥ 20 cm were identified and measured for Dbh, and within the 20 m radius all stumps were identified and measured for basal diameter (Bd) at 10 cm above the ground. In addition, three stems (with small, medium and large Dbh) in a plot were selected and measured for heights using Suunto hypsometer.

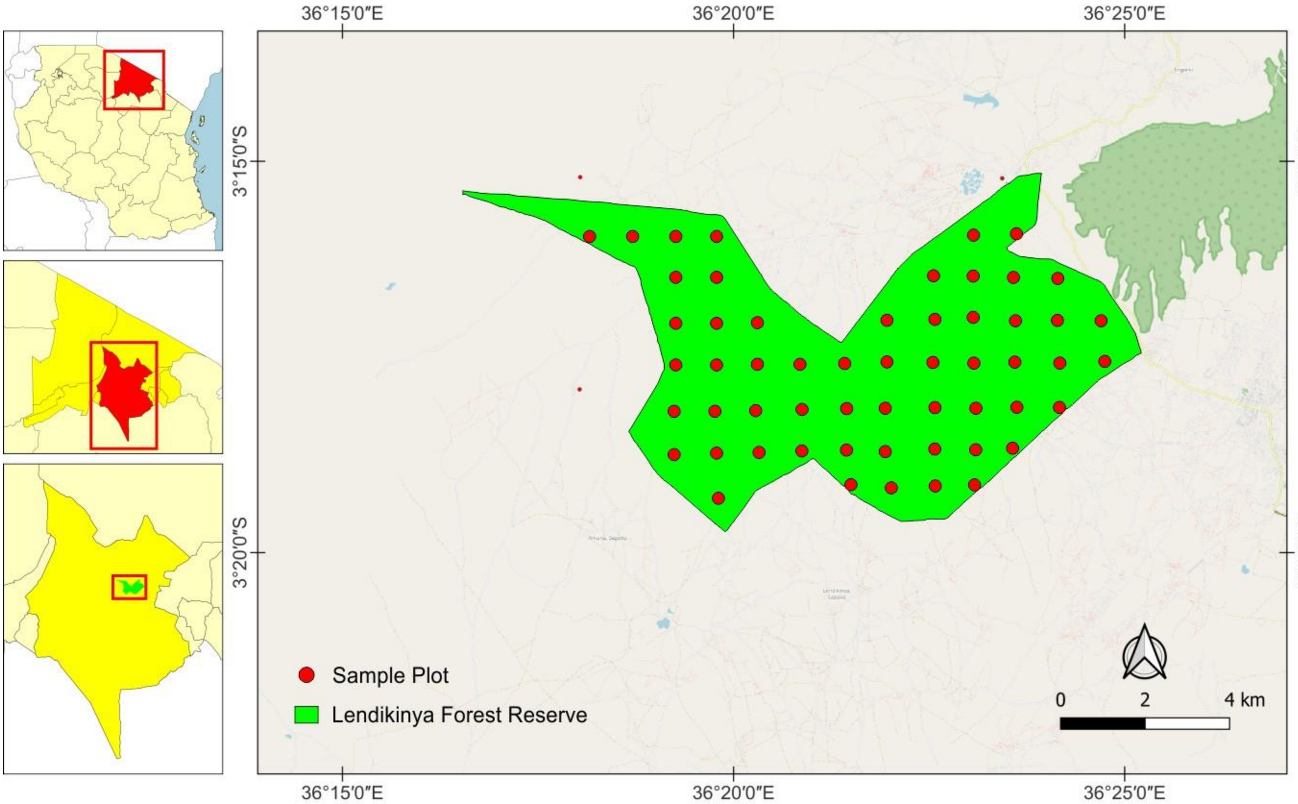

Figure 1. Map study location and layout of observation plots in the Lendikinya Forest Reserve, Tanzania

The Dbh was measured at 1.3 m above ground using diameter tape/caliper. Altitude was recorded at the plot center using GPS. Identification of trees and shrubs in vernacular and scientific names was carried out by an experienced local person and a botanist. When it proved difficult to identify in the field, voucher specimens were collected for proper identification in the Herbarium at the Department of Botany, University of Dar es Salaam.

Data analysis

Species composition was expressed through species richness and diversity measures, and abundance was determined in terms of the number of counts of each individual present in a community. Total species richness was computed as the total number of species across all 56 plots. Species diversity was computed using the Shannon-Wiener diversity (*H′*) index and Simpson's diversity index (*D*) whereas the Importance Value Index (IVI) was determined as the sum of relative density and dominance (basal area) and expressed in percent (Kent 2012). Forest structure was expressed through stem density, basal area and volume for species against diameter classes. Volume and biomass of the trees were estimated using regression models developed in this forest by the authors (Mwaluseke ML 2015. Unpublished data) as follow:

ln(V) = -9.845 + 1.915 x ln(DBH) + 1.089 x ln(Ht) (R^2 = 0.97, RMSE = 0.296, AIC = -144.18, Dbh range: 5 - 58.5 cm, n = 30)

ln(B) = -1.666 + 0.853 x ln(WD x DBH^2 x Ht) (R^2 = 0.95, RMSE = 0.324, AIC = 224.13, Dbh range: 5 - 58.5 cm, n = 30);

where V is the volume (m^3/tree); B is biomass (kg); DBH is the diameter at breast height (≥1 cm), RMSE is the residual standard error, R^2 is the coefficient of determination, AIC is Akaike Information Criterion, n is the total sample size, and ln is the natural logarithm. Carbon stock was estimated by multiplying with a conversion factor of 0.49 (Munishi and Shear 2004; Manyanda et al. 2019). All analyses were carried out in Microsoft Excel Spreadsheets, PAST and Minitab 15 software.

RESULTS AND DISCUSSION

Species composition

Including all size categories (small individuals of Dbh < 5 cm and large individuals of Dbh ≥ 5 cm) a total of 79 species (36 families) of standing trees and shrubs were identified in the LFR (Tables 1 and 2). Trees contributed 71% (28 families) and shrubs 29% (15 families) of the species. For stumps, a total of 35 species (23 families) of trees and shrubs with basal diameters ranging from 3 to 47 cm were identified (Table 1). Tree and shrub species from the family Rutaceae contributed the most (13.9%), followed by those from the families Ebenaceae (13.5%) and Euphorbiaceae (12.9%). Most standing tree species were found in the Rutaceae family (17.5%) followed by

Ebenaceae family (17.1%) and Euphorbiaceae family (16.1%). For shrub species, Verbenaceae contribute the most (21.1%), Meliaceae (13.5%) and Papilionaceae (12.1%). Regarding stumps, species from family Ebenaceae contributed the most (20%), followed by species from the family Rutaceae (11%); Euphorbiaceae (10%), and Sterculiaceae (9%).

