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FLORISTIC COMPOSITION, STRUCTURE, AND REGENERATION STATUS OF WOODY PLANT SPECIES IN HURUBU NATURAL FOREST, NORTH SHEWA, OROMIA REGION, ETHIOPIA

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ABSTRACT

Ethiopia harbour the Eastern afromontane and Horn of Africa hotspots of biodiversity. The general objective of this study was to investigate the floristic composition and diversity of species, the structure and the regeneration status of the Hurubu forest. Three parallel transects lines with 1 km length were systematically laid across the forest with an interval of 500 m in south to north direction. Thirty sample quadrants of 20 m × 20 m were placed along transects at an interval of 200 m for mature trees and shrubs, while for the purpose of seedling and sapling inventory, four sub-quadrants of 1 m × 1 m were laid at each corner of the main quadrant. A total of 32 woody species representing 25 families were recorded consisting of trees and shrubs. The lower storey consisted of all woody plant species, except Ekebergia capensis tree species. The middle storey consisted about 14.41 % of the tree species while the upper storey involved only 2.35 % of the total individual trees in the forest. The total basal area of woody plants in Hurubu forest was 90 m^2 per ha. The three most important woody species with the highest IVI were Juniperus procera, Osyris quadripartite and Myrsine africana in decreasing order. The general regeneration status of the tree species of the study site was satisfactory at the community level showing a 'fair' regeneration status. Therefore, special conservation actions should be implemented for the poorly and not regenerating woody species of the forest.

Keywords: Floristic, Structure, Regeneration, Hurubu, Natural forest

INTRODUCTION

The plant diversity and composition, quantified by present and absent of the species at any site is influenced by species distribution and abundance patterns (Palit & Chanda, 2012) and the richness of plant species is controlled by a variety of biotic and abiotic parameters. structure of woody plant species is expressed in terms of size class of individuals present in each of the definite girth class distribution of tree species (Sarkar & Devi, 2014). The structure of woody plant species used to identify regeneration of the species which is indicated by presence of number of seedlings, saplings and young trees in a given site (Tynsong *et al.*, 2012) and the number of seedling of any species can be considered as the regeneration potential of that species (Negi & Nautiyal, 2005).

Tropical forests revealed different in its floristic composition and regeneration status both through differences in their species composition and the environmental variables in which they grow. Ethiopia is one of the tropical countries geographically characterized by a great altitudinal variation from 116 meters below sea level to 4620 meters above sea level and endowed with diverse climatic conditions (IBC, 2012). The diverse altitude and climatic factors have driven the establishment of diverse vegetation, ranging from Afroalpine vegetation in the type of mountains to the arid and semi-arid vegetation in the lowlands (Asefa *et al*., 2020). Ethiopia harbour the Eastern Afromontane and the Horn of Africa biodiversity hotspots and possesses an estimated 6000 species of higher plants, of which 10 % are considered to be endemic. From these higher plants, woody plants composed of 1000 species, out of which 300 are trees (IBC, 2012).

The forest ecosystem of Ethiopia cover about 17 069, 000 ha or 15.11 % of land area in 2020 (FAO, 2020). However, deforestation and forest degradation are ongoing processes in Ethiopia (Wassie, 2020). Currently, the remaining forests of the country found in South West and South East; Western lowlands; and in central and Northern highlands specifically around the churches, respectively for Moist Afromontane forests, the Dry Forest (Combretum-Terminalia woodlands) and Dry Afromontane forests (Tigabu, 2016; MEFCC, 2018). Currently, the establishment of protected and forest priority areas, as well as the sacred forest sites and large-scale intervention in forest rehabilitation in degraded highlands, is among the efforts that the government and local communities are employing to maintain and conserve existing natural forests (Tigabu, 2016; MEFCC, 2018). Furthermore, the National REED+ Strategy (NRS) broadly targets intensifying efforts to protect existing natural forest resources while also increasing investments on forest restoration because forestry is among the four pillars of the Climate Resilient Green Economy Strategy which aims to reduce national emissions by 50 % by 2030 (MEFCC, 2018). It also highly emphasized the current need for large-scale restoration for the central and northern areas of Ethiopia, which historically lost most of its forest cover due to various forces (MEFCC, 2018). Closing and rehabilitation of existing degraded native forests through natural regeneration (high forest zone) and assisted natural regeneration with enrichment planting (high forest zone and forests) are among the strategic options for the Oromia region (MEFCC, 2018).

Consequently, data on woody plant communities which are defined largely by species presence or absence is crucial to take conservation actions. Further formal description generally focuses on features such as complete floristic composition, floristic structure, species diversity, and information on regeneration status has important applications in sustainable use of natural forests, the preservation of biodiversity, and detecting changes in the plant cover of the area (Maarel, 2005).

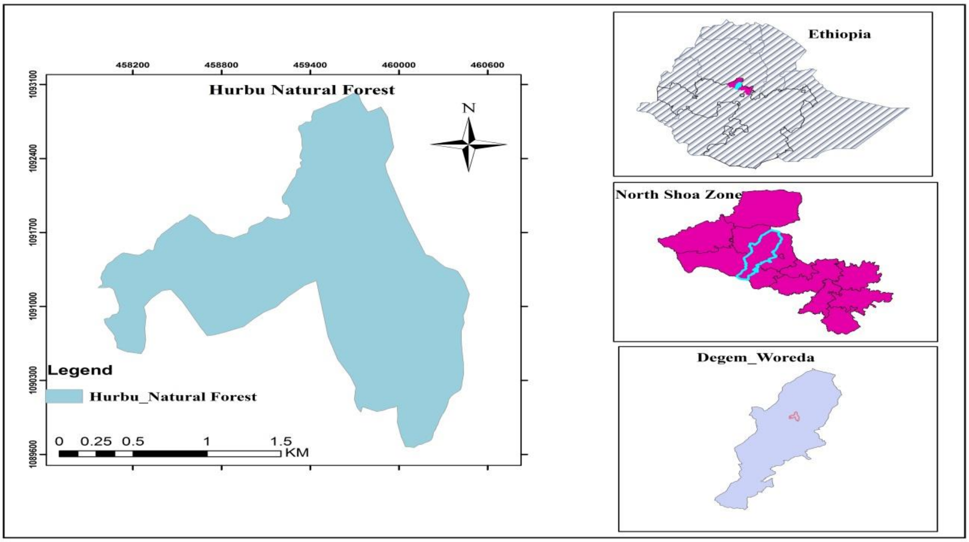
From the zones in Oromia regional state of Ethiopia, the north Shewa zone (Salale) has the smallest area coverage (11,290 km^2). Consequently, north Shewa has the lowest forest cover share (0.06 %) of the Oromia region (Bekele *et al*., 2015), and deforestation is one of the main problems identified with respect to the management of natural resources in this zone (Agajie Tesfaye *et al*., 2018). This zone is part of a highly emphasized area on the current need for large scale restoration. The Ellen forest is the largest forest cover found in this zone, having 728 ha and 1/3 (242 ha) of this forest is natural, which is called Hurubu forest. However, there is a lack of data on the floristic composition, species diversity, structure, and regeneration status of the Hurubu forest. Therefore, the purpose of this study was to give insight for policy makers and implementer on the conservation measures required for this forest. Furthermore, this research is the first paper published so far on this forest ecosystem. The objectives of this study were: i) to analyze the floristic composition and species diversity of Hurubu forest, (ii) to analyse the structure of the Hurubu forest, and (iii) to investigate the regeneration status of the Hurubu forest.

