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Original Article

Effect of Human Activities on Woody Species Diversity, Composition, Structure, and Carbon Storage in a Dry Miombo Woodland Site, Tanzania

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ABSTRACT

The effects of human activities on forest conditions in many forest reserves in Tanzania are well-acknowledged but inadequately studied. The absence of this information creates a challenge in planning for proper management and conservation of these reserves. This study assessed the effect of human activities on woody species composition, diversity, structure, and carbon stocks of Kitulanghalo catchment forest reserve managed by the Tanzania Forest Services Agency (TFS), located in Morogoro district, Tanzania. Data were collected from 30 concentric sample plots of 0.071 ha established systematically in the forest area of 2,038 ha at the distance of 800 m and 800 m between transects. Species diversity was analysed using the Shannon-Wiener Diversity Index (H’) while wood volume and biomass were calculated using developed allometric equations for Miombo woodlands. The effect of human activities on species diversity was determined using linear regression models. Results show that trees and shrubs with Dbh ≥1cm comprise 80 plant species and those with <1cm Dbh consist of 34 plant species. Shannon-Wiener Diversity Index (H’) for <1cm Dbh was 3.35 and for ≥1cm Dbh was 3.73, indicating the forest has high species diversity. Stem density for trees and shrubs with ≥1cm Dbh was 2 199 ± 1 325 stemsha-1, basal area of 7.61 ± 4.47 m2ha-1, standing volume of 56.25 ± 35.03 m3ha-1, above ground carbon stocks of 18.97±11.84 MgCha-1 and below ground carbon stocks of 9.81 ± 5.71 MgCha-1. Four major human disturbances namely charcoal making, fire, illegal logging, grazing, and erosion were identified in the study area. The harvested stems composed of 21 species with an estimated lost volume of 5.94 ± 4.47 m3ha-1 equivalent to the loss of above-ground biomass of 4.60 ± 3.43 Mgha-1 and carbon stocks of 2.30 ± 1.72 MgCha-1. Among the human disturbances found in the reserve, grazing activities were found to significantly lower the tree species diversity with a p-value <0.05. Preparation of plans to promote the management and conservation of biodiversity and carbon stocks found in the reserve is recommended.

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INTRODUCTION

It is estimated that 55% of the total land area of Tanzania's mainland is covered by forests which is equivalent to 48.1 million ha (MNRT, 2015). Woodlands occupy 44.7 million ha or 92% (MNRT, 2015). Dry and Wet miombo woodlands contribute 19% and 35% of Tanzania's total miombo woodland area, respectively (Chamshama & Vyamana, 2010). These woodlands provide many products and services supporting the livelihoods of many communities in Tanzania and in most of the Sub-Saharan countries (Abdallah & Monela, 2007; MNRT, 2015). However, despite their remarkable contribution to the livelihood, they are constantly threatened by the number of human activities (Mtimbanjayo & Sangeda, 2018; Bhattarai *et al*., 2020; Doggart *et al.*, 2020). These stresses have significantly altered tree species composition, richness, and diversity thus affecting the quality of this ecosystem to offer various ecosystem goods and services (Jew *et al.,* 2016).

Kitulanghalo Catchment Forest Reserve (KCFR) located in the Morogoro rural district is one among many forest reserves in Tanzania which is threatened by various human activities (Mwakalukwa & Masisi, 2024). However, there have been limited studies to quantify the effects of these activities on the conditions of the reserve. At Kitulaghalo in particular, the area under the management of Tanzania Forest Services Agency (TFS) has received very few studies (Luoga *et al*., 2002; Chamshama *et al*., 2004, Obiri *et al.,* 2010) unlike the other part under the management of Sokoine University of Agriculture (SUA) (Nduwamungu, 1996; Malimbwi *et al.,* 2000; Zahabu, 2001; Chamshama *et al.*, 2004; Obiri *et al.,* 2010; Lyimo & Shaaban, 2015). Assessing the extent to which human activities have affected the species composition, diversity and forest structure is important in planning for proper management and conservation.

It has been more than 20 years since the TFS area was surveyed to document the condition of the forest reserve (Chamshama *et al*., 2004). Documenting the current status of the reserve will help to know the ongoing challenges and set strategies to address them. This study, therefore, was conducted to establish; i) the current status of the TFS-Kitulanghalo catchment forest reserve in terms of woody species composition and diversity, ii) structural attributes (including stem density, basal area and volume), iii) the aboveground and belowground biomass and carbon stocks, iv) the amount of volume and biomass of wood that has been lost due to illegal harvesting of trees, and iv) effects of human activities on species diversity in the reserve.

MATERIALS AND METHODS

Study Area Description

Kitulanghalo Catchment Forest Reserve (KCFR) with an area of 2,638 ha was established in 1955 for the purpose of protecting the catchment area of the Sangasanga River and for the conservation of biodiversity (Lovett & Pocs, 1993). KCFR is located at (6º34'–6º45'S, 37º53'–38º04'E

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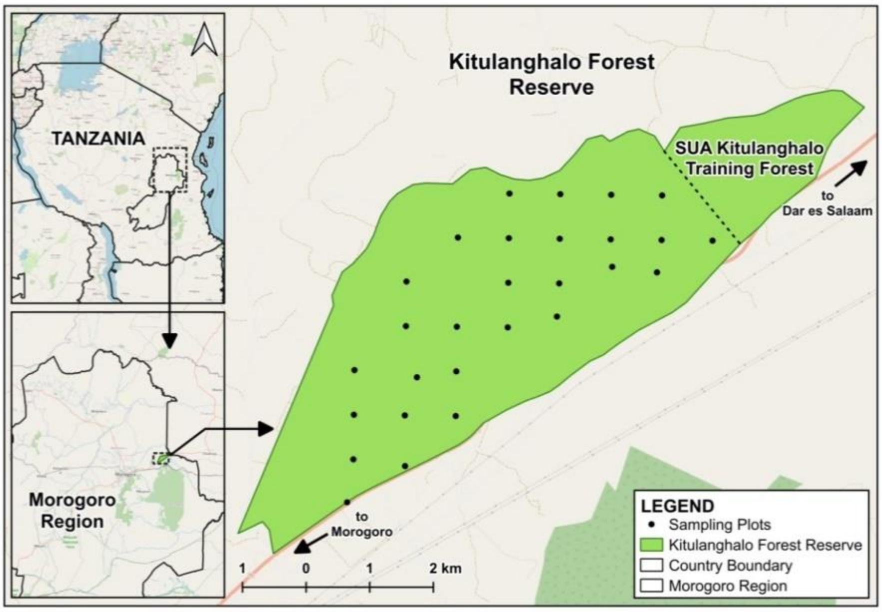
(Malimbwi *et al.*, 2000), 35 km Northeast of the Morogoro municipality, along the Morogoro-Dar es Salaam highway (Figure 1). It lies at an altitude between 350 m to 774 m above mean sea level. The average rainfall ranges between 700-900 $mmyr^{-1}$ (Lovett & Pocs, 1993). The dominant vegetation type is dry miombo woodland (60%) but also dry semi-evergreen forest occurs (Lovett & Pocs, 1993; Malimbwi *et al.*, 2000). The reserve is divided into two parts; one part is managed by the Tanzania Forest Services Agency (TFS) with a total area of 2,038 ha and the other part is managed by the Sokoine University of Agriculture (SUA) since 1995 with a total area of 600 ha (Malimbwi *et al.*, 2000; Obiri *et al.*, Lyimo & Shaaban, 2015). The current study focuses on the area managed by TFS. KCFR is surrounded by seven villages whose main economic activities range from small-scale farming to livestock keeping.

Figure 1. A map of Tanzania Showing the Location of the TFS-Kitulanghalo Catchment Forest Reserve in the Morogoro Region.



Data Collection

Forest inventory was conducted in February 2023. This study adopted a sampling intensity of 0.001% which is equivalent to 30 sample plots. This was arrived through the use of the formula (Malimbwi, 1997);

$$N = TA*Si/Ps \quad (1)$$

Where; N = number of sample plots, TA =total area of the forest (ha), Si = sampling intensity and Ps = plot size (ha)

A systematic sampling design was adopted (Malimbwi, 1997; Sharma, 2017), whereby the first plot was laid randomly followed by the next plot which was laid systematically at an interval of 800 m and 800 m between transects. QGIS software was used in the plot layout. This method was selected to ensure a fair representation of the area while minimising sample bias and guaranteeing a uniform coverage of the study area (Malimbwi, 1997). Concentric circular sample plots with four radiuses: 2m, 5m, 10m and 15m were used to collect plant data in the field (Chamshama *et al.*, 2004). This plot layout was adopted so as to ease the process of data collection and also to make a comparison between this study's findings with the previous studies done in the same study area (Chamshama *et al.*, 2004; MNRT 2015). The information that was recorded from each sample plot includes: Within a 2 m radius all seedlings with <1 cm diameter at breast height (Dbh) were counted and identified; Within a 5 m radius all saplings with > 1 cm Dbh but < 5 cm Dbh were identified and measured for Dbh;

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Within 10 m radius all young trees with ≥ 5cm Dbh but < 20 cm Dbh were identified and measured, and Within 15 m radius all adults trees with Dbh ≥ 20 cm were identified and measured for Dbh. Stumps were identified and measured for basal diameter and height in a 15 m radius plot. Other human activities/disturbances such as charcoal making, grazing, illegal logging, fire, and soil erosion were also recorded within the 15 m radius plot. The elevation and location of each plot (plot coordinates) were recorded using GPS (Garmin 76CSx) whereas the slope was measured using a Suunto clinometer. To ensure the validity and reliability of the collected data, all measurements were taken using acceptable methods and verifiable tools for vegetation surveys (Malimbwi, 1997). Furthermore, a botanist was employed to assist the authors with species identification in the field.