The size distribution of plant species was highly variable. A total of 69 species belonging to 32 families were found in trees and shrubs species of Dbh ≥ 5 cm (Table 1) dominated by species from the family Ebenaceae (15.4%), Euphorbiaceae (15.1%) and Rutaceae (9.6%). In contrast, a total of 32 species in 20 families have been recorded in trees and shrubs species of Dbh < 5 cm with 33% belonging to the Rutaceae family, while Rhizophoraceae and Apocynaceae families each contributed 10% (Table 2).

The average number of species per plot in LFR was nine species but there was high variation between plots. The species accumulation curve (Figure 2) indicates the rate of encountering new species. Species initially increased rapidly up to the 18^{th} plot and increased slowly up to the 50^{th} plot. However, since only 56 plots were sampled, the later result implies that any further increase in sample size might have included additional new species. The sample size was considered sufficient to provide baseline information necessary for understanding the composition and diversity of the species in LFR.

The species richness of 79 different trees and shrubs and 36 plant families reported in this study using 56 sample plots of 0.071 ha is lower when compared to other studies from other tropical forests. For instance, Masresha and Melkamu (2022) reported seven values of different species richness ranging from 80-122 tree species from dry evergreen afromontane forest patches in Ethiopia, Erenso et al. (2014) found a total of 95 species from a dry evergreen forest in Ethiopia, Kayombo et al. (2022) found a total of 84 tree species from 60 plots of 20m × 20m established in Monduli Mountain Forest Reserve in Tanzania, Kacholi et al. (2015) found a total of 101 species and 34 families from the Uluguru mountain forests in Tanzania and Tynsong et al. (2022) found a total of 146 species and 56 families from three 1 ha plots in the tropical evergreen forests of North East India. The higher values found elsewhere could be attributed to the sampling effort (total area and sample plots sizes) employed by other studies as compared to this study. For example, Erenso et al. (2014) apart from using 60 sample plots also conducted additional opportunistic sampling in selected microhabitats. They also included liana and epiphytes; but if liana and epiphytes are excluded, the total number of species is reduced to 76. The total number of species identified by Kacholi et al. (2015) was from a total of 114 plots and included seven different forests ranging from 3 to 995 ha. But the species richness from individual forests ranged from 17 to 67 species. Therefore, when the individual forest is considered, the findings obtained from this study are much higher.

However, compared to other studies, the species richness of 79 was relatively higher despite the smaller sample plot size used in this study (0.071 ha). For instance, Masresha and Melkamu (2022) in Ethiopia reported 12 different values of species richness ranging from 36-78 tree species, Boz and Maryo (2020) from Ethiopia reported a total of 76 woody species representing 40 families in a dry semi-evergreen Afromontane forest from 64 (0.04 ha) sample plots, Daba et al. (2022) from the moist Afromontane forest of southwestern Ethiopia recorded a total of 68 tree and shrub species and 33 families from 100 plots of 20m × 20m and Feroz et al. (2016) reported 40 species (in 0.16 ha) in tropical wet evergreen forest in Bangladesh.

The species richness found in this study is also much higher when compared to other studies done in other dry evergreen montane forests and elsewhere in Tanzania. For instance, Mialla (2002) using 48 sample plots of 0.071 ha reported species richness of 42 trees and shrubs and Dugilo (2009) using 28 sample plots of 0.071 ha reported 42 trees and shrubs. The main reason for the relatively low species richness reported by Mialla (2002) and Dugilo (2009) might be attributed to the fewer sample plots employed, which could not sufficiently capture the biodiversity in those study sites. The species richness found in this study falls in the range of species commonly found in miombo woodland of 40-229 species (Mwakalukwa et al. 2014; Jew et al. 2016). This shows that Lendikinya FR has a relatively large number of forest plant species, which signals the significance of enhancing various forest conservation efforts.

The species richness of harvested stems indicated the presence of the most common genera (*Olea, Cassipourea* and *Acacia*) usually found in this type of vegetation mostly referred to as upland dry evergreen forests (Lovett and Pocs 1993; Holmes 1995). The other common genera such as *Juniperus, Croton, Cordia,* and *Clausena* were not among the harvested stems (Lovett and Pocs 1993; Holmes 1995; Erenso et al. 2014). This could be either because they are still young or have been over-harvested. The presence of other genera in the list of harvested stems is clearly demonstrated by the IVI whereby *Olea europaea*, *Diospyros abyssinica* subsp. *abyssinica* and *Teclea simplicifolia* were the most important species among the harvested tree species. Excessive tree cutting, especially for the durable wood from *Olea* sp. had been experienced in LFR for either commercial purposes (e.g., timber and poles) or for house construction (UNDP 2003). Similarly, Mialla (2002) and Hitimana et al. (2004) reported *Olea capensis* and *D. abyssinica* to be rarely found in their study forests.

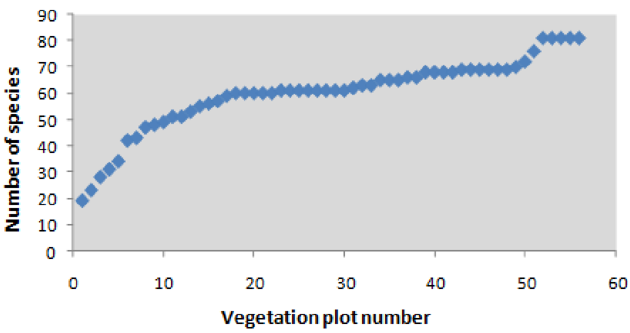

Figure 2. Species accumulation curve in Lendikinya Forest Reserve (LFR), Tanzania

Table 1. Checklist of tree and shrub species identified in Lendikinya FR, Tanzania showing frequency (%), density (mean±SE), basal area (mean±SE) and Importance Value Index (IVI) for trees with Dbh ≥ 5; S=Shrub and T=Tree