MATERIALS AND METHODS

Description of the Study Area

The research was conducted in Hurubu natural forest found in Degem Woreda, North Shewa Zone, and Oromia Regional State. Degem Woreda, lies between 9° 47’ 29” - 9° 47’ 13’’ N latitude and 38° 31’ 09” - 38° 32’ 50” E longitudes. Degem Woreda is found at 125 km distance north of Addis Ababa (Lemlem & Asfaw, 2018). The Climatic conditions of Degem woreda are divided into three as Highlands (30 %), Midlands (38 %) and Lowlands (32 %). The major soil types of the woreda includes verisols, nitosols, and cambisols. With regard to the soil color, 10% of the soil is black while 45 % is brown and 45 % is red (Lemma, 2011).

Fig. 1: Map of the study area



The research area (Hurubu natural forest) is among the remaining natural forest in central highlands of Ethiopia. It is geographically located at latitudes and longitudes of 09 0 51’ N and 38 0 38' E respectively. Hurubu natural forest is characterized by rugged topography and made up of mountain chains with an altitude ranges from 2100 m a.s.l to 3300 m a.s.l.

According to the data obtained from Degem woreda Agricultural office, the annual rainfall of the research area ranges from 900 mm -1400 mm with a bimodal rainfall distribution. The first rainy season is from February to April while the second rainy season is from June to the beginning of October. Temperature of the research area varies between the mean annual maximum of 20.3 °C and the mean annual minimum of 8.17 °C throughout the elevation gradient (Lemma, 2011).

Sampling Design

A systematic sampling design was employed for woody plant data collection. Three parallel transects with 1 Km length were systematically laid across the forest with an interval of 500 m in the south to north orientation. For the inventory of mature trees and shrubs, a total of thirty sample quadrants of 20 m × 20 m were placed along the three transects at an interval of 200 m. while for the purpose of seedling and sapling inventory, four sub-quadrates of 1 m × 1 m were laid at each corner of the main quadrat.

Data Collection Method

Floristic data collection: In each quadrant, all species of woody plants were identified by their local names, pressed, coded, and then grouped as trees and shrubs. Plant species occurring outside sample quadrants but inside the forest was recorded only as present, but not used in subsequent vegetation data analyses (Shiferaw *et al*., 2018). These species and the rest plant specimens were collected, pressed, dried, and brought to the Ethiopia Biodiversity Institute, for taxonomic identification using flora of Ethiopia and Eritrea.

Structural data collection: In each quadrant, for all woody plants having diameter at breast height (DBH) ≥ 2.5 cm, the circumference measurements were made at breast height (1.3 m) by using diameter tape and calliper following the methods described by (Martin, 1995). According to Ayanaw Abunie & Dalle (2018), stems born from the same root were considered a single plant during measurement for the woody plants. The diameter of stems branching below or at the breast height was measured separately for each branch and summed.

For regeneration survey, only counting of seedlings (height less than 1.0 m), saplings (height between 1-3m) and trees (height greater than 3.0 m) were used for individual woody categorization (Ostrom, 2007). In this study, height was measured using clinometer. However, where slope, topography, and/or crown structure made it difficult to use clinometer, height was estimated visually.

Data Analysis Method

Species diversity in the forest was calculated using the Shannon Wiener Diversity Index and species richness (Magurran, 2004) :

$$H' = -\sum Pi \ln Pi$$

Where, H'= Shannon diversity index, Pi = proportion of individual found in the i-th species. The Ratio of observed Shannon index to maximum diversity (Hmax = lns) was used to measure evenness (J') (Magurran, 2004). Equitability (evenness)

$$J = H'/Hmax \text{ or } J = -\sum Pi \ln PIi/\ln S,$$

where S is the number of species.

Structural Data Anaalysis

Basal area was calculated as follows (Mueller-Dombois & Ellenberg, 1974):

$$\text{Basal area (BA)} = \frac{\pi DBH^2}{4},$$

Where, BA: basal area, DBH: diameter at breast height, Π = 3.14

The Importance Value Index (IVI) indicates the importance of species in the system and was calculated with three components as follows (Nguyen *et al*., 2014).

$$\text{Relative density (RD)} = \frac{Number\ of\ individual\ species}{(Total\ number\ individual)} x100$$

Relative dominance (RDo) $= \frac{Dominance\ of\ species}{Total\ dominance\ of\ all\ species} x100$, where dominance is the basal area of species times number of species

Relative frequency (RF) = $\frac{Frequency\ of\ species}{frequency\ of\ all\ species}$X 100, where frequency is number of plots in which species found divided by the total number of plot times one hundred

Importance value index (IVI) = RD + RDo +RF

Vertical structure

The vertical structure of trees in the Hurbu natural forest was described based on the International Union for Forestry Research Organization (IUFRO) classification scheme (Lamprecht, 1989). According to the scheme, three vertical structures, namely; upper floor (tree height >2/3 of top height), middle storey (tree height between 1/3 and 2/3 of top height) and lower storey (<1/3 of the top height) were distinguished in tropical forests.

Height and DBH class distribution: was analyzed using height and DBH class categorization.

Regeneration status: was analyzed by comparing saplings and seedlings with the matured trees as given below (Dhaulkhandi *et al*., 2008):

1. Good regeneration, if seedling is greater than sapling and mature tree/adult (seedling density > sapling density > mature tree/adults);
2. Fair regeneration, if seedling > or ≤ sapling ≤ mature tree;
3. Poor regeneration, if a species survives only in the sapling stage, but has no seedlings (even though saplings may be <, >, or = mature);
4. Not regenerating, if a species is present only in an adult form; and
5. New, if a species has no matured trees, but only sapling and/ or seedling stages.