Data Analysis

Species richness was computed as the total number of species identified in the study area. Species diversity was computed using Shannon's Wienner Diversity Index (*H'*).

$$H' = -\Sigma Pi * \ln Pi \quad (2)$$

Where *Pi* is the importance value of a species as a proportion of all species, and ln is the natural logarithm.

The number of stems per hectare (N) from each individual was calculated through:

$$N = (n/ai) \quad (3)$$

Where ai = area of plot (ha), *n* = number of individual plants (count).

Basal area (m^2 ha^{-1}) was calculated from stem diameters for all woody individuals:

$$G = \sum\left(\frac{Gi}{n}\right) \quad (4)$$

Where G= Average basal area per hectare of the stand, *Gi*=basal area of the plot and *n* = number of sample plots.

The Importance Value Index (IVI) was computed as the sum of Relative frequency, Relative density and Relative basal area and expressed in percentage (Kent & Cooker, 1992).

Stand volume was estimated following Mauya *et al.*, (2014):

$$\text{Volume } (m^3 \text{ tree}^{-1}) = 0.00016 \times DBH^{2.46300}, \quad (5)$$

Aboveground and belowground biomass was estimated following Mugasha *et al.*, (2013):

$$\text{Aboveground biomass (kg tree}^{-1}) = 0.1027 \times DBH^{2.4798} \quad (6)$$

$$\text{Belowground biomass (kg tree}^{-1}) = 0.2113 \times DBH^{1.9838} \quad (7)$$

Estimation of volume and biomass which has been removed/lost due to human activities were conducted following Manyanda *et al.*, (2019):

$$\text{Volume removed } (m^3 \text{ tree}^{-1}) = 0.000032 \times SD^{2.7992} \quad (8)$$

Where: R^2= 0.709; MPE%=10.5; AIC=-90.16.

$$\text{Aboveground biomass lost (kg tree}^{-1}): = 0.03785 \times SD^{2.6700} \quad (9)$$

Where: R^2= 0.92; MPE %=-7.9; AIC=1541.1; SD is stump diameter (cm); DBH is the diameter at breast height (cm).

Carbon stock was estimated by multiplying biomass with a conversion factor of 0.50 (Mwakalukwa *et al*., 2024) and presented per hectare basis (Mg C ha^{-1}).

$$\text{Carbon stock} = \text{Biomass (Mg ha}^{-1}) \times 0.50. \quad (10)$$

Linear regression models were used to assess the effect of human activities on species diversity. Data were checked for normality and results revealed a normal distribution curve. Different models were tested by integrating a single factor and by combining different factors.

lm(formula = H ~ Charcoal making + Grazing + Fire + Soil erosion + Illegal logging + Charcoal * Grazing * Fire * Soil erosion * Illegal logging, data = D.data). (11)

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The model's performance was tested by AIC and the strongest model that explained the variables well was adopted. Data summarization was done using MS Excel Spreadsheet 2010 and analysed in R free software version 4.2.0 (R Core Team, 2024).

RESULTS AND DISCUSSION

Species Composition and Richness

A total of 1,013 individual tree and shrub species of all categories (regenerants with Dbh <1cm and large individuals with Dbh ≥1cm but ≤ 63cm) were identified in the TFS-Kitulaghalo catchment forest reserve (TFS-KCFR) (Table 1 & 2). These trees belong to 84 species, 60 genera and 26 plant families comparable to Obiri *et al*. (2010) using a sample size of 82 plots. About 68% of all species were trees with 19 plant families and shrubs were 32% of all species with 17 plant families. Fabaceae family had the highest number of species (31%) followed by the Combretaceae family (11%), Malvaceae family (7%) and Burseraceae Family (5%).

When large individuals (≥1cm Dbh) were considered separately, a total of 963 individuals which belongs to 80 species, 61 genera and 24 plant families were identified (Table 1). Fabaceae family had the highest number of species (33%), followed by the Combretaceae family (11%), and the Malvaceae family (7%). *Combretum zeyheri* was the most frequent species (43%) followed by *Julbernardia globiflora* (40%) and *Senegalia nigrescens* (40%). The 80 plant species identified in this study using 30 sample plots was higher compared to the value reported by Lyimo & Shaban (2015) of 71 species from SUA-KTF using 52 plots. However, the 80 species was lower than the value reported by Mwakalukwa *et al.* (2014) from dry miombo woodlands of Gangalamtumba Village Land Forest Reserve in Iringa, Tanzania who reported 88 species using 35 plots; Chamshama *et al*. (2004) who reported 120 species from three forest strata of TFS-KCFR, SUA-KTF and General land using 247 plots; Jew *et al.* (2016) from Kipembawe division in Chunya district who reported 122 species using 106 plots of 25m x 25m; and Banda *et al.* (2008) from Katavi-Rukwa ecosystem in Mpanda district who reported 229 species using 133 plots. The higher species richness reported by other studies could be due to more sampling effort compared to this study, fewer disturbances and the presence of various microhabitats which created favourable environments for many species to grow. The species richness of 80 found in this study is reasonably higher and hence deserves to be protected through strengthening the existing forest conservation initiatives to curb the ongoing disturbances in the forest.

For regenerants (<1cm Dbh), a total of 34 species which belong to 26 genera and 14 plant families were identified (Table 2). About 32% of them belong to the Fabaceae family followed by the Combretaceae family (15%), and the Sapindaceae family (9%). The most frequent species were *C. zeyheri* (17%), *Dichrostachys cinerea* (17%) and *J. globiflora* (10%). These 34 species were lower than that reported by Chamshama *et al*. (2004) who reported three values of 58 species from TFS-KCFR, 53 species from SUA-KTF and 44 species from General land. The reason for the low value could be due to the effects of disturbances which hinder the survival of many seedlings to older stages as shown in Table 4. Grazing activities have been shown to significantly lower plant diversity among other observed human disturbances. Dominant species reported by Chamshama *et al.* (2004) were different from those reported in this study i.e. *Julbernardia globiflora*, *Dichrostachys cinerea* and *Combretum molle*. This shows that *J. globiflora* is becoming a rare species in the forest perhaps due to illegal harvesting.

According to the species accumulation curve (Figure 2), the 30 sites/plots used in this study were sufficient to reflect the majority (but not all) of species diversity of the studied area. The graph has not yet reached its asymptotic level, but it is starting to converge at 30 sites/plots. This implies that any further increase in sample size would probably include any more rare species. The average species per plot was 8 (range: 0 - 14 species).

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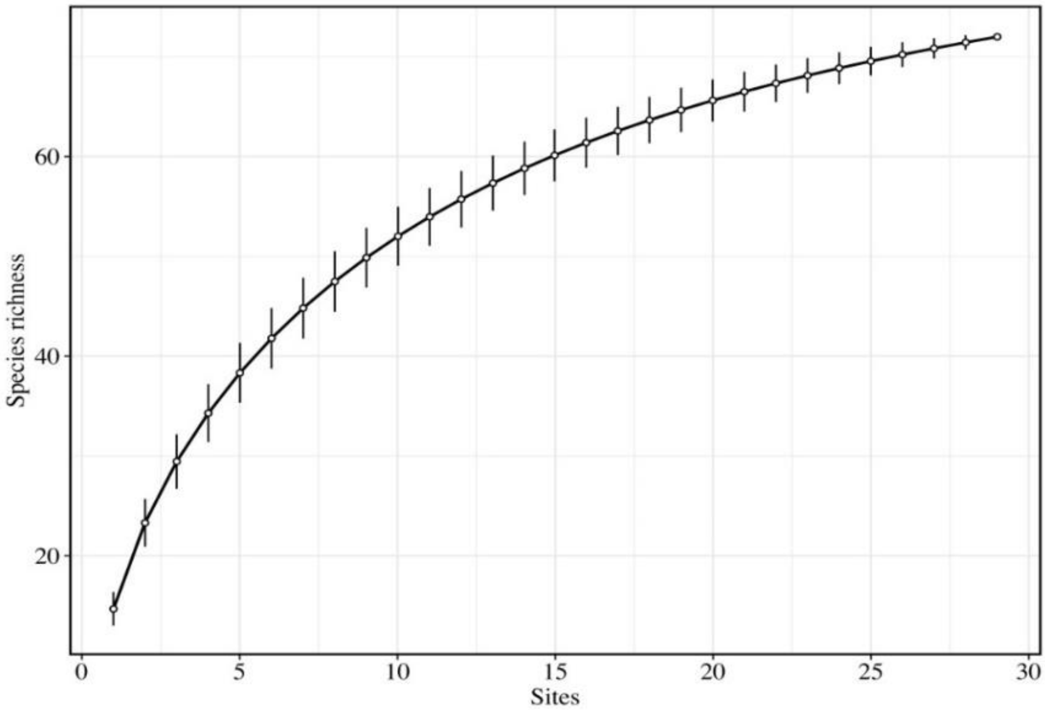
Figure 2. Species Accumulation Curve Showing the Distribution of Species per Sites in the TFS-Kitulaghalo Catchment Forest Reserve, Morogoro Region in Tanzania.



The results for harvested stems show that a total of 86 individuals (diameter range 3-39 cm, average of 16 cm), which belong to 21 species, 17 genera and 9 plant families were illegally harvested from TFS-KCFR (Table 3). About 57% of stumps were trees with 6 plant families and shrubs had 43% with 5 plant families. Fabaceae family had the highest number of species (52%) followed by the Combretaceae family (14%) and Anacardiaceae Family (5%). The 21 species reported in this study were higher than that reported by Lyimo & Shaaban (2015) from SUA-KTF who reported 16 species equivalent to 12.79 stems ha^{-1} and volume removed of 0.58 m^3ha^{-1}. Unlike this study in which the 21 species were equivalent to 41 ± 26 stems ha^{-1} and volume removed of 5.94 ± 4.47 m^3ha^{-1} (Table 3). This shows that there is a higher rate of illegal harvesting of trees in TFS-KCFR than in SUA-KTF hence threatening the existence of biodiversity found in this forest.