Vernacular/ local name	Species/botanical name	Family name	Habit/ life form	Current population				Stumps			
				Frequency (%)	Density stems/ha	Basal area (m^2/ha)	IVI	Frequency (%)	Density stems/ha	Basal area (m^2/ha)	IVI
Msundari	*Drypetes natalensis* (Harv.) Hutch.	Euphorbiaceae	T	21	139 ± 74	1.59 ± 0.66	9.2	13	6 ± 3	0.11 ± 0.06	8
Entatrian	*Diospyros abyssinica* subsp. *abyssinica* (Hiern) F. White	Ebenaceae	T	23	105 ± 51	1.1 ± 0.42	7.1	23	8 ± 3	0.14 ± 0.06	12
Osuputiai	*Dombeya rotundifolia* (Hochst.) Planch.	Sterculiaceae	T	25	99 ± 34	0.91 ± 0.26	6.5	13	6 ± 3	0.10 ± 0.06	8
Olgelai	*Teclea simplicifolia* (Engl.) I. Verd	Rutaceae	T	27	80 ± 42	0.81 ± 0.36	5.8	18	7 ± 3	0.11 ± 0.05	9
Orkinyei	*Euclea natalensis* A. DC.	Ebenaceae	T	30	77 ± 26	0.54 ± 0.15	5.2	29	5 ± 2	0.05 ± 0.02	8
Ol-cani lenkashe	*Turraea holstii* Gürke	Meliaceae	S	38	91 ± 18	0.23 ± 0.04	5	0	0	0	0
Osinoni	*Lippia javanica* (Burm.f.) Spreng.	Verbenaceae	S	34	86 ± 18	0.21 ± 0.05	4.7	0	0	0	0
Sananguri	*Rhus pyroides* Burch.	Rhizophoraceae	T	16	88 ± 41	0.39 ± 0.18	4.2	16	3 ± 2	0.03 ± 0.01	5
Alaataabhe	*Embelia schimperi* Vatke	Myrsinaceae	S	25	61 ± 16	0.17 ± 0.04	3.4	0	0	0	0
Ormagirgian	*Lantana triflora* L.	Verbenaceae	S	27	57 ± 14	0.14 ± 0.14	3.3	0	0	0	0
Olaiselegi	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae	T	16	34 ± 22	0.37 ± 0.19	2.8	9	1 ± 1	0.01 ± 0.01	2
Oldang'anayo	*Elaeodendron buchananii* (Loes.) Loes	Celastraceae	T	9	10 ± 5	0.7 ± 0.3	2.8	9	1 ± 1	0.02 ± 0.01	3
Endugai	*Strychnos mitis* S. Moore	Strychnaceae	T	14	33 ± 15	0.22 ± 0.09	2.3	4	1	0	1
Olarashi	*Calodendrum capense* (L.f.) Thunb.	Rutaceae	T	16	15 ± 10	0.32 ± 0.15	2.2	4	0	0.02 ± 0.01	1
Oloirieroi	*Combretum molle* R.Br ex G. Don	Combretaceae	T	9	25 ± 16	0.26 ± 0.13	1.9	4	1 ± 1	0.01 ± 0.01	2
Orgumi	*Vangueria madagascariensis* J.F. Gmel.	Rubiaceae	T	14	25 ± 14	0.13 ± 0.05	1.8	7	1 ± 1	0.01	2
Ormorijoi	*Acokanthera schimperi* G. Don	Apocynaceae	T	11	18 ± 12	0.23 ± 0.13	1.7	11	2 ± 2	0.04 ± 0.02	4
Oloirien	*Olea europaea* L.	Oleaceae	T	11	4 ± 2	0.3 ± 0.14	1.6	13	5 ± 3	0.27 ± 0.16	12
Olaiseremai	*Ximenia americana* L.	Olacaceae	T	9	24 ± 16	0.16 ± 0.08	1.6	7	1	0.01 ± 0.01	2
Sangupesi	*Albizia schimperiana* Oliv.	Mimosoideae	T	5	13 ± 10	0.29 ± 0.21	1.5	5	3 ± 2	0.03 ± 0.02	3
osteti lendim	*Celtis africana* Burm.f.	Celtididaceae	T	13	14 ± 6	0.12 ± 0.05	1.4	4	1 ± 1	0.02 ± 0.01	2
Oirhii	*Grewia kakothamnos* (K. Schum.) Burret	Tiliaceae	T	5	28 ± 22	0.14 ± 0.11	1.4	0	0	0	0
Olmotoo	*Thespesia garckeana* F. Hoffm	Malvaceae	T	7	21 ± 13	0.16 ± 0.1	1.4	9	2 ± 1	0.03 ± 0.02	3
Mberapapaa	*Asparagus flagellaris* L.	Asparagaceae	S	9	25 ± 12	0.06 ± 0.03	1.3	0	0	0	0
Emparasentru	*Mystroxylon aethiopicum* (Thunb.) Loes	Celastraceae	T	9	10 ± 6	0.14 ± 0.09	1.2	5	1 ± 1	0.02 ± 0.01	2
Elerai	*Acacia xanthophloea* Benth.	Mimosoideae	T	7	5 ± 3	0.2 ± 0.13	1.1	0	0	0	0
Altarara	*Acacia abyssinica* Hochst. ex Benth.	Mimosoideae	T	7	2 ± 1	0.18 ± 0.1	1	4	2 ± 2	0.03 ± 0.02	3
Emermenyi	*Acacia gerrardii* Benth.	Mimosoideae	T	7	11 ± 7	0.12 ± 0.1	1	2	0	0	0
Olkiloriti	*Acacia nilotica* (L.) Willd. ex Delile	Mimosoideae	T	5	19 ± 18	0.08 ± 0.07	1	4	0	0.01 ± 0.01	1
Olamuriaki	*Carissa edulis* Vahl.	Apocynaceae	S	5	18 ± 10	0.08 ± 0.04	1	0	0	0	0
Olaiyepasai	*Melanthera punges* Oliv. & Hiern	Asteraceae	S	7	18 ± 9	0.05 ± 0.03	1	0	0	0	0
Enkoroye	*Indigofera* sp.	Papilionoideae	S	7	16 ± 9	0.05 ± 0.02	0.9	0	0	0	0
Arparasentru	*Turraea robusta* Gürke	Meliaceae	T	9	7 ± 4	0.07 ± 0.03	0.9	4	0	0	1
Orpopong'i	*Euphorbia candelabrum* Trem. ex Kotschy.	Euphorbiaceae	T	7	7 ± 5	0.06 ± 0.03	0.8	0	0	0	0
Osupukiai Orok	*Pavonia urens* Cav.	Malvaceae	S	5	16 ± 9	0.04 ± 0.02	0.8	0	0	0	0
Marasentru	*Trichocladus ellipticus* Eckl. & Zeyh.	Hamamelidaceae	T	5	10 ± 8	0.05 ± 0.03	0.7	7	3 ± 2	0.03 ± 0.02	4
Esimundeti	*Maytenus senegalensis* (Lam.) loes.	Celastraceae	T	4	7 ± 5	0.04 ± 0.03	0.5	0	0	0	0