RESULTS AND DISCUSSION

Floral composition and the species diversity of Hurubu forest

A total of 32 woody species representing 25 families were recorded consisting of trees (46.88 %), shrubs (40.63 %), creeping shrubs (6.25 %), climbing shrub, and tree/shrub (3.13 % each). This forest had 2 endemic species to Ethiopia, 29 indigenous and 1 exotic woody species. The families with the highest number of species were Fabaceae (15.63 %) followed by Apocynaceae (6.25 %), Loganiaceae (6.25 %), and Myrsinaceae (6.25 %). The remaining 21 families contained one species (3.13 %) (Table 1 and Fig. 2). This study showed that the Hurubu forest's Shannon diversity index was 2.76 with 0.83 evenness index.

Fig. 2: Number of species per family

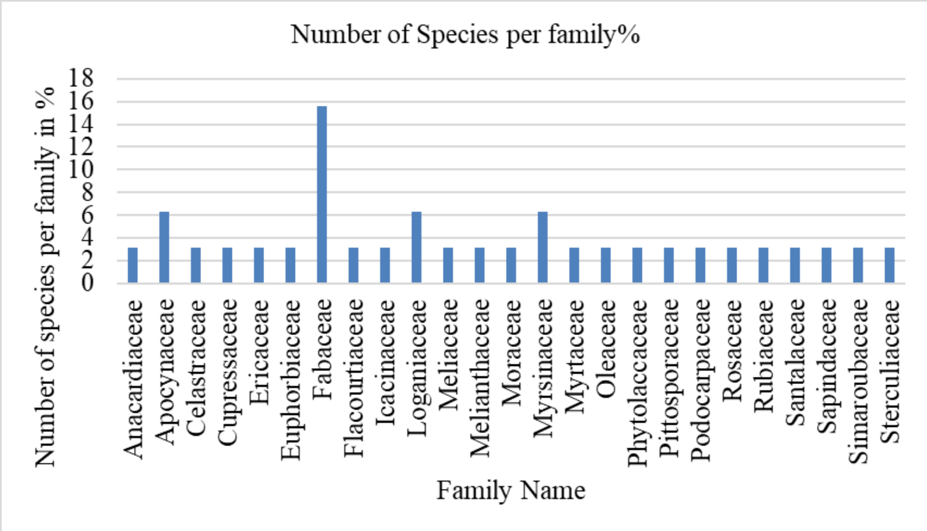


Table 1: Woody floristic composition of hurubu forest

No	Scientific name	Local name (Afaan Oromoo)	Family	Habit	To Ethiopia
1	*Acacia decarance*	-	Fabaceae	Tree	Exotic
2	*Acacia negrii*	Laaftoo	Fabaceae	Tree	Endemic
3	*Acokanthera schimperi*	Qaraaruu	Apocynaceae	Tree	Indigenous
4	*Albizia schimperiana*	Mukaa Arbaa	Fabaceae	Tree	Indigenous
5	*Apodytes dimidiata*	Calalaqaa	Icacinaceae	Tree	Indigenous
6	*Bersama abyssinica*	Lolchiisaa	Melianthaceae	Tree	Indigenous
7	*Brucea antidysenterica*	Liqimmee	Simaroubaceae	Shrub	Indigenous
8	*Buddleja polystachya*	Adaadii	Loganiaceae	Shrub	Indigenous
9	*Calpurnia aurea*	Ceekaa	Fabaceae	Shrub	Indigenous
10	*Carissa spinarum*	Agamsa	Apocynaceae	Creeping shrub	Indigenous

11	*Croton macrostachyus*	Baakkanniisaa	Euphorbiaceae	Tree	Indigenous
12	*Dodonaea angustifolia*	Itacha	Sapindaceae	Shrub	Indigenous
13	*Dombeya torrida*	Daanniisaa	Sterculiaceae	Tree	Indigenous
14	*Dovyalis abyssinica*	Koshammii	Flacourtiaceae	Shrub	Indigenous
15	*Ekebergia capensis*	Somboo	Meliaceae	Tree	Indigenous
16	*Erica arborea*	Astii	Ericaceae	Shrub	Indigenous
17	*Ficus sur*	Harbuu	Moraceae	Tree	Indigenous
18	*Juniperus procera*	Gaattiraa haabasha	Cupressaceae	Tree	Indigenous
19	*Maesa lanceolata*	Abbayyii	Myrsinaceae	Shrub	Indigenous
20	*Maytenus obscura*	Qarxammee	Celastraceae	Shrub	Indigenous
21	*Myrica salicifolia*	Kataba	Myrtaceae	Tree	Indigenous
22	*Myrsine africana*	Qacama	Myrsinaceae	Shrub	Indigenous
23	*Nuxia congeta*	Adaadii garraami	Loganiaceae	Tree/Shrub	Indigenous
24	*Olea europaea*	Ejarsa	Oleaceae	Tree	Indigenous
25	*Osyris quadripartita*	Waatoo	Santalaceae	Shrub	Indigenous
26	*Phytolacca dodecandra L'Herit.*	Andoodee	Phytolaccaceae	Shrub	Indigenous
27	*Pittosporum viridiflorum*	Shoolee	Pittosporaceae	Tree	Indigenous
28	*Podocarpus falcatus*	Birbirsa	Podocarpaceae	Tree	Indigenous
29	*Pterolobium stellatum*	Qanxaffaa	Fabaceae	climbing shrub	Indigenous
30	*Rhus glutinosa*	Xaaxeessaa	Anacardiaceae	Shrub	Endemic
31	*Rosa abyssincia*	Goraa	Rosaceae	Creeping shrub	Indigenous
32	*Rytigynia neglecta*	Gagaafataa	Rubiaceae	Shrub	Indigenous