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Table 1. Species Diversity and Structural Attributes of Individuals with Dbh ≥ 1cm Sorted by IVI Found in TFS-Kitulaghalo Catchment Forest Reserve, Tanzania.

NO	Species name	Plant Family	Habit	*H'*	Frequency	Stem Density (Stems ha^{-1})	Basal area (m^{2}ha^{-1})	Rel. freq	Rel. density	Rel. basal area	IVI	Volume (m^{3}ha^{-1})	AGC (MgCha^{-1})	BGC (MgC ha^{-1})
1	*Combretum zeyheri* Sond.	Combretaceae	Tree	0.19	43	166±50	0.32±0.12	5.1	6.6	6.0	17.7	1.64±0.67	0.54±0.22	0.41±0.16
2	*Senegalia nigrescens* (Oliv.) P.J.H.Hurter	Fabaceae	Tree	0.13	37	66±22	0.63±0.19	4.3	3.1	8.1	15.6	5.90±1.90	2.00±0.65	0.88±0.25
3	*Julbernardia globiflora* (Benth.) Troupin	Fabaceae	Tree	0.15	40	64±20	0.71±0.41	4.7	2.6	5.6	12.9	6.65±4.55	2.26±1.55	0.91±0.53
4	*Combretum apiculatum* Sond.	Combretaceae	Tree	0.16	33	81±30	0.33±0.13	4.0	4.6	4.0	12.5	1.92±0.79	0.64±0.26	0.42±0.16
5	*Dombeya rotundifolia* (Hochst.) Planch.	Malvaceae	Shrub	0.15	33	74±30	0.28±0.11	4.0	4.3	4.2	12.4	1.55±0.62	0.52±0.21	0.36±0.14
6	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	Shrub	0.13	33	140±60	0.14±0.06	4.0	5.1	1.9	10.9	0.55±0.24	0.18±0.08	0.18±0.08
7	*Diplorhynchus condylocarpon* (Müll.Arg.) Pichon	Apocynaceae	Shrub	0.14	27	79±36	0.35±0.14	3.2	2.7	4.4	10.2	2.23±0.88	0.75±0.29	0.46±0.18
8	*Pterocarpus rotundifolius* (Sond.) Druce	Fabaceae	Shrub	0.15	20	94±44	0.18±0.09	2.4	4.2	3.2	9.7	0.84±0.43	0.28±0.14	0.23±0.11
9	*Grewia similis* K.Schum.	Malvaceae	Shrub	0.15	23	137±77	0.17±0.07	2.8	3.8	2.8	9.4	0.78±0.31	0.26±0.10	0.23±0.09
10	*Vachellia robusta* (Burch.) Kyal. & Boatwr.	Fabaceae	Tree	0.09	20	27±12	0.46±0.23	2.4	1.5	5.3	9.1	3.90±1.96	1.32±0.66	0.59±0.29
11	*Allophylus rubifolius* (Hochst. ex A.Rich.) Engl.	Sapindaceae	Shrub	0.11	20	121±58	0.09±0.06	2.4	4.9	1.2	8.5	0.33±0.23	0.11±0.08	0.12±0.08
12	*Dalbergia melanoxylon* Guill. & Perr.	Fabaceae	Tree	0.08	27	46±18	0.12±0.06	3.2	1.9	1.6	6.7	0.70±0.39	0.23±0.13	0.15±0.07
13	*Senegalia goetzei* (Harms) Kyal. & Boatwr.	Fabaceae	Tree	0.09	20	46±24	0.14±0.07	2.4	1.8	2.1	6.3	0.48±0.27	0.16±0.09	0.11±0.05
14	*Combretum collinum* Fresen.	Combretaceae	Tree	0.13	13	97±87	0.15±0.11	1.6	2.5	2.1	6.1	0.72±0.53	0.24±0.18	0.19±0.14
15	*Drypetes gerrardii* Hutch.	Putranjivaceae	Tree	0.06	13	26±13	0.18±0.12	1.6	2.4	2.0	6.0	1.26±0.89	0.42±0.30	0.23±0.15
16	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	Shrub	0.07	20	58±30	0.05±0.03	2.4	2.8	0.7	5.9	0.18±0.10	0.06±0.03	0.06±0.03
17	*Sterculia africana* (Lour.) Fiori	Malvaceae	Tree	0.04	7	15±14	0.29±0.20	0.8	1.8	3.4	5.9	3.28±2.31	1.12±0.79	0.37±0.26
18	*Spirostachys africana* Sond.	Euphorbiaceae	Shrub	0.09	13	64±34	0.14±0.07	1.6	2.2	2.1	5.8	0.74±0.39	0.25±0.13	0.18±0.09
19	*Terminalia mollis* M.A.Lawson	Combretaceae	Tree	0.09	10	52±44	0.16±0.10	1.2	1.4	3.2	5.8	0.91±0.53	0.30±0.18	0.21±0.12
20	*Vachellia tortilis* (Forssk.) Galasso & Banfi	Fabaceae	Shrub	0.06	17	13±9	0.15±0.10	2.0	1.2	2.3	5.5	1.03±0.67	0.35±0.22	0.20±0.13

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NO	Species name	Plant Family	Habit	*H'*	Frequency	Stem Density (Stems ha^{-1})	Basal area (m^2ha^{-1})	Rel. freq	Rel. density	Rel. basal area	IVI	Volume (m^3ha^{-1})	AGC ($MgCha^{-1}$)	BGC ($MgC\ ha^{-1}$)
21	*Croton sylvaticus* Hochst.	Euphorbiaceae	Tree	0.07	7	65±49	0.03±0.02	0.8	3.5	1.1	5.4	0.10±0.07	0.03±0.02	0.04±0.03
22	*Ricinodendron heudelotii* (Baill.) Heckel	Euphorbiaceae	Tree	0.01	7	1±1	0.20±0.15	0.8	0.2	4.2	5.2	2.62±2.08	0.90±0.72	0.25±0.19
23	*Scorodophloeus fischeri* (Taub.) J.Léonard	Fabaceae	Tree	0.05	7	11±8	0.16±0.11	0.8	2.5	1.5	4.8	1.17±0.82	0.39±0.27	0.21±0.15
24	*Trema orientale* (L.) Blume	Cannabaceae	Shrub	0.03	3	10±10	0.04±0.04	0.4	3.0	1.4	4.8	0.25±0.25	0.08±0.08	0.05±0.05
25	*Albizia petersiana* (Bolle) Oliv.	Fabaceae	Tree	0.15	3	176±176	0.11±0.11	0.4	2.9	1.2	4.5	0.41±0.41	0.13±0.13	0.15±0.15
26	*Cassia abbreviata* Oliv.	Fabaceae	Tree	0.06	17	33±17	0.08±0.04	2.0	1.3	1.1	4.3	0.54±0.26	0.18±0.09	0.11±0.05
27	*Lannea welwitschii* (Hiern) Engl.	Anacardiaceae	Tree	0.03	10	4±3	0.21±0.13	1.2	0.6	2.0	3.7	2.08±1.29	0.71±0.44	0.27±0.16
28	*Pteleopsis myrtifolia* (M.A.Laws on) Engl. & Diels	Combretaceae	Tree	0.05	7	31±22	0.07±0.05	0.8	1.4	1.2	3.5	0.33±0.24	0.11±0.08	0.09±0.06
29	*Brachystegia boehmii* Taub.	Fabaceae	tree	0.04	13	6±3	0.14±0.10	1.6	0.3	1.2	3.1	1.21±0.96	0.41±0.33	0.18±0.13
30	*Margaritaria discoidea* var. nitida (Pax) Radcl.-Sm.	Phyllanthaceae	Shrub	0.03	17	15±7	0.02±0.01	2.0	0.8	0.3	3.0	0.08±0.04	0.03±0.01	0.03±0.01
31	*Lannea schimperi* (Hochst. ex A.Rich.) Engl.	Anacardiaceae	Tree	0.02	13	4±2	0.07±0.03	1.6	0.3	1.1	2.9	0.48±0.25	0.16±0.08	0.09±0.04
32	*Commiphora africana* (A.Rich.) Engl.	Burseraceae	Tree	0.03	13	16±10	0.05±0.03	1.6	0.6	0.7	2.8	0.34±0.25	0.11±0.08	0.06±0.04
33	*Erythroxylum emarginatum* Thonn.	Erythroxylaceae	Shrub	0.04	10	20±17	0.02±0.01	1.2	1.4	0.3	2.8	0.09±0.06	0.03±0.02	0.02±0.01
34	*Albizia harveyi* E.Fourn.	Fabaceae	Tree	0.05	10	24±15	0.03±0.03	1.2	0.9	0.6	2.7	0.14±0.12	0.05±0.04	0.04±0.03
35	*Combretum schumanii* Engl.	Combretaceae	Shrub	0.02	7	4±3	0.10±0.07	0.8	1.1	0.8	2.7	0.96±0.78	0.33±0.27	0.12±0.09
36	*Bridelia cathartica* Bertol.	Phyllanthaceae	Shrub	0.03	10	25±14	0.03±0.01	1.2	1.0	0.4	2.6	0.10±0.05	0.03±0.02	0.03±0.02
37	*Lecaniodiscus fraxinifolius* Baker	Sapindaceae	Tree	0.02	7	6±5	0.06±0.04	0.8	1.1	0.6	2.5	0.51±0.36	0.17±0.12	0.08±0.06
38	*Dobera loranthifolia* (Warb.) Harms	Salvadoraceae	Tree	0.02	7	2±2	0.11±0.08	0.8	0.3	1.3	2.4	1.06±0.79	0.36±0.27	0.15±0.10
39	*Celtis philippensis* Blanco	Cannabaceae	Tree	0.02	3	17±17	0.01±0.01	0.4	1.9	0.1	2.3	0.03±0.03	0.01±0.01	0.01±0.01
40	*Milletia usaramensis* subsp. Usaramensis	Fabaceae	Tree	0.02	10	10±6	0.01±0.01	1.2	0.8	0.2	2.2	0.05±0.04	0.02±0.01	0.01±0.01
41	*Combretum molle* R.Br. ex G.Don	Combretaceae	Tree	0.03	10	13±10	0.03±0.02	1.2	0.5	0.4	2.1	0.14±0.08	0.05±0.03	0.04±0.02
42	*Philenoptera eriocalyx* (Harms) Schrire	Fabaceae	Shrub	0.03	10	6±4	0.05±0.03	1.2	0.3	0.5	2.0	0.33±0.23	0.11±0.08	0.07±0.04
43	*Tamarindus indica* L.	Fabaceae	Tree	0.01	7	1±1	0.08±0.07	0.8	0.1	0.9	1.8	0.92±0.80	0.31±0.27	0.11±0.09