Emwiimbi	*Nuxia floribunda* Benth.	Buddlejaceae	T	4	4 ± 3	0.07 ± 0.05	0.5	4	1 ± 1	0	1
Eseki	*Cordia monoica* Roxb.	Boraginaceae	T	2	9 ± 9	0.02	0.4	2	0	0	0
Armabaiti	*Croton megalocarpus* Hutch.	Euphorbiaceae	T	4	1 ± 1	0.05 ± 0.05	0.4	4	1	0.01 ± 0.01	2
Oloponi	*Erythrina abyssinica* Lam. ex DC.	Papilionoideae	T	4	2 ± 1	0.05 ± 0.04	0.4	0	0	0	0
Inkarane	*Hibiscus* sp.	Malvaceae	S	4	5 ± 3	0.03 ± 0.02	0.4	0	0	0	0
Olboboki	*Schrebera alata* (Hochst.) Welw.	Oleaceae	T	4	1	0.04 ± 0.03	0.4	0	0	0	0
Olmasei	*Tarenna* sp.	Rubiaceae	T	4	3 ± 3	0.03 ± 0.02	0.4	0	0	0	0
Enderikesi	*Acacia senegal* (L.) Willd.	Mimosoideae	T	2	3 ± 3	0.04 ± 0.04	0.3	0	0	0	0
Gosida	*Asystania gangetica* (L.) T. Anderson.	Asteraceae	S	2	5 ± 5	0.01 ± 0.01	0.3	0	0	0	0
Olkirpanyani	*Clutia* sp.	Euphorbiaceae	S	2	7 ± 7	0.02 ± 0.02	0.3	0	0	0	0
Olaiyapiyapi	*Croton macrostachyus* Hochst. ex Delile	Euphorbiaceae	T	2	5 ± 5	0.03 ± 0.03	0.3	0	0	0	0
Oloholo	*Ozoroa insignis* Delile	Anacardiaceae	T	2	5 ± 5	0.02 ± 0.02	0.3	2	1 ± 1	0.01 ± 0.01	1
Oledeti	*Trimeria grandifolia* (Hochst.) Gilg.	Flacourtiaceae	T	2	5 ± 5	0.01 ± 0.01	0.3	2	0	0	0
Orminihoi	*Acacia* sp.	Mimosoideae	T	2	3 ± 3	0.02 ± 0.02	0.2	0	0	0	0
Mbangwe-Nyekundu	*Allophylus africanus* P. Beauv.	Sapindaceae	T	2	2 ± 2	0	0.2	2	0	0	0
Amatanguyu	*Boscia salicifolia* Oliv.	Capparaceae	T	2	1 ± 1	0.01 ± 0.01	0.2	0	0	0	0
Olaturrudiai	*Capparis tomentosa* Lam.	Capparaceae	S	2	2 ± 2	0.01 ± 0.01	0.2	0	0	0	0
Olaiselegi	*Cassipourea mollis* Alston	Rhizophoraceae	T	2	0	0.02 ± 0.02	0.2	0	0	0	0
Ematasya	*Clausena anisata* (Willd.) Hook.f. ex Benth.	Rutaceae	T	2	2 ± 2	0.01 ± 0.01	0.2	0	0	0	0
Ortimarwei	*Cussonia arborea* Hochst. ex A. Rich	Araliaceae	T	2	0	0.03 ± 0.03	0.2	2	0	0	0
	Dodonaea viscosa Jacq.	Sapindaceae	T	2	2 ± 2	0.01 ± 0.01	0.2	0	0	0	0
Ormorogi	*Dovyalis hispidula* Willd.	Flacourtiaceae	T	2	1 ± 1	0.02 ± 0.02	0.2	0	0	0	0
Enjaninaiboro	*Erythrococca bongensis* Pax.	Euphorbiaceae	T	2	2 ± 2	0.01 ± 0.01	0.2	2	0	0	0
Ondorokoo	*Grewia bicolar* Juss.	Tiliaceae	T	2	2 ± 2	0.01 ± 0.01	0.2	0	0	0	0
Ormadwee	*Kigelia africana* (Lam.) Benth.	Bignoniaceae	T	2	1 ± 1	0.03 ± 0.03	0.2	0	0	0	0
Engaemirhoki	*Lannea schweinfurthii* (Engl.) Engl.	Anacardiaceae	T	2	1 ± 1	0.01 ± 0.01	0.2	0	0	0	0
Esimundeti	*Maytenus mossambiensis* (Klotzsch) Blackelock	Celastraceae	T	2	1 ± 1	0.03 ± 0.03	0.2	0	0	0	0
Olordardar	*Olea* sp.	Oleaceae	T	2	0	0.02 ± 0.02	0.2	2	0	0.01 ± 0.01	1
Oloron'doo	*Rhoicissus tridentate* (L.) Willd.	Vitaceae	T	2	2 ± 2	0.01 ± 0.01	0.2	0	0	0	0
	Toddalia asiatica (L.) Lam.	Rutaceae	S	2	2 ± 2	0.01 ± 0.01	0.2	0	0	0	0
Oloisuki	*Zantoxylum usambarense* (Engl.) Kokwaro	Rutaceae	T	2	1 ± 1	0.02 ± 0.02	0.2	2	0	0	0
Ololiontoi	*Olea capensis subsp. hochstetteri* Baker.	Oleaceae	T	2	0	0.01 ± 0.01	0.1	0	0	0	0
Total				574	1398 ± 678	11.42 ± 5.41	100	241	63 ± 37	1.12 ± 0.63	100