The structure of Hurubu forest

Vertical structure

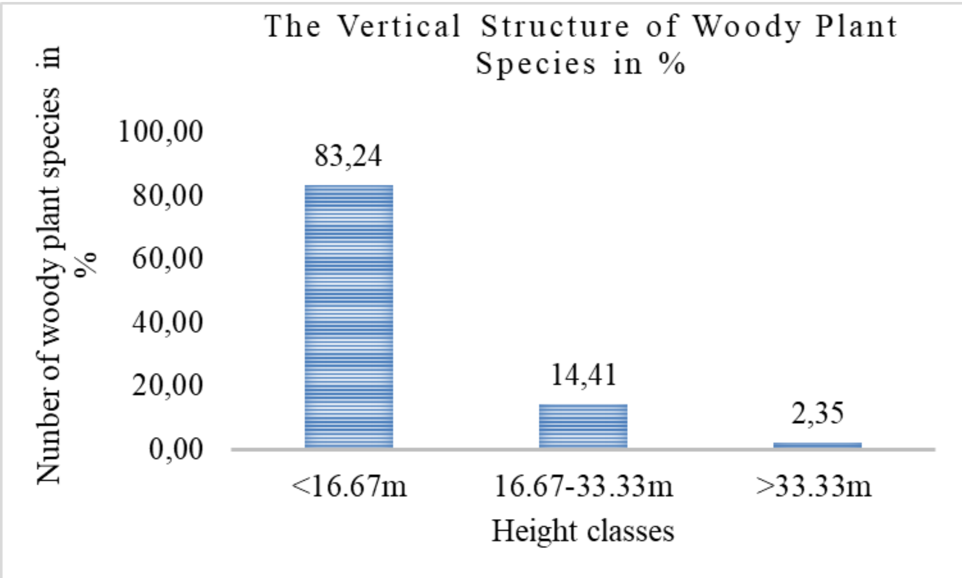
The vertical structure of woody species of the Hurubu forest was analyzed into three vertical layers based on the mximum 50 m tree height of this forest. These were upper storey (top height > 33.33 m), middle storey (height between 16.67-33.33 m) and lower storey (height <16.67 m).

The lower storey consisted of all woody plant species, except that Ekebergia capensis tree was only found in the midle storey. The most dominant woody plant in the lower story were, *Juniperus procera* (15.95 %), *Myrsine africana* (12.56 %), *Dodonaea angustifolia* (9.16 %), *Erica arborea* (8.82 %) and *Osyris quadripartita* (7.58 %), the remaining accounts less than 6 % each.

The middle storey of the forest contributed by eleven tree speceis about 14.41 % of the total tree species. This layer was dominated by *Juniperus procera* (69.9 %), *Brucea antidysenterica* (13.7 %) and *Olea europaea* (4.6 %) and the remaining contributed less than 3 % each.

The upper storey involved only 2.35 % of the total of individual trees in the forest with five tree spceis. The dominant emergent tree species in this layer were *Juniperus procera* (48 %) and *Podocarpus falcatus* (20 %). The rest of the emergent tree species were *Olea europaea* (16 %), *Brucea antidysenterica* (8 %) and *Ficus sur* (8 %). *Juniperus procera*, *Podocarpus falcatus* and *Olea europaea* tree species were common to all storeys (Fig. 3).

Fig. 3: Vertical structure of woody plant species in Hurubu fores



Height and DBH Class Distribution

The tallest tree was 50 m and the largest DBH was 450 cm. Height and DBH classes of woody species of the forest were categorized in to ten and eleven classes respectively. The height classes of this forest indicated that decrease in number of individuals with increase in class sizes. Woody plant species of the forest that belongs to 1-5m account 62.8 % while, 40-50 m contributed 0.3 % (Fig. 4).

In the same way, the DBH classes of the forest belonging to DBH classes 2.5- 10 cm contributed 50.09 % of the number of individuals. This indicate that half of the individuals of the forest are small sized (Fig. 5).

Fig. 4: Distribution of height class in Hurubu forest

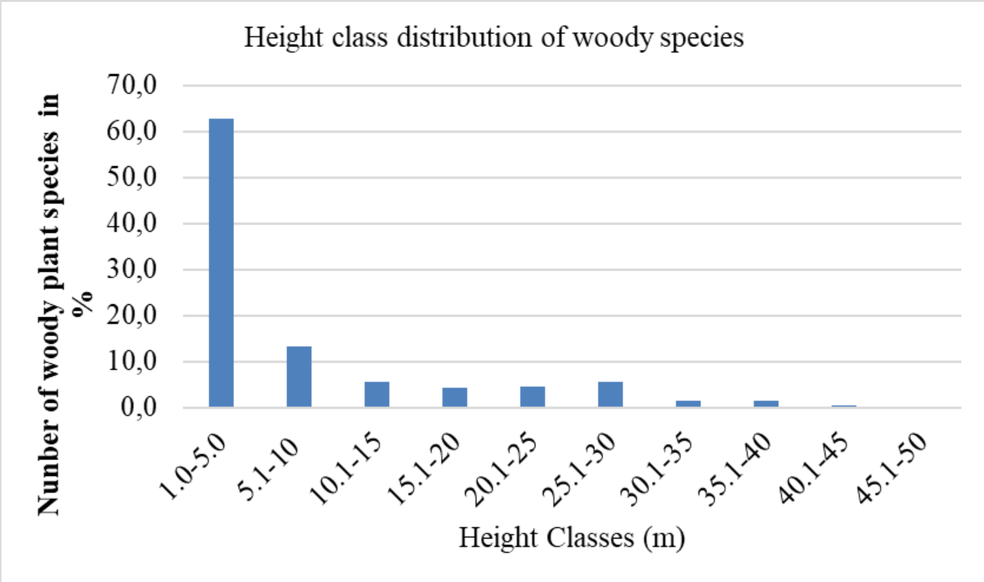
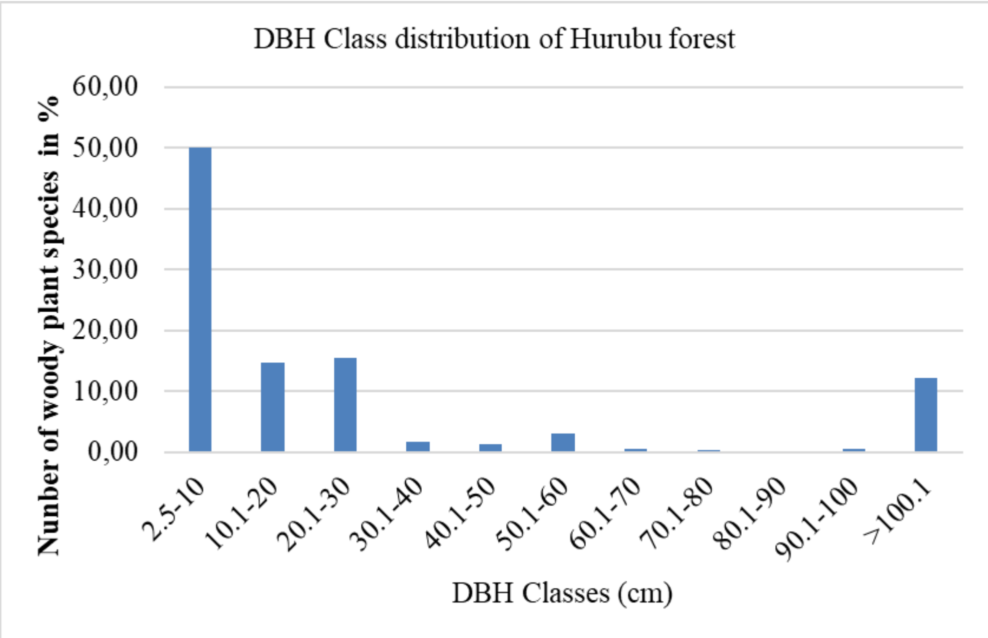