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NO	Species name	Plant Family	Habit	*H'*	Frequency	Stem Density (Stems ha^{-1})	Basal area (m^{2}ha^{-1})	Rel. freq	Rel. density	Rel. basal area	IVI	Volume (m^{3}ha^{-1})	AGC (MgCha^{-1})	BGC (MgC ha^{-1})
44	*Vitex payos* (Lour.) Merr.	Lamiaceae	Tree	0.03	3	25±25	0.02±0.02	0.4	0.9	0.5	1.8	0.06±0.06	0.02±0.02	0.02±0.02
45	*Albizia anthelmintica* (A.Rich.) Brongn.	Fabaceae	Tree	0.04	7	21±15	0.03±0.02	0.8	0.5	0.4	1.7	0.13±0.10	0.04±0.03	0.04±0.03
46	*Brachystegia bussei* Harms	Fabaceae	Tree	0.04	3	18±18	0.05±0.05	0.4	0.6	0.7	1.7	0.27±0.27	0.09±0.09	0.06±0.06
47	*Sclerocarya birrea* (A.Rich.) Hochst.	Anacardiaceae	Tree	0.02	7	1±1	0.11±0.08	0.8	0.1	0.8	1.7	1.08±0.80	0.37±0.27	0.14±0.10
48	*Uvariodendron* sp.	Annonaceae	Shrub	0.02	7	13±9	0.00±0.00	0.8	0.7	0.2	1.7	0.01±0.01	0.00±0.00	0.01±0.00
49	*Commiphora zimmermannii* Engl.	Burseraceae	Tree	0.01	7	2±1	0.04±0.03	0.8	0.3	0.5	1.6	0.36±0.25	0.12±0.08	0.06±0.04
50	*Erythrophleum africanum* (Benth.) Harms	Fabaceae	Tree	0.04	3	8±8	0.09±0.09	0.4	0.4	0.9	1.6	0.66±0.66	0.22±0.22	0.11±0.11
51	*Senegalia polyacantha* (Willd.) Seigler & Ebinger	Fabaceae	Tree	0.02	7	4±4	0.02±0.02	0.8	0.3	0.5	1.6	0.09±0.09	0.03±0.03	0.02±0.02
52	*Terminalia sambesiaca* Engl. & Diels	Combretaceae	Tree	0.01	7	2±1	0.03±0.02	0.8	0.5	0.3	1.6	0.20±0.17	0.07±0.06	0.04±0.03
53	*Ximenia caffra* Sond.	Olacaceae	Shrub	0.02	7	6±5	0.02±0.02	0.8	0.4	0.3	1.6	0.10±0.09	0.03±0.03	0.02±0.02
54	*Carpodiptera africana* Mast.	Malvaceae	Tree	0.02	7	3±2	0.04±0.03	0.8	0.4	0.3	1.5	0.30±0.26	0.10±0.09	0.05±0.04
55	*Combretum fragrans* F.Hoffm.	Combretaceae	Tree	0.02	7	7±6	0.03±0.02	0.8	0.3	0.4	1.5	0.15±0.13	0.05±0.04	0.03±0.03
56	*Commiphora eminii* Engl.	*Burseraceae*	Tree	0.01	7	2±1	0.01±0.01	0.8	0.2	0.5	1.5	0.05±0.04	0.02±0.01	0.01±0.01
57	*Markhamia obtusifolia* (Baker) Sprague	Bignoniaceae	Tree	0.01	7	5±4	0.02±0.02	0.8	0.3	0.4	1.5	0.14±0.12	0.05±0.04	0.03±0.02
58	*Philenoptera bussei* (Harms) Schrire	Fabaceae	Tree	0.02	7	11±9	0.02±0.01	0.8	0.5	0.3	1.5	0.07±0.05	0.02±0.02	0.02±0.01
59	*Sterculia appendiculata* K.Schum.	Malvaceae	Tree	0.01	3	0±0	0.08±0.08	0.4	0.1	0.8	1.4	0.93±0.93	0.32±0.32	0.10±0.10
60	*Dalbergia obovata* E.Mey.	Fabaceae	Shrub	0.03	3	25±25	0.01±0.01	0.4	0.8	0.1	1.3	0.02±0.02	0.01±0.01	0.01±0.01
61	*Ehretia cymosa* Thonn.	Boraginaceae	Shrub	0.02	3	17±17	0.00±0.00	0.4	0.8	0.1	1.3	0.02±0.02	0.01±0.01	0.01±0.01
62	*Boscia salicifolia* Oliv.	Capparaceae	Shrub	0.01	7	2±1	0.01±0.01	0.8	0.2	0.1	1.1	0.05±0.03	0.02±0.01	0.01±0.01
63	*Brachystegia microphylla* Harms	Fabaceae	Tree	0.01	3	5±5	0.01±0.01	0.4	0.4	0.3	1.1	0.04±0.04	0.01±0.01	0.01±0.01
64	*Diospyros mespiliformis* Hochst. ex A.DC.	Ebenaceae	Tree	0.02	3	9±8	0.03±0.02	0.4	0.4	0.3	1.1	0.18±0.15	0.06±0.05	0.03±0.02
65	*Cordia africana* Lam.	Boraginaceae	Tree	0.01	3	2±2	0.04±0.04	0.4	0.3	0.3	1.0	0.31±0.31	0.11±0.11	0.05±0.05
66	*Zanthoxylum chalybeum* var. molle Kokwaro	Rutaceae	Tree	0.02	3	7±7	0.01±0.01	0.4	0.4	0.2	1.0	0.07±0.07	0.02±0.02	0.02±0.02

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NO	Species name	Plant Family	Habit	*H'*	Frequency	Stem Density (Stems ha^{-1})	Basal area (m^{2}ha^{-1})	Rel. freq	Rel. density	Rel. basal area	IVI	Volume (m^{3}ha^{-1})	AGC (MgCha^{-1})	BGC (MgC ha^{-1})
67	*Commiphora zanzibarica* (Baill.) Engl.	Burseraceae	Tree	0.02	3	3±3	0.01±0.01	0.4	0.4	0.1	0.9	0.07±0.07	0.02±0.02	0.02±0.02
68	*Senna singueana* (Delile) Lock	Fabaceae	Tree	0.01	3	8±8	0.01±0.01	0.4	0.4	0.1	0.9	0.04±0.04	0.01±0.01	0.01±0.01
69	*Sterculia quinqueloba* (Garcke) K.Schum.	Malvaceae	Tree	0.01	3	0±0	0.05±0.05	0.4	0.0	0.5	0.9	0.54±0.54	0.18±0.18	0.06±0.06
70	*Flueggea virosa* (Roxb. ex Willd.) Royle	Phyllanthaceae	Shrub	0.01	3	4±4	0.00±0.00	0.4	0.3	0.1	0.8	0.01±0.01	0.00±0.00	0.00±0.00
71	*Pseudolachnostylis maprouneifolia* Pax	Phyllanthaceae	Tree	0.01	3	8±8	0.00±0.00	0.4	0.3	0.1	0.8	0.01±0.01	0.00±0.00	0.01±0.01
72	*Thylachium africanum*	Capparaceae	Shrub	0.01	3	1±1	0.02±0.02	0.4	0.1	0.3	0.7	0.11±0.11	0.04±0.04	0.02±0.02
73	*Albizia zimmermannii* Harms	Fabaceae	Tree	0.01	3	0±0	0.02±0.02	0.4	0.1	0.1	0.6	0.18±0.18	0.06±0.06	0.03±0.03
74	*Diospyros consolatae* Chiov.	Ebenaceae	Shrub	0.01	3	0±0	0.01±0.01	0.4	0.1	0.1	0.6	0.12±0.12	0.04±0.04	0.02±0.02
75	*Haplocoelum inoploeum* Radlk.	Sapindaceae	Shrub	0.01	3	0±0	0.01±0.01	0.4	0.1	0.1	0.6	0.12±0.12	0.04±0.04	0.02±0.02
76	*Holarrhena febrifuga* Klotzsch	Apocynaceae	Tree	0.01	3	1±1	0.00±0.00	0.4	0.1	0.0	0.6	0.02±0.02	0.01±0.01	0.01±0.01
77	*Manilkara sulcata* (Engl.) Dubard	Sapotaceae	Tree	0.01	3	1±1	0.01±0.01	0.4	0.1	0.0	0.6	0.03±0.03	0.01±0.01	0.01±0.01
78	*Ziziphus mucronata* Willd.	Rhamnaceae	Tree	0.01	3	4±4	0.00±0.00	0.4	0.1	0.0	0.6	0.00±0.00	0.00±0.00	0.00±0.00
79	*Senegalia senegal* (L.) Britton	Fabaceae	Shrub	0.01	3	0±0	0.02±0.02	0.4	0.0	0.1	0.5	0.15±0.15	0.05±0.05	0.02±0.02
80	*Zanha africana* (Radlk.) Exell	Sapindaceae	Tree	0.01	3	1±1	0.00±0.00	0.4	0.0	0.0	0.5	0.01±0.01	0.00±0.00	0.00±0.00
	Grand Total			**3.73**	**843**	**2199±1325**	**7.61±4.47**	**100**	**100**	**100**	**300**	**56.25±35.03**	**18.97±11.84**	**9.81±5.71**

Note. AGC is above-ground carbon, BGC is below-ground carbon and IVI is the Importance Value Index.