Table 2. Checklist of tree and shrub species identified in Lendikinya FR showing frequency (%) and density (mean±SE), for plant species with Dbh < 5; S=Shrub and T=Tree

Vernacular/ Local name	Species/botanical name	Family	Habit/ life form	Frequency (%)	Density Stems/ha
Orkilikil	*Crotalaria* sp.	Papilionoideae	S	27	412 ± 99
Endamedoi	*Urtica massaica* Mildbr	Urticaeae	S	25	326 ± 97
Ematasya	*Clausena anisata* (Willd.) Hook. f. ex Benth	Rutaceae	T	18	994 ± 473
Orkinyei	*Euclea natalensis* A. DC.	Ebenaceae	T	11	295 ± 184
Entaniposi	*Artemisia affra* Jacq.	Asteraceae	S	11	184 ± 78
Oleikidongo	*Achyranthes aspera* L.	Amaranthaceae	S	11	142 ± 61
Olgelai	*Teclea simplicifolia* (Engl.) I. Verd.	Rutaceae	T	9	500 ± 345
Oldadai	*Abutilon mauritianum* (Jacq.) Medik.	Malvaceae	S	9	142 ± 64
	Vernonia sp.	Asteraceae	S	9	128 ± 57
Msundari	*Drypetes natalensis* (Harv.) Hutch.	Euphorbiaceae	T	7	199 ± 145
Oldadai	*Abutilon longiscupe* Hochst. ex A. Rich.	Malvaceae	S	7	156 ± 82
Angaisiijoi	*Plumbago zeylanica* L.	Plumbaginaceae	S	5	85 ± 52
Entatrian	*Diospyros abyssinica* subsp. *Abyssinica* (Hiern) F. White	Ebenaceae	T	5	71 ± 47
Olaiselegi	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae	T	4	369 ± 355
Ormorijoi	*Acokanthera schimperi* G. Don	Apocynaceae	T	4	313 ± 233
Oirhii	*Grewia kakothamnos* (K. Schum.) Burret	Tiliaceae	T	4	170 ± 144
Endugai	*Strychnos mitis* S. Moore	Strychnaceae	T	4	28 ± 20
Entulelei	*Solanum incanum* L.	Solanaceae	S	4	28 ± 20
Esikilianjoi	*Ormocarpum trachycarpum* (Taub.) Harms	Papilionoideae	T	2	85 ± 85
Elerai	*Acacia xanthophloea* Benth.	Mimosoideae	T	2	71 ± 71
Armabaiti	*Croton megalocarpus* Hutch.	Euphorbiaceae	T	2	71 ± 71
Oldang'anayo	*Elaeodendron buchananii* (Loes.) Loes.	Celastraceae	T	2	43 ± 24
Sangupesi	*Albizia schimperiana* Oliv.	Mimosoideae	T	2	28 ± 28
Sananguri	*Rhus pyroides* Burch.	Rhizophoraceae	T	2	28 ± 28
Orpopong'i	*Euphorbia candelabrum* Trem. ex Kotschy	Euphorbiaceae	T	2	14 ± 14
Esimundeti	*Maytenus senegalensis* (Lam.) loes.	Celastraceae	T	2	14 ± 14
Olmasei	*Tarenna* sp.	Rubiaceae	T	2	14 ± 14
Marasentru	*Trichocladus ellipticus* Eckl. & Zeyh.	Hamameliaceae	T	2	14 ± 14
Orgumi	*Vangueria madagascariensis* J.F. Gmel.	Rubiaceae	T	2	14 ± 14
Olaiseremai	*Ximenia americana* L.	Olacaceae	T	2	14 ± 14
Oloisuki	*Zantoxylum usambarense* (Eng.) Kokwaro	Rubiaceae	T	2	14 ± 14
Olaturrudiai	*Capparis tomentosa* Lam.	Capparaceae	S	2	14 ± 14
Total				196	4980 ± 2975

Species diversity

Both large (Dbh ≥ 5 cm) and small (Dbh < 5 cm) individuals had Shannon-Wiener diversity index (*H´*) values of 3.46 and 2.88 and Simpson's diversity index values of 0.05 and 0.08 respectively. For large individuals (Dbh ≥ 5 cm), the most diverse species that contributed most to the Shannon-Wiener diversity index were *Drypetes natalensis* (0.27), *Diospyros abyssinica* subsp. *abyssinica* (0.23) and *Dombeya rotundifolia* (0.21). For small individuals, the most diverse species were *Clausena anisata* (0.33), followed by *Crotalaria* sp. (0.21) and *Cassipourea malosana* (0.20). Among the large-sized standing individuals, the most frequently occurring species were *Turraea holstii* (38%) followed by *Lippia javanica* (34%) and *Euclea natalensis* (30%). Regarding the Importance Value Index (IVI) for individuals of Dbh ≥ 5 cm (Table 1), *D. natalensis* (9.2%), *Diospyros abyssinica* (7.1%) and *D. rotundifolia* (6.5%) were the most important, whereas for smaller individuals was 0.2% for both *Toddalia asiatica (Zanthoxylum asiaticum)* and *Zanthoxylum usambarense* followed by *Olea capensis* subsp. *hochstetteri* (0.1%). Stumps of the harvested tree species were mainly from *Diospyros abyssinica* subsp. *abyssinica* (12%), *Olea europaea* (12%) and *Teclea simplicifolia* (9%).

The values of the Shannon-Wiener index (*H´*= 3.46) for trees and shrubs in the present study are lower than that documented in other tropical forests. For instance, Kacholi et al. (2015) from the Uluguru forests in Tanzania found an overall *H´* value of 4.03 with Kilengwe forest leading by having a *H´* value of 4.02. Tynsong et al. (2022) from the tropical evergreen forests in India found a *H´* values ranging from 3.74 - 3.95 (mean 3.85 ± 0.06). However, *H´* values in this study are much higher than those documented by Masresha and Melkamu (2022) from dry evergreen afromontane forest patches in Ethiopia where they reported 18 different *H´* values ranging between 1.31-3.35, Kayombo et al. (2022) from Tanzania reported *H´* value of >1.5, Boz and Maryo (2020) from Ethiopia reported an average *H´* value of 3.38, Erenso et al. (2014) reported *H´* value of 1.79 and Dugilo (2009) reported *H´* value of 1.298. Furthermore, the *H´*value of 3.46 in this study falls in the range of *H´* value commonly found in miombo woodland of 1.05- 4.27 (Shirima et al. 2011; Mwakalukwa et al. 2014; Jew et al. 2016).