Fig. 5: Distribution of the DBH class in Hurubu forest



The *Basal Area (BA)* and importance value index (IVI) of a forest

The total BA of the woody plants in the Hurubu forest was 90.00 m^2 per ha. *Juniperus procera* was the most important tree species of the forest with BA of 48.4 m^2 per ha which is about 53.8 %. The second most important tree species was *Podocarpus falcatus* with BA of 12.2 m^2 per ha which is 13.6 %. Others plant species were *Brucea antidysenterica* with 8.1 and *Olea europaea* with 8.0 BA in m^2 per ha. *Pittosporum viridiflorum* contributed the least amount of BA, approximately 0.01 m^2 per ha to the Hurubu forest (Table 2).

The IVI of the most common and frequent trees of Hurubu forest was calculated and *Juniperu sprocera* was found to have the highest IVI. The ten most important woody species with the highest IVI were *Juniperus procera, Osyris quadripartite, Myrsine africana, Erica arborea, Podocarpus falcatus, Olea europaea, Dodonaea angustifolia, Maytenus obscura, Calpurnia aurea and Brucea antidysenterica* in their descending order of IVI value. These woody plant species contributed over 67.7 % of the total IVI and implies that these ten species are the most ecologically important woody species at Hurubu forest (Table 2).

Table 2: The BA and IVI of woody plant species in the Hurubu forest

No	Local name of Species (Afaan oromoo)	Scientific name of the species	RBA (m^2 ha-1)	RDO (%)	RD (%)	RF (%)	IVI	IVI (%)
1	Gaatiraa Haabashaa	*Juniperus procera*	48.4	53.8	24.5	76.7	154.9	19.0
2	Waatoo	*Osyris quadripartita*	0.4	0.4	6.3	60.0	66.7	8.2
3	Qacammee	*Myrsine africana*	0.2	0.3	10.5	46.7	57.4	7.0
4	Astii	*Erica arborea*	2.1	2.4	7.6	40.0	50.0	6.1
5	Birbirsa	*Podocarpus falcatus*	12.2	13.6	5.3	30.0	48.9	6.0
6	Ejarsa	*Olea europaea*	8.0	8.9	2.8	33.3	45.1	5.5
7	Ittacha	*Dodonaea angustifolia*	0.1	0.2	7.6	26.7	34.5	4.2
8	Qarxammee	*Maytenus obscura*	0.6	0.6	2.5	30.0	33.2	4.1
9	Ceekaa	*Calpurnia aurea*	0.1	0.1	4.6	26.7	31.3	3.8
10	Liqimmee	*Brucea antidysenterica*	8.1	9.0	2.3	20.0	31.3	3.8
11	Goraa	*Rosa abyssincia*	0.0	0.0	2.0	23.3	25.4	3.1
12	Koshammii	*Dovyalis abyssinica*	0.0	0.0	4.0	20.0	24.1	2.9
13	Mukarba	*Albizia schimperiana*	1.9	2.1	2.0	20.0	24.1	2.9

14	Gagaafataa	*Rytigynia neglecta*	0.3	0.4	3.3	20.0	23.7	2.9
15	Agamsa	*Carissa spinarum*	0.0	0.0	1.8	20.0	21.8	2.7
16	Adaadii	*Buddleja polystachya*	0.1	0.1	1.2	16.7	17.9	2.2
17	Xaaxeessaa	*Rhus glutinosa*	0.1	0.1	2.3	13.3	15.7	1.9
18	Lolchiisaa	*Bersama abyssinica*	0.3	0.3	1.9	13.3	15.5	1.9
19	Bakanniisaa	*Croton macrostachyus*	1.3	1.5	2.2	10.0	13.7	1.7
20	Kataba	*Myrica salicifolia*	1.4	1.6	0.4	10.0	12.0	1.5
21	Harbuu	*Ficus sur*	3.0	3.3	1.6	6.7	11.5	1.4
22	Qanxaffaa	*Pterolobium stellatum*	0.0	0.0	0.9	10.0	10.9	1.3
23	Daannisaa	*Dombeya torrida*	0.0	0.0	0.6	10.0	10.6	1.3
24	Qaraaruu	*Acokanthera schimperi*	0.0	0.0	0.5	10.0	10.5	1.3
25	Somboo	*Ekebergia capensis*	0.8	0.9	0.4	6.7	7.9	1.0
26	Abayyii	*Maesa lanceolata*	0.0	0.0	0.5	6.7	7.1	0.9
27	Shoolee	*Pittosporum viridiflorum*	0.0	0.0	0.3	6.7	7.0	0.9
28	Calalaqaa	*Apodytes dimidiata*	0.4	0.4	0.3	3.3	4.0	0.5
			90.00	100.00	100.00	616.67	816.67	100.00

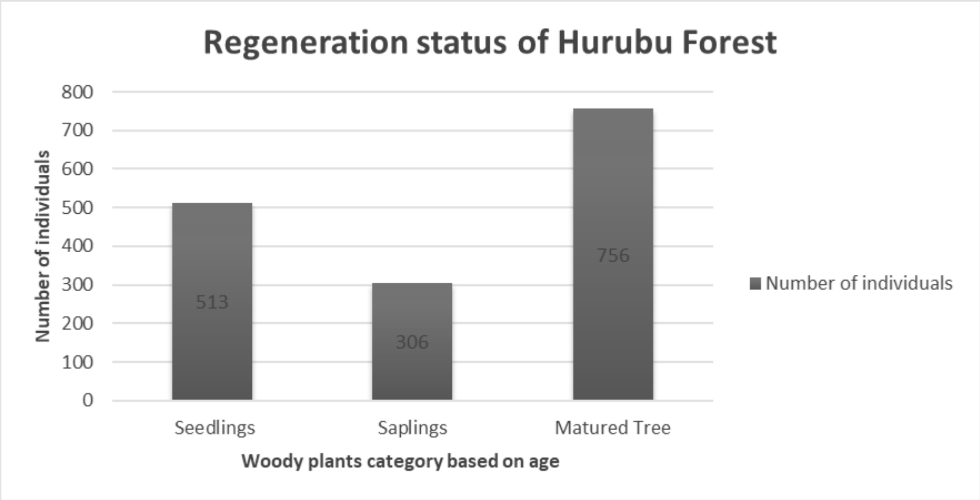
The Regeneration Status of Hurubu Forest

In this study, 14.29 %, 46.43 %, and 7. 14 % of woody plant species were found to have good, fair, and poor regeneration status, respectively. A total of 28.57 % of the woody plant species did not re-generate at all. Woody plant species which were available only in a sapling or seedling stage were considered as new and Hurbu forest constituted 3.57 % woody species (Appendix 1). The good regenerating woody species were *Calpurnia aurea* and *Myrsine africana*, while *Dodonaea angustifolia, Juniperus procera, Maytenus obscura, Olea europaea, Osyris quadripartite and Podocarpus falcatus* woody species had fair regeneration status from the top ten ecologicaly important woody species.