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Table 2: Species Diversity, Richness and Structural Attributes of Regenerants (Dbh < 1cm) Sorted by Stem Density Found in TFS-Kitulaghalo Catchment Forest Reserve, Tanzania.

No.	Species name	Plant family	Habit	*H'*	Frequency	Stem density (Stems ha^{-1})
1	*Scorodophloeus fischeri* (Taub.) J.Léonard	Fabaceae	Tree	0.17	10	1459±1083
2	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	Shrub	0.23	17	690±359
3	*Erythroxylum emarginatum* Thonn.	Erythroxylaceae	Shrub	0.08	3	531±531
4	*Combretum zeyheri* Sond.	Combretaceae	Tree	0.23	17	371±186
5	*Allophylus rubifolius* (Hochst. ex A.Rich.) Engl.	Sapindaceae	Shrub	0.08	3	159±159
6	*Croton sylvaticus* Hochst.	Euphorbiaceae	Tree	0.08	3	159±159
7	*Albizia petersiana* (Bolle) Oliv.	Fabaceae	Tree	0.08	3	133±133
8	*Brachystegia bussei* Harms	Fabaceae	Tree	0.08	3	133±133
9	*Dombeya rotundifolia* (Hochst.) Planch.	Malvaceae	Shrub	0.13	7	133±94
10	*Julbernardia globiflora* (Benth.) Troupin	Fabaceae	Tree	0.17	10	133±86
11	*Combretum collinum* Fresen.	Combretaceae	Tree	0.08	3	106±106
12	*Diospyros mespiliformis* Hochst. ex A.DC.	Ebenaceae	Tree	0.08	3	106±106
13	*Ouratea warneckei* Gilg ex Engl.	Ochnaceae	Shrub	0.08	3	106±106
14	*Terminalia sambesiaca* Engl. & Diels	Combretaceae	Tree	0.08	3	106±106
15	*Brachystegia boehmii* Taub.	Fabaceae	Tree	0.13	7	106±83
16	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	Shrub	0.13	7	106±83
17	*Combretum fragrans* F.Hoffm.	Combretaceae	Tree	0.08	3	80±80
18	*Combretum molle* R.Br. ex G.Don	Combretaceae	Tree	0.08	3	80±80
19	*Lecaniodiscus fraxinifolius* Baker	Sapindaceae	Tree	0.08	3	80±80
20	*Pterocarpus rotundifolius* (Sond.) Druce	Fabaceae	Shrub	0.08	3	80±80
21	*Vepris nobilis* (Delile) Mziray	Rutaceae	Tree	0.08	3	80±80
22	*Melia azedarach* L.	Meliaceae	Tree	0.08	3	53±53
23	*Milletia usaramensis* subsp. Usaramensis	Fabaceae	Tree	0.08	3	53±53
24	*Lannea schimperi* (Hochst. ex A.Rich.) Engl.	Anacardiaceae	Tree	0.13	7	53±37
25	*Albizia anthelmintica* (A.Rich.) Brongn.	Fabaceae	Tree	0.08	3	27±27
26	*Albizia harveyi* E.Fourn.	Fabaceae	Tree	0.08	3	27±27

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No.	Species name	Plant family	Habit	*H'*	Frequency	Stem density (Stems ha^{-1})
27	*Carpodiptera africana* Mast.	Malvaceae	Tree	0.08	3	27±27
28	*Commiphora africana* (A.Rich.) Engl.	Burseraceae	Tree	0.08	3	27±27
29	*Commiphora eminii* Engl.	Burseraceae	Tree	0.08	3	27±27
30	*Dalbergia melanoxylon* Guill. & Perr.	Fabaceae	Tree	0.08	3	27±27
31	*Dobera loranthifolia* (Warb.) Harms	Salvadoraceae	Tree	0.08	3	27±27
32	*Haplocoelum inoploeum* Radlk.	Sapindaceae	Shrub	0.08	3	27±27
33	*Lannea welwitschii* (Hiern) Engl.	Anacardiaceae	Tree	0.08	3	27±27
34	*Turraea robusta* Gürke	Meliaceae	Shrub	0.08	3	27±27
	Grand Total			**3.35**	**167**	**5,358±4,319**

Table 3: Species Diversity, Richness and Structural Attributes of Harvested Stems (diameter ≥3 cm and <40 cm with Mean Diameter of 16 cm) Sorted by IVI Found in TFS-Kitulaghalo Catchment Forest Reserve, Tanzania.

No	Species name	Plant family	Habit	*H'*	Frequency	Stem Density (stems ha^{-1})	Basal area (m^{2}ha^{-1})	Rel. freq	Rel. density	Rel. basal area	IVI	Stumps volume (m^{3}ha^{-1})	Volume removed (m^{3}ha^{-1})	AGC lost (MgCha^{-1})
1	*Julbernardia globiflora* (Benth.) Troupin	Fabaceae	Tree	0.37	23	13±6	0.28±0.12	17.5	27.4	27.0	71.9	0.08±0.03	1.17±0.52	0.48±0.21
2	*Vachellia robusta* (Burch.) Kyal. & Boatwr.	Fabaceae	Tree	0.14	13	2±1	0.14±0.07	10	12.9	17.4	40.2	0.04±0.02	0.90±0.47	0.34±0.18
3	*Spirostachys africana* Sond.	Euphorbiaceae	Shrub	0.32	13	8±4	0.16±0.10	10	14.3	10.8	35.1	0.06±0.04	0.71±0.48	0.28±0.19
4	*Dombeya rotundifolia* (Hochst.) Planch.	Malvaceae	Shrub	0.20	17	3±1	0.01±0.01	12.5	8.4	1.5	22.4	0.00±0.00	0.02±0.01	0.01±0.01
5	*Vachellia tortilis* (Forssk.) Galasso & Banfi	Fabaceae	Shrub	0.12	7	1±1	0.05±0.03	5	7.1	9.4	21.6	0.02±0.02	0.25±0.18	0.10±0.07
6	*Scorodophloeus fischeri* (Taub.) J.Léonard	Fabaceae	Tree	0.12	3	1±1	0.08±0.08	2.5	4.8	4.8	12.0	0.03±0.03	0.47±0.47	0.18±0.18
7	*Combretum apiculatum* Sond.	Combretaceae	Tree	0.14	7	2±1	0.01±0.01	5	4.0	2.4	11.4	0.00±0.00	0.03±0.02	0.01±0.01
8	*Senegalia nigrescens* (Oliv.) P.J.H.Hurter	Fabaceae	Tree	0.09	7	1±1	0.07±0.06	5	1.3	3.2	9.5	0.05±0.04	0.49±0.42	0.18±0.15
9	*Dobera loranthifolia* (Warb.) Harms	Salvadoraceae	Tree	0.05	3	0±0	0.05±0.04	2.5	1.6	4.5	8.6	0.01±0.01	0.30±0.30	0.11±0.11
10	*Combretum schumanii* Engl.	Combretaceae	Shrub	0.12	3	1±1	0.04±0.04	2.5	3.6	2.3	8.4	0.01±0.01	0.17±0.17	0.07±0.07
11	*Pseudolachnostylis maprouneifolia* Pax	Phyllanthaceae	Tree	0.05	3	0±0	0.05±0.05	2.5	1.6	3.6	7.7	0.02±0.02	0.41±0.41	0.15±0.15
12	*Diplorhynchus condylocarpon* (Müll.Arg.) Pichon	Apocynaceae	Shrub	0.05	3	0±0	0.05±0.05	2.5	1.6	3.2	7.3	0.01±0.01	0.40±0.40	0.15±0.15
13	*Brachystegia bussei* Harms	Fabaceae	Tree	0.09	3	1±1	0.02±0.02	2.5	3.2	1.5	7.2	0.01±0.01	0.10±0.10	0.04±0.04
14	*Lannea welwitschii* (Hiern) Engl.	Anacardiaceae	Tree	0.05	3	0±0	0.04±0.04	2.5	1.2	2.4	6.1	0.02±0.02	0.25±0.25	0.09±0.09