According to Kent (2012), a forest community is said to be rich if it has a *H´* value of 3.5. Other studies have indicated that the value normally varies between 1.5 and 4.5 and rarely exceeds 5, and a threshold value of 2 has been mentioned to be the minimum value, above which an ecosystem can be regarded as medium to highly diverse (Magurran 2004; Mwakalukwa et al. 2014). Therefore, a value of 3.46 found in this study implies that the LFR is relatively undisturbed and hence supports high species diversity compared to other forests of similar vegetation type. Thus, the dry evergreen forest of LFR in Monduli Tanzania may be considered to have a high diversity and abundance of tree species. Higher levels of disturbance and the small number of sample units employed by Dugilo (2009) of 28 sample plots might be among the main reasons which reduced the probability of capturing more new species. Erenso et al. (2014) employed a slightly larger sample size of 60 plots which could explain the biodiversity of the population. High diversity might be attributed to relatively intermediate levels of disturbance experienced in the forest leaving plant species that are adapted to withstand disturbances (fugitive species). According to Conell (1978), the intermediate disturbance hypothesis suggests that species diversity will be maintained at its highest levels when the patterns of disturbance are intermediate.

The lower Shannon's evenness index value also reflects either adverse environmental conditions or random distribution of available resources in the forest (Wale et al. 2012). The reasons for the woody plants being distributed in an uneven manner might be attributed to the inability of individuals to cope with harsh environments. For instance, low rainfall range, anthropogenic disturbance, trampling and browsing effects by livestock and browsers (e.g., Elephants) observed in the forest or other biotic and abiotic factors might explain the observed trend (Boz and Maryo 2020). On the other hand, natural regeneration and dispersal patterns of species might also explain this uneven distribution of species (Elias et al. 2011).

Stem density

The total mean stem density for large individuals (Dbh ≥ 5 cm) was 1,398 ± 679 stems ha^{-1} while for small individuals (Dbh < 5cm) was 4,980 ± 2975 stems ha^{-1} (Table 1). It was further observed that for large individuals, species that had a higher number of stems were: *D. natalensis* (9.9% of 1,398 ± 679 stems ha^{-1}) followed by *Diospyros abyssinica* subsp. *abyssinica* (7.5%) and *D. rotundifolia* (7.1%). For small individuals, more shrubs were found in *Clausena anisata* (20%), followed by *Teclea simplicifolia* (10%) and *Crotalaria* sp. (8%). The mean stem density of stumps was 63 ± 37 stems ha^{-1} with *Diospyros abyssinica* subsp. *abyssinica* being the most contributing species (12.7% of the total), followed by *Teclea simplicifolia* (11.1%), while both *D. natalensis* and *D. rotundifolia* contributed 9.5% each. Stem density distribution per diameter size class showed the expected reversed "J" shape with higher stem density in Dbh class ≤ 10 cm, indicating that the forest has good regeneration and recruitment. Stumps distribution showed the same trend, but no stumps with Dbh > 50 cm were found (Figure 3).

The stem density of 1,398 stems ha^{-1} for the woody species with Dbh ≥ 5 cm reported in this study is lower than that documented by Mialla (2002) from a dry evergreen mountain forest in Tanzania, who reported a mean density of 1822 stems ha^{-1}, Atomsa and Dibbisa (2019) reported a mean density of 1,453 stems ha^{-1} from Ethiopia, Boz and Maryo (2020) from Ethiopia reported the total density of 1745.3 stems ha^{-1} and Tynsong et al. (2022) in the tropical evergreen forests of North-East India reported a mean density of 2005 ± 48.01 trees ha^{-1} with a range from 1944 to 2100 trees ha^{-1}. However, the stem density of 1,398 stems ha^{-1} from this study is much higher than that documented by Kacholi et al. (2015) from seven forests in the Uluguru forests in Tanzania who reported an overall mean density of 390 stems ha^{-1}, Dugilo (2009) from the dry evergreen mountainous forest in Tanzania who reported a mean density of 310 stems ha^{-1} and Gebeyetu et al. (2019) from five forests in Ethiopia who reported a range of 365.6 - 664.1 stems ha^{-1} with a mean of 636.5 stems ha^{-1-}. The mean stems density values in this study fall in the range of density value found in miombo woodland of 281-1521 stems ha^{-1} (Shirima et al. 2011; Mwakalukwa et al. 2014). This implies that LFR is among the highly stocked dry evergreen montane forests in Tanzania and other forests in tropical countries. The higher density reported by other studies might be attributed to the intact conditions of the forest and the influence of microclimate, which creates favorable conditions for the growth of more species.

Although LFR is among the highly stocked dry evergreen montane forests, density distribution indicated a dominance of small trees while large trees were already overexploited, depleting the large diameter size class. The reversed "J" indicated the strong regeneration status of the forest and showed that LFR had active regeneration and recruitment with a population of natural mixed species of different ages, as reported by Mialla (2002) and Mwakalukwa et al. (2014). Figure 3 indicates that the forest had no single tree having Dbh > 60 cm. On the other hand, data on harvested trees revealed that trees harvested were within a diameter size class (≤10 to 50 cm), implying that larger size trees were overexploited. This concurs with a previous report by UNDP (2003) that LFR had excessive tree cutting that targeted large trees for timber and poles and for construction materials. Lack of large trees could also be attributed to trampling effects due to overgrazing which might have killed seedlings and caused soil compaction creating unfavorable conditions for their emergency and development (Hitimana et al. 2004).