Species which were found in not regenerating category from the top ten ecologically important woody species were *Erica arborea* and *Myrica salicifolia*. Of all woody species of the study area, *Rytigynia neglect* and *Maesa lanceolata* had poor regeneration, while *Pterolobium stellatum* had a new regeneration status. The newly regenerated species may have reached or colonized the study site by different mechanisms like the dispersal of seeds through drooping of birds, mammals, and wind.

The poor and non-regenerating categories that comprise around 35.7 % of the woody plants in the study area have many important and useful tree species which have certain economic, medical, and ecological values. The general regeneration status of the tree species of the study site was satisfactory at the community level showing a fair regeneration status (Fig. 6), but as stated above, 35.7 % of the woody species fall into a poor and non-regenerating state.

Fig. 6: Regeneration status of of woody plant species in the Hurubu forest



Discussion

Woody species composition and diversity

The study demonstrated the presence of significant diversity of woody plant species in terms of composition. A similar total woody plant species and number of families were reported by (Tesfaye *et al.*, 2019; Yahya *et al.*, 2019; Yineger *et al.*, 2008). Similar to this study, (Mesfin *et al.*, 2018) found that Fabaceae was the dominant family in the Yegof dry afromontane forest. Endemic tree species of *Acacia negrii* was also found in the Kumuli dry evergreen afromontane forest (Woldemariam *et al.*, 2016). The Shannon-Wiener index of Hurubu forest diversity showed 2.76 with 0.83 evenness index, which is nearly similar to the Ades dry afromontane forest (2.82) (Reshad, 2019). However, species richness of Hurubu forest was much lower than that reported by (Ahmed, *et al.*, 2022; Asfaw, 2018; Koricho *et al.*, 2020; Liyew *et al.*, 2018; Mesfin, *et al.*, 2018; Mucheye and Yemata, 2020; Reshad, 2019; Woldemariam *et al.*, 2016) (Table 3). Climate and topography have broad effects on diversity across the landscape, whereas biological factors and availability of conducive environmental gradients influence diversity more at the site level (Brown *et a*l., 2007; DUKE *et al*., 1998).

Woody Vegetation structure

The BA of woody species of the forest was 90.00 m^2 per ha. This finding was comparable to the study reported by (Tilahun, 2015) for the Menagesha Amba Mariam forest and (Mucheye & Yemata, 2020) for the dry afromontane forest of the Gelawoldie community.

However, it was higher than dry afromontane forest at Bale Mountains National Park (in Adelle & Boditi forests) (Yineger *et al.*, 2008); Wanzaye natural forest (Asfaw, 2018); Yegof forest (Mesfin *et al*, 2018); Kumuli dry evergreen afromontane forest (Woldemariam *et al.*, 2016). Whereas Hurubu forest has less BA than Boda forest (Fikadu *et al.*, 2014) (Table 3).

Juniperus procera, *Podocarpus falcatus*, *Brucea antidysenterica* and *Olea europaea* were the top four largest woody species of the study site in terms of BA in decreasing order. *Juniperus procera* had highest reltive BA in Adelle forest (Yineger *et al.*, 2008); Boda forest (Fikadu *et al*, 2014); Menagesha Amba Mariam Forest (Tilahun, 2015); and Chilimo-Gaji dry afromontane forest (Mammo and Kebin, 2018). This indicate that *Juniperus procera* is ecologically important and dominant because BA increment is primarily controlled by competition and tree size. Contrary to this findings, other than *Juniperus procera* tree was recorded with highest BA in Boditi forest (Yineger *et al.*, 2008); Gelawoldie community forest ((Mucheye & Yemata, 2020); and Wanzaye natural forest (Asfaw, 2018). Tree size and competition within a forest stand are the main determinants of tree growth in terms of BA (Liu *et al.*, 2022; Tenzin *et al.*, 2017).

Species IVI is a measure of how dominant a species is in a given ecosystem and conservation status (Cottam & Curtis, 1956). Higher IVIs were recorded for *Juniperus procera*, *Osyris quadripartita*, and *Myrsine africana* in decreasing order in this study. *Juniperus procera* was the most ecologically important woody species due to its relatively higher frequency, density, and dominance in the forest. Nearly all species in this study showed variation in terms of their IVI, indicting different ecological importance of each species in the forest. This finding was in agreement with the study reported by (Ahmed *et al*, 2022; Fikadu *et al*, 2014; Koricho *et al.*, 2020; Mammo and Kebin, 2018; Tesfaye *et al*, 2019; Yahya *et al*, 2019) where *Juniperus procera* tree was the most ecologically important tree with highest IVI. This might be *Juniperus procera* tree is well adapted to the high pressure of disturbance and environmental factors that determine the distribution, abundance, and productivity of the species. Whereas, it was different to the study reported by (Asfaw, 2018; Mesfin *et al*, 2018; Reshad, 2019; Mucheye and Yemata, 2020;Woldemariam *et al.*, 2016) (Table 3).