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No	Species name	Plant family	Habit	*H'*	Frequency	Stem Density (stems ha^{-1})	Basal area (m^{2}ha^{-1})	Rel. freq	Rel. density	Rel. basal area	IVI	Stumps volume (m^{3}ha^{-1})	Volume removed (m^{3}ha^{-1})	AGC lost (MgCha^{-1})
15	*Senegalia senegal* (L.) Britton	Fabaceae	Shrub	0.05	3	0±0	0.03±0.03	2.5	0.5	3.0	6.0	0.01±0.01	0.19±0.19	0.07±0.07
16	*Pterocarpus rotundifolius* (Sond.) Druce	Fabaceae	Shrub	0.09	3	1±1	0.01±0.01	2.5	1.9	0.9	5.3	0.00±0.00	0.02±0.02	0.01±0.01
17	*Combretum zeyheri* Sond.	Combretaceae	Tree	0.05	3	0±0	0.01±0.01	2.5	1.6	0.8	4.9	0.00±0.00	0.05±0.05	0.02±0.02
18	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	Shrub	0.05	3	0±0	0.00±0.00	2.5	0.8	0.7	4.0	0.00±0.00	0.01±0.01	0.00±0.00
19	*Philenoptera eriocalyx* (Harms) Schrire	Fabaceae	Shrub	0.09	3	1±1	0.00±0.00	2.5	1.1	0.3	3.8	0.00±0.00	0.01±0.01	0.00±0.00
20	*Zanha africana* (Radlk.) Exell	Sapindaceae	Tree	0.05	3	0±0	0.00±0.00	2.5	0.8	0.3	3.6	0.00±0.00	0.00±0.00	0.00±0.00
21	*Brachystegia boehmii* Taub.	Fabaceae	Tree	0.05	3	0±0	0.00±0.00	2.5	0.5	0.0	3.1	0.00±0.00	0.00±0.00	0.00±0.00
	Grand Total			**2.34**	**133**	**41±26**	**1.11±0.79**	**100**	**100**	**100**	**300**	**0.38±0.28**	**5.94±4.47**	**2.30±1.72**

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Species Diversity

The Shannon-Wiener diversity indices (*H'*) for large individuals (Dbh ≥1cm) and small individuals (Dbh <1cm) were 3.73 (Table 1) and 3.35 (Table 2) respectively. The *H'*value of 3.75 obtained in this study was higher than those reported by Chamshama *et al.* (2004) who reported the *H`* value of 3.2 from TFS-KCFR, 3.2 from SUA-KTF and 3.1 from General land and Mwakalukwa *et al.* (2014) who reported a *H'* value of 3.44. However, the *H'*value of 3.75 was lower than that of Gilliba *et al.* (2011) who reported an *H'* value of 4.27 from dry miombo woodlands of the Bereku forest reserve in Tanzania. According to Magurran (2004), *H´* values typically range from 1.5 to 4.5 but not exceed 5. A threshold value of 2 is considered the minimum value at which an ecosystem can be classified as moderately to highly diverse (Kent, 2012; Mwakalukwa *et al*., 2014). Therefore, the value of 3.75 found in this study implies that the TFS-KCFR has high species diversity.

The IVI for large individuals shows that *Combretum zeyheri* (17.7), *Senegalia nigrescens* (15.6), and *Julbernardia globiflora* (12.9) were the most important species in the TFS-KCFR (Table 1). Different patterns were observed by Chamshama *et al.* (2004) in which *J. globiflora* was dominant (44) followed by *Combretum molle* (32), and *Combretum adonogonium* (19). This shows that some species have been over-harvested to the extent of affecting their dominance and they are now being replaced by uncommon species. For harvested species, the *H'* value was 2.34 (Table 3). *J.globiflora* contributed higher (0.37) followed by *Spirostachys africana* (0.32), and *Dombeya rotundifolia* (0.20).

Stem Density

The total mean stem density of large individuals was 2 199 ± 1 325 $stemha^{-1}$ (Table 1). The density distribution by diameter classes shows an inverted 'J' shape which is common for natural forests with active regeneration (Figure 3). The 2 199 ± 1 325 $stemha^{-1}$ reported in this study was higher than those reported by Chamshama *et al.* (2004) who reported three values of 1 085 ± 115 $stemsha^{-1}$ from TFS-KCFR, 1 027 ± 88 $stemsha^{-1}$ from SU-TFR, and 1 495 ± 208 $stemsha^{-1}$ from general land; Lyimo & Shaban (2015) who reported 995 ± 256 $stemha^{-1}$ from SUA-KTF; Gilliba *et al*. (2011) who reported 616 ± 46 $stemsha^{-1}$ and Mwakalukwa *et al.* (2014) who reported 1 521 ± 594 $stemha^{-1}$. The value of 2 199 ± 1 325 $stemha^{-1}$ reported in this study falls outside the range of stem densities commonly found in the dry miombo woodlands (Mwakalukwa *et al*., 2014). This indicates that despite the anthropogenic activities taking place in the reserve, TFS-KCFR is still fairly stocked.

With regards to regenerants, the mean stem density of 5 358 ± 4 319 $stemha^{-1}$ reported in this study (Table 2) was lower than that reported by Lyimo & Shaban (2015) who reported a value 6 121 ± 2 777 $stemha^{-1}$ from SUA-KTF and Chamshama *et al*. (2004) who reported three values of 10 337 $stemha^{-1}$ from TFS-KCFR, 11 671 $stemha^{-1}$ from SUA-KTF and 16 919 $stemha^{-1}$ from general land. The low number of regenerants recorded in this study could be due to the high rate of disturbances occurring in the reserve which reduces the chances for the newly emerged seedlings to survive and grow to older life stages.

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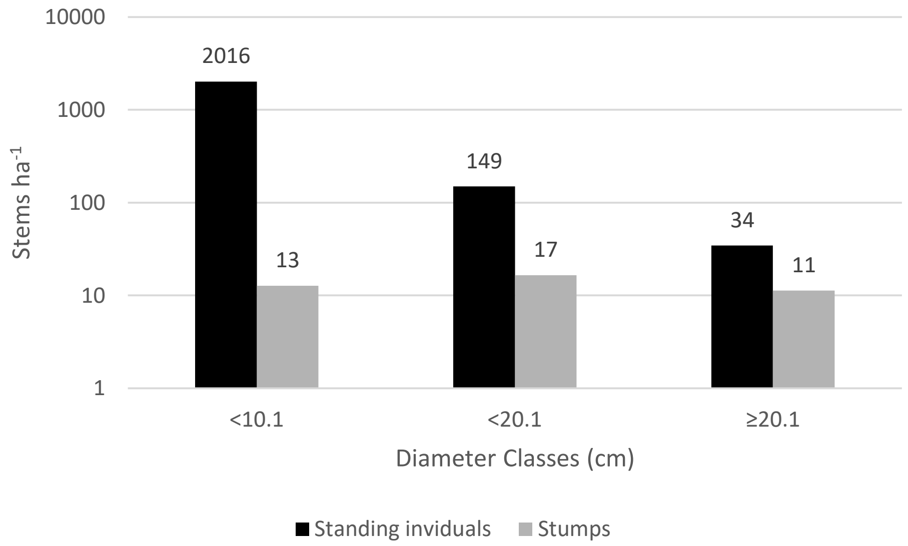
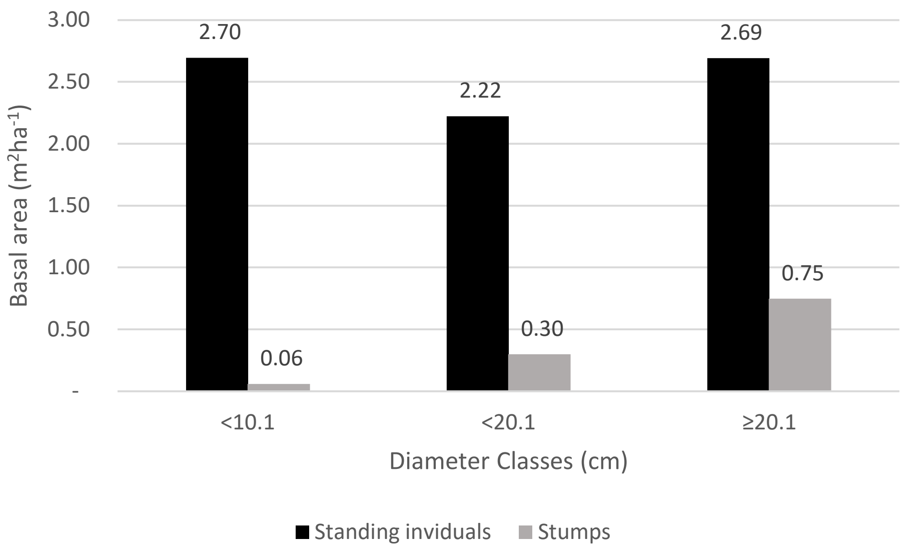
Figure 3. The density of Standing Trees ≥1 cm Dbh and Stumps ≥1 cm by Diameter Classes in TFS-Kitulangalo Catchment Forest Reserve, Tanzania (n = 30). NB: Logarithmic Ccale on Vertical Axis.



Basal Area

The mean basal area for large individuals was 7.61 ± 4.47 m^2ha^{-1} in which *J. globiflora* contributed the most (9.33%) (Table 1). This value is lower than values reported by Chamshama *et al.* (2004), who reported three values of 9.13 ± 0.78 m^2ha^{-1} from TFS-KCFR, 8.95 ± 0.73 m^2ha^{-1} from SUA-KTF and 7.78 ± 1.1 m^2ha^{-1} from general land; Lyimo & Shaban (2015) reported a value of 7.96 ± 0.8 m^2ha^{-1} from SUA-KTF and Mwakalukwa *et al.* (2014) reported a value of 13.55 ± 5.52 m^2ha^{-1}. The lower value of basal area reported in this study could be due to the presence of many trees with smaller diameters as compared to large trees found in other studies. This could also be attributed to the high rate of disturbances (selective harvesting of large trees) happening in the TFS-KCFR. This is supported by the trend shown by harvested stems in which basal area shows to increase with increasing in diameter classes (Figure 4).