Basal area

Basal area determined for large individuals (Dbh ≥ 5 cm) was 11.42 ±5.41 m^{2}ha^{-1}, while for stumps was 1.12 ± 0.63 m^{2}ha^{-1} (Table 1). Species that contributed most to the total mean basal area of standing large individuals were: *D. natalensis* (13.9%), followed by *O. europaea* (9.6%) and *Diospyros abyssinica* subsp. *abyssinica* (8%). Regarding stumps, the species that most contributed to the removed mean basal area were: *O. europaea* (24.1%), followed by *Diospyros abyssinica* subsp. *abyssinica* (12.5%), *D. natalensis* (9.8%) and *D. rotundifolia* (9.8%). The mean basal area distributed by Dbh size class (Figure 4) showed a reversed "J" shape. Stumps, however, did not follow the "J" shaped trend.

The mean basal area of 11.42 ±5.41 m^2ha^{-1} determined in this study is much lower than that documented in other tropical forests. For instance, Kacholi et al. (2015) from Uluguru mountain forests reported a mean basal area of 24 m^2ha^{-1}, Mialla (2002) from a dry evergreen mountain forest in Tanzania reported a mean basal area of 69.3 ± 1.6 m^2ha^{-1} and Tynsong et al. (2022) reported a range from 52.26 to 68.05 m^2ha^{-1} (mean 61.72±4.82 m^2ha^{-1}) in the tropical evergreen forests in India. The basal area determined in this study is ten times lower than the mean basal area of 114.64 m^2ha^{-1} reported by Erenso et al. (2014) from Ethiopia, a mean basal area of 126.47 m^2ha^{-1} from lowland dry semi-evergreen forest in Ethiopia (Boz and Maryo 2020), and a total basal area of 454.52 $m^2{\cdot}ha^{-1}$ from a dry Afromontane forest in Ethiopia (Siraj and Zhang 2018). Otherwise, the mean basal area found in this study falls in the range of values commonly found in other forests including miombo woodland of 3.9-16.7 m^2ha^{-1} (Backeus et al. 2006; Dugilo 2009; Mwakalukwa et al. 2014). The low basal area obtained in this study could be due to excessive tree cutting that took place previously in the forest hence the absence of an emergent layer comprising very tall trees. The higher basal area observed in other studies could be associated with a high stem density in the higher DBH class density of individuals in the respective forests as compared to other forests.

Stand volume

The total mean volume of the forest for standing trees and shrubs with Dbh ≥ 5 cm was 54.47 ± 24.1 m^3ha^{-1}. Trees contributed 92.7% (50.52 ± 22.29 m^3ha^{-1}) while shrubs contributed 7.3% (3.95 ± 1.81 m^3ha^{-1}) of the total volume. Tree species that had the highest contribution to the total volume were *D. natalensis* (15%), followed by *Diospyros abyssinica* subsp. *abyssinica* (10.4%) and *D. rotundifolia* (8.1%). For the shrubs, the species that contributed most to the total volume was *T. holstii* (1.49%) followed by *L. javanica* (1.41%) and *Embelia schimperi* (1.1%). Plotting tree volume against Dbh-size classes indicated an unexpected normal reversed "J" shape showing a decrease in volume with an increase in diameter size classes (Figure 5).

The total mean volume of 54.5 ± 24.1 m^3ha^{-1}reported in this study for trees and shrubs with Dbh ≥ 5 cm was considered higher than other values reported by Dugilo (2009) who reported a lower value of 40.03 ±11.21 m^3ha^{-1}. Otherwise, the volume reported in this study falls in the range of value commonly found in other forests including miombo woodland of 16.7 to 92.17 ± 39.0 m^3ha^{-1} (Mwakalukwa et al. 2014). The lower volume reported by this study might be caused by the presence of many small-sized trees and shrubs in the forest which contributed less to the total volume since large size woody plants were scarce. The scarcity of large trees in this study was attributed to excessive tree cutting which was targeted for timber, poles and construction materials (UNDP 2003). The much higher volume reported by Mialla (2002) might be attributed to a few large trees of Dbh up to 400 cm which had a significant contribution to the total mean volume. By contrast, the woody plants assessed in LFR had a Dbh range of 5 to 58.5 cm.

Biomass and carbon stock

The total mean aboveground biomass and carbon stocks of the trees and shrubs with Dbh ≥ 5 cm were estimated to be 32.98 ± 15.7 t ha^{-1} and 16.04 ± 7.7 t C ha^{-1}, respectively. Trees contributed 87.3% (14.01 ± 6.98 t C ha^{-1}) of the total carbon while shrubs had 12.7% (2.03 ± 0.72 t C ha^{-1}). For tree species, about 32% of carbon storage was from *D. natalensis* (14.4%) followed by *Diospyros abyssinica* subsp. *abyssinica* (8.9%) and *D. rotundifolia* (8.7%). For shrubs, a considerable storage of carbon was in *T. holstii* (2.8%), followed by *L. javanica* (2.6%) and *E. schimperi* (2.0%). The biomass and carbon distribution in different diameter classes indicated a reversed "J" shape (Figure 6) showing a decrease with increasing diameter. About 95% of the biomass and carbon was stored in small diameter classes (5-20 cm) and 5% in the rest of the diameter classes suggesting overharvesting of forest resources.

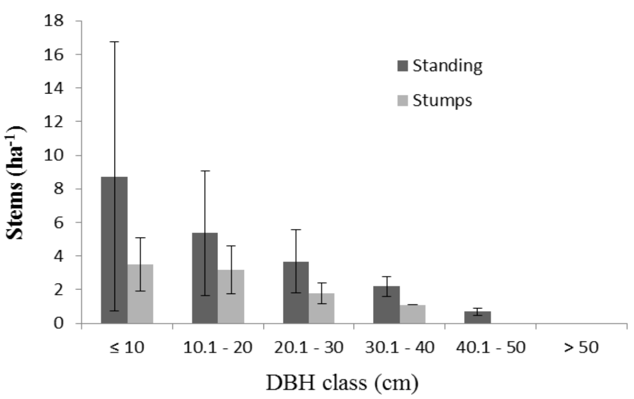

Figure 3. Stem density distribution for standing individuals and stumps in Lendikinya Forest Reserve (LFR), Tanzania