Table 3: Comparison of floristic composition and structure of Hurubu forest with other afromontane natural forest

No	Nme of the forest	Florstic composition and structure indicators				Source
		Species richness	number of families	Basal Area (m^2 per ha)	Woody species with highest importance value index	
1	Hurubu forest	32	25	90.00	*Juniperus procera*	Present study
2	Bale Mountains National Park	32	-	26 and 23 in Adelle and Boditi respectivelly	-	(Yineger *et al.*, 2008)
3	Chilimo forest	31	25	-	*Juniperus procera*	(Mammo and Kebin, 2018; Tesfaye *et al*, 2019)
4	Yerer forest	31	23	-	*Juniperus procera*	(Yahya *et al*, 2019)
5	Kumuli forest	133	53	30.16	*Carisa spinarum*	(Woldemariam *et al*,

						2016)
6	Yegof forest	64	43	15.85	*Albizia gummifera*	(Mesfin *et al*, 2018)
7	Amoro forest	57	38	-	-	(Liyew *et al*, 2018)
8	Wanzaye forest	49	29	23.3	*Ficus sycomorus*	(Asfaw, 2018)
9	Ades forest	65	38	-	*Podocarpus falcatus*	(Reshad, 2019)
10	Debre Libanos	70	-	-	*Juniperus procera*	(Koricho *et al.*, 2020)
11	Gelawoldie forest	59	38	93.8	*B. abyssinica*	(Mucheye and Yemata, 2020)
12	Gennemar forest	55	34	-	*Juniperus procera*	(Ahmed *et al*, 2022)
12	Menagesha Amba Mariam forest	-	-	84.17	-	(Tilahun, 2015)
14	Boda forest	-	-	114.64	*Juniperus procera*	(Fikadu, *et al*, 2014)

The height and DBH class distribution of woody plant species in Hurubu forest indicated that a reverse *J shape* distribution. A similar pattern of population structure was reported by (Ahmed *et al*., 2022; Asfaw, 2018; Liyew *et al*., 2018; Mammo & Kebin, 2018; Mucheye & Yemata, 2020; Tilahun, 2015; Woldemariam *et al*., 2016; Yemata & Haregewoien, 2022; Yineger *et al*., 2011). This distribution pattern shows a normal population structure where most species had the highest number of individuals at lower height and DBH classes and gradually decreases in the number of individuals towards the higher classes. This form of distribution is an indicator of an overall healthy regenerating forest and also a secondary forest.

The relatively small number of high trees with height ≥ 30.1 m and DBH values ≥ 30.1 cm can be elucidated by growth trait of species and selective logging practice. There might be a limited number of species that naturally grow up to these heights and diameters (Hartshorn, 1980). The numbers of certain big tree species could have been already reduced by selective logging for local use, especially timber and charcoal production.

Woody Species Regeneration Status

The overall regeneration status of the woody species of the study site was satisfactory at community level showing fair regeneration status. The good regenerating woody species were *Calpurnia aurea* and *Myrsine africana*, while *Dodonaea angustifolia*, *Juniperus procera*, *Maytenus obscura*, *Olea europaea*, *Osyris quadripartite* and *Podocarpus falcatus* woody species had fair regeneration status from the top ten ecologically important woody species. This result was in accord with the study conducted by (Mucheye & Yemata, 2020) that indicated *Calpurnia aurea was* found to have good regeneration in the Gelawoldie community forest.

Species which were found in not regenerating category from the top ten ecologically important woody species were *Erica arborea* and *Myrica salicifolia*. Similarly, Tesfaye *et al*., (2019), reported that *Erica arborea* was not regenerating in Chilimo dry Afromontane.

Regarding to *Myrica salicifolia* species, poor regeneration status was documented in Susgen-Bosena forest (Awoke, 2018). Of all woody species of the study area, *Rytigynia neglect* and *Maesa lanceolata* had poor regeneration. For *Maesa lanceolata* woody species, Hailemariam & Temam (2018), reported that no saplings in Gole natural forest. The reason for not-regenerating and poorly regenerating species could be the intensive trampling by livestock. Becouse, browsing and grazing in the forest compacts the soil and thereby reduces the germination of the seeds from the soil seed bank. Furthermore, tropical dry forests are highly sensitive to climate change phenomena that drought, decreased precipitation amount and fluctuation of season, and increased temperature are indicated as strong drivers of tree/seedling mortality in these forests (Bhadouria *et al*., 2016; Siyum, 2020)

CONCLUSION AND RECOMMENDATIONS

This study revealed that the Hurubu forest has various species of woody plants. The characteristic tree species of dry afromontane tree species such as *Juniperus procera*, *Podocarpus falcatus* and *Olea europaea* were found to be dominant in this forest. About one-third of woody species, including the dominant tree species were either not regenerating or fail to regenerate due to frequent movement of livestock and human being in the forest.

Thus, we recommend conservation and management actions are mandatory for the entire forest. We suggest that free grazing within the forest and trampling of seedlings should be abandoned. Additionally, for the species *Erica arborea* and *Myrica salicifolia*, *special* consideration should be given to ensure the presence of their seedlings and saplings. Furthermore, enrichment planting should be undertaken for the species that has fewer seedlings than their saplings and mature trees.

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CONFLICT OF INTEREST

The authors declare that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Agajie Tesfaye *et al.* (2018). *Agricultural Production Systems in AGP-II Districts in the Central Highlands of Ethiopia. Research Report No 118*. EIAR. Available at: https://www.researchgate.net/publication/326031611.

Ahmed, S., Lemessa, D. and Seyum, A. (2022). 'Woody Species Composition, Plant Communities, and Environmental Determinants in Gennemar Dry Afromontane Forest, Southern Ethiopia', *Scientifica*, 2022, pp. 1–10. doi: 10.1155/2022/7970435.

Asefa, M. *et al.* (2020) 'Ethiopian vegetation types, climate and topography', *Plant*

Diversity, 42(4), pp. 302–311. doi: 10.1016/j.pld.2020.04.004.

Asfaw, A. G. (2018). 'Woody Species Composition, Diversity and Vegetation Structure of Dry Afromontane Forest, Ethiopia', *Journal of Agriculture and Ecology Research International*, 16(3), pp. 1–20. doi: 10.9734/jaeri/2018/44922.

Awoke, T. G. (2018). 'Floristic Composition and Structural Analysis of Susgen-Bosena Forest, Floristic Composition and Structural Analysis of Susgen-Bosena Forest, Ambasel District, North Wollo, Amhara Region, Ethiopia Tsegaye Gobezie Awoke*', *Abyssinia Journal of Science and Technology*, 3(November), pp. 24–35.

Ayanaw Abunie, A., & Dalle, G. (2018). Woody Species Diversity, Structure, and Regeneration Status of Yemrehane Kirstos Church Forest of Lasta Woreda, North Wollo Zone, Amhara Region, Ethiopia. *International Journal of Forestry Research*, *2018*. https://doi.org/10.1155/2018/5302523

Bekele, M. *et al.* (2015). *The context of REDD+ in Ethiopia: Drivers, agents and institutions.*, *CIFOR*. Bogor, Indonesia: CIFOR. doi: 10.17528/cifor/005744.