Figure 4. Distribution of Basal Area for Standing Trees ≥1 cm Dbh and Stumps ≥1 cm by Diameter Classes at TFS-Kitulangalo Catchment Forest Reserve, Tanzania (n=30). NB: Logarithmic Scale on Vertical Axis.



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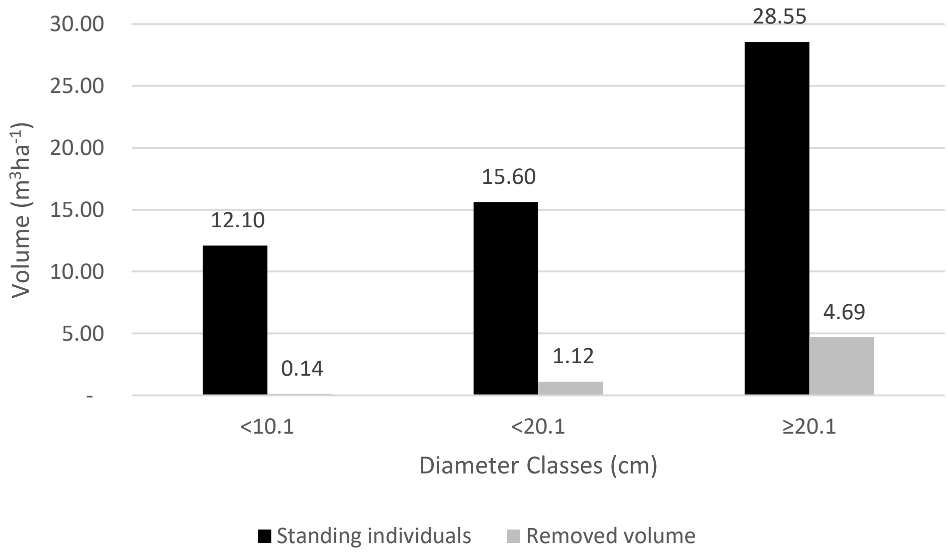
Stand Volume

A similar trend observed for the basal area was also observed in standing volume where *J. globiflora* contributed the most (11.82%) to the mean standing volume for large individuals of 56.25 ± 35.03 m^3ha^{-1} (Table 1). In general, trees with large diameters contributed higher to the mean total standing volume (Figure 5). This value is lower than that reported by Chamshama *et al.* (2004), who reported two values of 76.02 ± 9.14 m^3ha^{-1} from TFS-KCFR, and 76.03 ± 9.34 m^3ha^{-1} from SUA-KTF; and Mwakalukwa *et al.* (2014) who reported a mean volume of 92.17 ± 39.0 m^3ha^{-1}. The low value reported in this study could be due to the presence of many trees with lower diameter classes as compared to other studies. However, the mean volume of 56.25 ± 35.03 m^3ha^{-1} reported in this study was higher than that reported by Chamshama *et al.* (2004) from general land (43.9 ± 7.75 m^3ha^{-1}) and Lyimo and Shaban (2015) from SUA-KTF (54.73 ± 11.3 m^3ha^{-1}). This could have been contributed to by the presence of a few large trees in the reserve (Figure 5). Generally, the distribution of basal area per diameter classes shows the normal 'J' shape which is common in natural forests (Figure 5).

Figure 5. Distribution of Mean Stand Volume per Hectare and Volume Removed for Trees and Shrubs ≥ 1 cm Dbh by Diameter Classes in TFS-Kitulangalo Catchment Forest Reserve, Tanzania.



Biomass and Carbon Storage

The mean aboveground biomass (AGB) and carbon stocks for large individuals (Dbh ≥ 1 cm) were 37.94 ± 23.68 $Mgha^{-1}$ and 18.97 ± 11.84 $MgCha^{-1}$, respectively (Table 1). The estimated mean aboveground biomass removed and corresponding carbon lost from TFS-KCFR were 4.60 ± 3.43 $Mgha^{-1}$ and 2.30 ± 1.72 $MgCha^{-1}$ respectively (Table 3). Generally, trees with diameters ≥ 20.1 had a higher contribution to aboveground carbon stocks, and large stumps with diameters ≥ 20.1 reveal a large amount of aboveground carbon loss (Figure 6). The mean AGB reported in this study of 37.94 ± 23.68 $Mgha^{-1}$ is lower than that reported by Chamshama *et al*. (2004), who reported two values of 43.56 ± 7.06 $Mgha^{-1}$ from TFS-KCFR, and 41.40 ± 4.90 $Mgha^{-1}$ from SUA-KTF; and Mwakalukwa *et al*. (2024) who reported a mean carbon density of 35.59 ± 3.06 $MgCha^{-1}$. However, the AGB reported in this study of 37.94 ± 23.68 $Mgha^{-1}$ was relatively larger than that reported by Chamshama *et al*. (2004) from general land (29.31 ± 6.56 $Mgha^{-1}$). The low value of biomass reported in this study could be due to the presence of many trees with lower diameter classes which have contributed less to the biomass values as compared to other studies.

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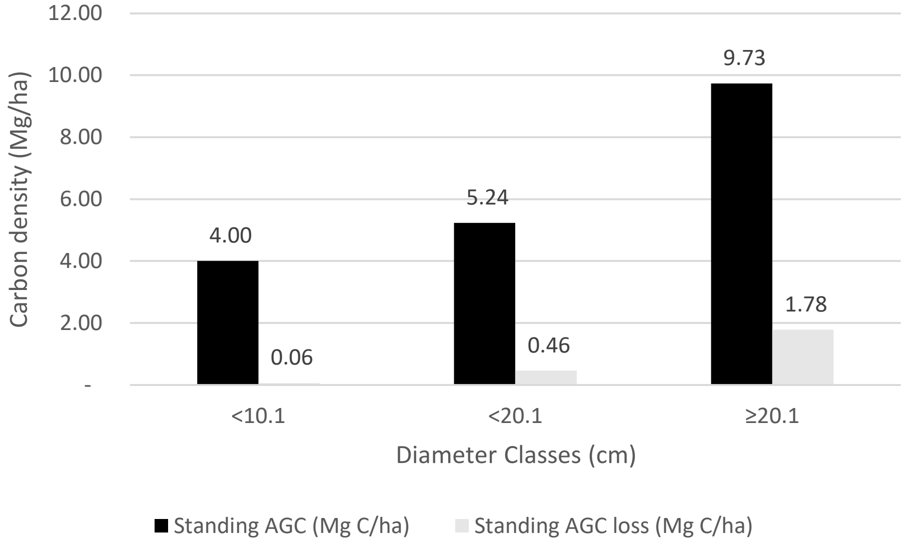
Figure 6. Distribution of Aboveground Carbon Stocks and Loss by Diameter Classes for Trees and Shrubs with ≥ 1 cm Dbh in TFS-Kitulangalo Catchment Forest Reserve, Tanzania.



Effect of Human Activities on Species Diversity

Out of all observed disturbances, grazing activities significantly lower the tree species diversity by 0.886 ± 0.002 with p-value <0.05 (Table 4; Figure 7) unlike areas with no disturbances which showed to have high species diversity (1.9156 ± 0.237) followed by fire areas (1.7654 ± 0.002), charcoal making (1.72 ± 0.44), illegal logging (1.6939 ± 0.733), and soil erosion (1.5292). The reason why grazing has shown significant impacts could be due to the fact that grazing of different intensities was observed to occur widely across the entire forest reserve (Figure 7). Traditional grazing practices which normally involve grazing large groups of cattle at once cause vegetation loss due to animal movement and trampling (Mtimbanjayo & Sangeda, 2018). Excessive animal movement causes soil compaction, loss of organic matter and soil erosion resulting in nutrient loss on the top soil (Klumpp *et al*. 2009), affecting the plant growth (Andrew, 2021). Moreover, animal movement disrupts the soil condition which may favour the growth of invasive species which compete with the native species thus lowering the diversity of native plant species (Klumpp *et al*., 2009).

Table 4. Results From the Linear Regression Model Showing the Effect of Human Activities on Species Diversity in TFS-Kitulangalo Catchment Forest Reserve, Tanzania.

Disturbance	Estimate	Std. error	t-value	P-value
Intercept	1.8484	0.1694	10.913	4.11e-10 ***
Charcoal making	-0.9353	0.55	-1.7	0.1038
Grazing	-0.9624	0.4481	-2.147	0.0436 *
Fire	0.8794	0.5867	1.499	0.1488
Soil erosion	-0.3148	0.6775	-0.465	0.6469
Illegal logging	0.8078	0.5081	1.59	0.1268
Charcoal making: Grazing	1.0855	0.7095	1.53	0.141