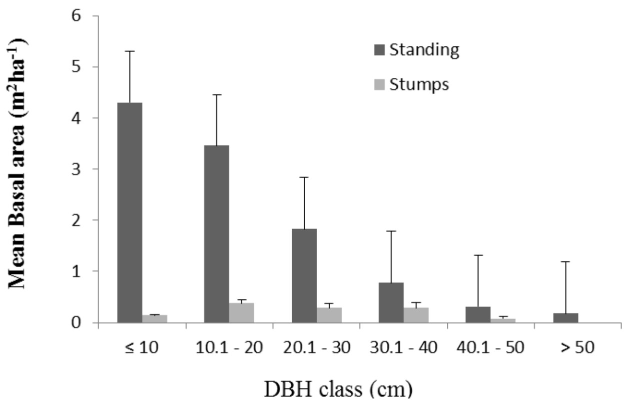

Figure 4. Mean basal area distributed by Dbh size class for standing and stumps in Lendikinya Forest Reserve (LFR), Tanzania

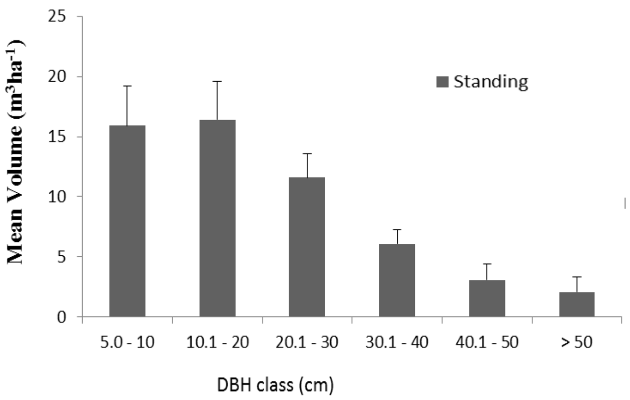

Figure 5. Volume per Dbh class distribution in Lendikinya Forest Reserve (LFR), Tanzania

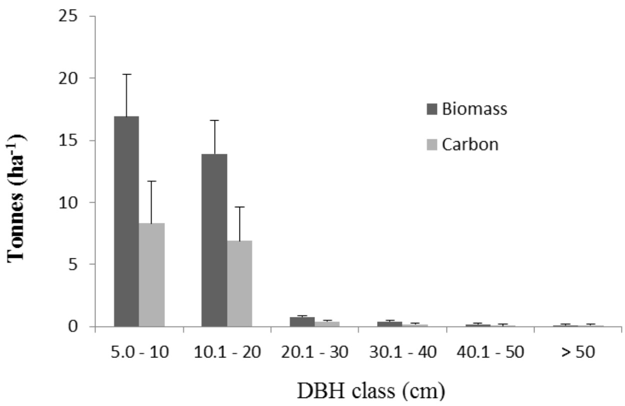

Figure 6. Biomass and carbon distribution per diameter size class in Lendikinya Forest Reserve (LFR), Tanzania

The total mean aboveground carbon stocks of the trees and shrubs with Dbh ≥ 5 cm of 16.04 ± 7.7 t C ha^{-1} determined in this study is lower than that documented from other tropical forests. For instance, Solomon et al. (2017) reported a mean carbon stock of 40.99 ± 0.40 t·C $ha^{–1}$ from dry forests in Ethiopia, Asrat et al. (2022) reported two values of 180.18 ± 17.19 t·C $ha^{–1}$ and 106.71 ± 7.64 t·C $ha^{–1}$ from dry evergreen afromontane forests in Ethiopia, Biadgligne et al. (2022) from Ethiopia reported a mean carbon stock density of 43.72± 3.79 t C ha^{-1}, Swai et al. (2014) reported a mean carbon stock of 48.4 ± 8.0 t C ha^{-1} from Hanang mountain forest in Tanzania, Shirima et al. (2015) reported a value of 54.30 ± 5.84 Mg C ha^{-1} from several montane sites in Tanzania, and Mauya and Madundo 2021 reported a range of 88.5 Mg C ha^{-1} to 436 Mg C ha^{-1} with an overall average of 175.54 Mg C ha^{-1} from mountain forests in Tanzania. Others include Wondimu et al. (2021) reported a value of 332.69 ± 37.42 t C ha^{-1} from a dry evergreen Afromontane forest in Ethiopia, Gebeyehu et al. (2019) reported a mean value of 191.6±19.7 Mg C ha^{-1} from five different dry afromontane forests in Ethiopia, Daba et al. (2022) reported a value of 203.80 ± 12.38 t·C ha^{-1} from moist Afromontane forest in Ethiopia, Naveenkumar et al. (2017) reported a range of 99 - 216 t·C $ha^{–1}$ from a tropical dry forest in India and Rawal and Subedi (2022) reported two values of mean carbon stock of 59.55 t C ha^{-1} and 51.86 t C ha^{-1} from two community forests in Nepal. In contrast, the total mean aboveground carbon stocks found in this study are higher than that reported by Biadgligne et al. (2022) from two community forests in Ethiopia of 14.84 ± 1.27 t C ha^{-1} and 3.49± 0.66 t C ha^{-1} and that reported by Jew et al. (2016) from one site of miombo vegetation in Tanzania to be 14.6 t C ha^{-1}.

The high value reported by several authors could be due to differences in climatic conditions of these sites in terms of rainfall received and the presence of many large trees which had a significant contribution to the total mean carbon density than the presence of many small trees attributed to excessive cutting reported in this study (Mauya and Madundo 2021). It has been reported that forests that have been subjected to human disturbances tend to have lower biomass and hence carbon storage than their potential (Sist et al. 2014; Lutz et al. 2018). According to Mauya and Madundo (2021) climate, topography as well as estimation methods particularly the selection of allometric models is also key factors when it comes to accurate estimation of AGB and AGC in the different study sites.

In conclusion, the results showed that LFR has a relatively rich diversity of woody species (79 species), and high species diversity values as compared to many dry evergreen mountainous forests of Tanzania and other tropical forests. Tree density and basal area are lower in our studied area as compared to other tropical forests. *O. europaea* and other *Olea* sp. were the most overexploited in the forest. The carbon stock was relatively lower compared to those reported in other studies from dry evergreen montane forests. However, the carbon stock obtained provides baseline data for the possibility of future payment schemes for REDD+ project implementation in Tanzania. In order to maintain or enhance the current and future biodiversity and management of LFR it is recommended that forest managers should put extra effort into protecting the resources, especially the most demanded tree species such as *Olea europaea, Drypetes natalensis, Diospyros abyssinica* subsp. *abyssinica, Dombeya rotundifolia, Teclea simplicifolia,* and other *Olea* sp.

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