Note: * indicates a significant level at α 0.05

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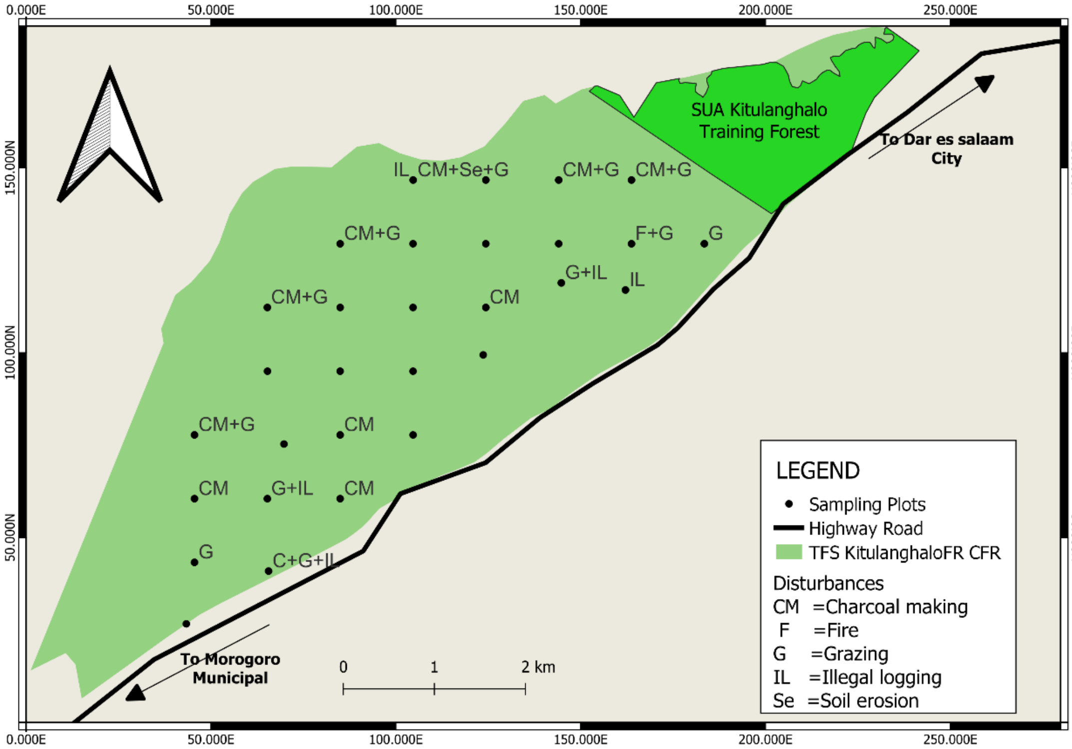
***Figure 7*. The Sketch Map of TFS-Kitulanghalo Catchment Forest Reserve Showing Different Disturbances Which Occur Within a Reserve.**



CONCLUSION

The study has revealed that the dry Miombo woodlands of TFS-KCFR have higher species diversity, richness, stem densities and reasonably higher basal area. However, the forest has on average lower stand volume and biomass due to the illegal harvesting of large trees in the forest. *Julbernardia globiflora* is the most harvested species probably due to its multiple uses for firewood and charcoal making. Generally, regeneration was found to be good. This indicates a good sign of a healthier forest and ensures the sustainability of the woodland stock. The study recommends that effective management and conservation strategies are to be implemented in order to reduce the observed effects of human disturbances within the reserve. Such strategies include enrichment planting of native trees in harvested areas, conducting forest patrols, preparation of management plans and involvement of local communities in the management of forest reserve through Joint Forest Management (JFM) arrangements.

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REFERENCES

Abdallah, J. M., & Monela, G. G. (2007). Overview of Miombo woodlands in Tanzania. In Proceedings of the First MITMIOMBO Project Workshop held in Morogoro, Tanzania, 6th-12th February 2007. W*orking Papers of the Finnish Forest Research Institute*, 50, 9-23.

Andrew, S. (2021). Effects of plant species diversity and biomass on grazing patch selection by semi-free-ranging cattle. *Tanzania Journal of Science*, 47(1), 282-295.

Article DOI: https://doi.org/10.37284/eajfa.8.1.2809

Banda, T., Mwangulango, N., Meyer, B., Schwartz, M. W., Mbago, F.M, Sungula, M., & Caro, T. (2008). The woodland vegetation of the Katavi-Rukwa ecosystem in western Tanzania. *Forest Ecology and Management*, 255(8), 3382-3395.

Bhattarai, S., Dons, K., & Pant, B. (2020). Assessing spatial patterns of forest degradation in dry Miombo woodland in Southern Tanzania. *Cogent Environmental Science*, 6(1), 1801218.

Chamshama, S.A.O., & Vyamana, V.G. (2010). Forests and Forestry in Tanzania. In F. Bongers & T. Tennigkeit (Eds.), *Degraded Forests in Eastern Africa. Management and Restoration* (pp. 89 -108). Earthscan, London.

Chamshama, S.A.O., Mugasha, A.G., Zahabu, E., (2004). Stand biomass and volume estimation for Miombo Woodlands at Kitulangalo, Morogoro, Tanzania. *Southern African Forestry Journal*, 200, 59-69.

Doggart, N., Morgan-Brown, T., Lyimo, E., Mbilinyi, B., Meshack, C. K., Sallu, S.M., & Spracklen. D.V., (2020). Agriculture is the main driver of deforestation in Tanzania. *Environmental Research Letters*, 15(3), 034028.

Giliba, R. A., Boon, E. K., Kayombo, C. J., Musamba, E. B., Kashindye, A. M., & Shayo, P. F. (2011). Species composition, richness and diversity in Miombo woodland of Bereku Forest Reserve, Tanzania. *Journal of Biodiversity*, 2(1),1-7.

Jew, E.K.K., Dougill, A. J., Sallu, S. M., O’Connell, J., & Benton, T. G. (2016). Miombo woodland under threat: Consequences for tree diversity and carbon storage. *Forest Ecology and Management*, 361, 144-153.

Kent, M. (2012). *Vegetation Description and Data Analysis: A Practical Approach*. 2nd ed. Wiley-Blackwell, John Wiley & Sons, Hoboken, NJ, USA.

Kent, M., & Coker, P. (1992). *Vegetation Description and Analysis: a practical approach*. Belhaven Press, 25 Floral Street, London.

Klumpp, K., Fontaine, S., Attard, E., Le Roux, X., Gleixner, G., & Soussana, J.F. (2009). Grazing triggers soil carbon loss by altering plant roots and their control on soil microbial community. *Journal of Ecology*, *97*(5), 876-885.

Lovett, J.C., & Pocs, T. (1993). *Assessment of the Condition of the Catchment Forest Reserves, a Botanical Appraisal*. The Catchment Forestry Project. Ministry of Natural Resource and Tourism, Dar es Salaam, Tanzania.

Luoga, E. J., Witkowski, E. T. F., & Balkwill, K. (2002). Harvested and standing wood stocks in protected and communal miombo woodlands of eastern Tanzania. *Forest Ecology and Management,* 164(1-3), 15-30.

Lyimo, P., & Shaaban, S. (2015). Assessment of forest condition at SUA-Kitulangalo forest reserve in Tanzania Miombo Woodland. *Scholarly Research paper*. www.GRIN.com.

Magurran, A.E. (2004). *Measuring Biological Diversity*. Blackwell, Oxford, UK.

Malimbwi, R.E. (1997). *Fundamentals of Forest Mensuration*. A compendium. Sokoine University of Agriculture, Department of Forest Mensuration and Management. Morogoro, Tanzania. 84p.

Malimbwi, R.E., Misana, S., Monela, G.C., Jambiya G., & Zahabu, E., (2000). Impact of charcoal extraction on the forest resources of Tanzania: the case of Kitulangalo area, Tanzania. Proceedings of the 1st University Wide Scientific Conference, 5th – 7th April 2000: Volume 3.

Manyanda, B. J., Mugasha, W. A., Nzunda, E. F., & Malimbwi, R. E. (2019). Biomass and volume models based on stump diameter for assessing degradation of miombo woodlands

Article DOI: https://doi.org/10.37284/eajfa.8.1.2809

in Tanzania. *International Journal of Forestry Research*, 2019(1), 1876329.

Mauya, E. W., Mugasha, W. A., Zahabu, E., Bollandsås, O. M., & Eid, T. (2014). Models for estimation of tree volume in the miombo woodlands of Tanzania. *Southern Forests: a Journal of Forest Science*, 76(4): 209-219.

MNRT. (2015). *National Forest Resources Monitoring and Assessment of Tanzania Mainland*, *Main Results*. Ministry of Natural Resource and Tourism, Dar es Salaam, Tanzania.

Mtimbanjayo, J. R., & Sangeda, A. Z. (2018). Ecological effects of cattle grazing on Miombo tree species regeneration and diversity in Central-Eastern Tanzania. *Journal of Environmental Research*, *2*(1:3), 1-7.

Mugasha, W. A., Eid, T., Bollandsås, O. M., Malimbwi, R. E., Chamshama, S. A. O., Zahabu, E., & Katani, J. Z. (2013). Allometric models for prediction of above-and belowground biomass of trees in the miombo woodlands of Tanzania. *Forest Ecology and Management*, 310, 87-101.

Mwakalukwa, E.E., & Masisi, B. (2024). Diversity, structure, and carbon storage of Rau catchment forest reserve in Moshi District, Tanzania. *Asian Journal of Forestry*, 9 (1), 1-11.

Mwakalukwa, E.E., Meilby, H., & Treue, T. (2014). Floristic composition, structure and species associations of dry Miombo woodland in Tanzania. *International Scholarly Research Notices:* 153278.

Mwakalukwa, E.E., Meilby, H., & Treue, T. (2024). Carbon storage in a dry Miombo woodland area in Tanzania. *Southern Forests*, 86, 1–10.

Nduwamungu, J. (1996). *Tree and shrub diversity in Miombo woodland: A case study at SUA Kitulangalo Forest Reserve, Morogoro, Tanzania*. Masters Dissertation, Tanzania. Sokoine University of Agriculture.

Obiri, J.A.F., Hall, J.B., & Healey, J. R. (2010). Composition, Structure and Regeneration of Miombo Forest at Kitulangalo, Tanzania. In F. Bongers & T. Tennigkeit (Eds.), *Degraded Forests in Eastern Africa- Management and Restoration*. (pp.109-122). Earthscan, London.

Sharma, G. (2017). Pros and cons of different sampling techniques. *International journal of applied research*, 3(7), 749-752.

Zahabu, E, (2001). *Impact of Charcoal Extraction on the Miombo Woodlands: The Case of Kitulangalo Area, Tanzania*. Masters Dissertation, Tanzania. Sokoine University of Agriculture.