Bhadouria, R., Singh, R., Srivastava, P., & Raghubanshi, A. S. (2016). "Understanding the ecology of tree-seedling growth in dry tropical environment: a management perspective". *Energy, Ecology and Environment*, 1(5), 296–309. https://doi.org/10.1007/s40974-016-0038-3

Brown, R. L., Jacobs, L. A., & Peet, R. K. (2007). "*Species Richness: Small Scale*". ELS, 1–8. https://doi.org/10.1002/9780470015902.a0020488

Cottam, G. and CurtisT., J. (1956). 'Cottam&Curtis, 1956.pdf', *Ecology*, 37(3), pp. 451–460.

Dhaulkhandi, M., Dobhal, A., Bhatt, S., & Kumar, M. (2008). Community structure and regeneration potential of natural forest site in Gangotri, India. *Journal of Basic and Applied Science*, *4*(1), 49–52. https://www.researchgate.net/publication/237732681%0ACommunity

Duke, N. C., Ball, M. C., Ellison, J. C., & Ballt, M. C. (1998). gradients and distributional biodiversity Factors influencing in mangroves. *Global Ecology and Biogeography Letters*, 7(1), 27–47.

FAO, (2020). *Global Forest Resources Assessment 2020: Main report, Rome. https://doi.org/10.4060/ca9825en*. doi: 10.4324/9781315184487-1.

Fikadu, E., Melesse, M. and Wendawek, A. (2014) 'Floristic composition, diversity and vegetation structure of woody plant communities in Boda dry evergreen Montane Forest, West Showa, Ethiopia', *International Journal of Biodiversity and Conservation*, 6(5), pp. 382–391. doi: 10.5897/ijbc2014.0703.

Hailemariam, M. B. and Temam, T. D. (2018) 'The vegetation composition, structure and regeneration status of Gole Natural Forest, West Arsi Zone, Oromia Regional State, Ethiopia', *Journal of Agricultural Science and Botany*, 02(02). doi: 10.35841/2591-7897.2.2.10-21.

Hartshorn, G. S. (1980). Neotropical Forest Dynamics. *Biotropica*, 12(2), 23–30. https://doi.org/10.2307/2388152

IBC, (2012). *The state of forest genetic resources of Ethiopia*, Ibc, Addis Ababa.

Koricho, H. H. *et al.* (2020). 'Woody plant species diversity and composition in and around Libanos church forests of North Shoa Zone of Oromiya, Ethiopia', *Journal of Forestry Research*, 32(5), pp. 1929–1939. doi: 10.1007/s11676-020-01241-4.

Debre Lamprecht, H. (1989). *Silviculture in the Tropics: Tropical Forest Ecosystems and*

Their Tree Species-Possibilities and Methods for Their Long-Term Utilization. Federal Republic of Germany, Eschborn.

Liu, D., Zhou, C., He, X., Zhang, X., Feng, L., & Zhang, H. (2022). The Effect of Stand Density, Biodiversity, and Spatial Structure on Stand Basal Area Increment in Natural Spruce-Fir-Broadleaf Mixed Forests. *Forests*, 13(2), 1–13. https://doi.org/10.3390/f13020162

Lemlem, T., & Asfaw, G. (2018). Income contribution and adoption potential of apple based agroforestry on homestead farms in West and North Shoa zones of Ethiopia. *Journal of Development and Agricultural Economics*, *10*(6), 176–185. https://doi.org/10.5897/jdae2017.0886

Lemma, E. (2011). *Assessment of soil acidity and determination of lime requirnment for different land use types the case of Degem Wereda, north Shoa zone, northwestern Ethiopia*. M.Sc., 1–86. http://hdl.handle.net/123456789/3338

Liyew, B., Tamrat, B. and Sebsebe, D. (2018). 'Woody species composition and structure of Amoro Forest in West Gojjam Zone, North Western Ethiopia', *Journal of Ecology and The Natural Environment*, 10(4), pp. 53–64. doi: 10.5897/jene2018.0688.

Maarel, E. van der (2005). *Vegetation Ecology*, *Blackwell Science Ltd*. Blackwell Science Ltd.

Mammo, S. and Kebin, Z. (2018). 'Structure and natural regeneration of woody species at central highlands of Ethiopia', *Journal of Ecology and The Natural Environment*, 10(7), pp. 147–158. doi: 10.5897/jene2018.0683.

Magurran, A. (2004). Measuring Biological Diversity - Chapter 2. *Measuring Biological Diversity*, 18–215.

Martin, G. J. (1995). *Ethnobotany: A Methods Manual*. Chapaman and Hill, London.

MEFCC, (2018). *National Redd+ Strategy (2018 - 2030)*, National REDD+ Secretariat.

Mesfin, W., Zerihun, W. and Lulekal, E. (2018). 'Species diversity, population structure and regeneration status of woody plants in Yegof dry afromontane forest southeastern Ethiopia', *European Journal of Advanced Research in Biological and Life Sciences*, 6(4), pp. 20–34.

Mucheye, G. and Yemata, G. (2020). 'Species composition, structure and regeneration status of woody plant species in a dry Afromontane forest, Northwestern Ethiopia', *Cogent Food & Agriculture*, 6(1), p. 1823607. doi: 10.1080/23311932.2020.1823607.

Mueller-Dombois, D., & Ellenberg, H. (1974). *Aims and Methods of Vegetation Ecology* (p. 547). John Wiley and Sons, New York.

Negi CS. & Nautiyal S. (2005). "Phytosociological studies of a traditional reserve forest-Thal Ke Dhar, Pithoragarh, Central Himalayas (India)". *Indian Forester* 131: 519–534.

Nguyen, H., Lamb, D., Herbohn, J., & Firn, J. (2014). *Designing Mixed Species Tree Plantations for the Tropics : Balancing Designing Mixed Species Tree Plantations for the Tropics : Balancing Ecological Attributes of Species with Landholder Preferences in the Philippines*. *April*. https://doi.org/10.1371/journal.pone.0095267

Ostrom, E. (2007). *Field manual, International Forestry Resources and Institutions (IFRI) Research Program.* www.ifriresearch.net

Palit, D, Pal, S. & Chanda, S. (2012). Diversity and richness of plants in Darjeeling Himalaya with an eye on Gaddikhana forest beat, Senchal east zone forest range, Darjeeling. *Indian Journal of Forestry* 35: 39–44.

Reshad, M. (2019) 'Woody Species Richness and Diversity at Ades Dry Afromontane Forest of South Eastern Ethiopia', *American Journal of Agriculture and Forestry*, 7(2), p. 44. doi: 10.11648/j.ajaf.20190702.12.

Sarkar, M. & Devi, A. (2014). "Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India". *Tropical Plant Research* 1(2): 26–36]

Shiferaw, W., Lemenih, M., & Gole, T. W. M. (2018). Analysis of plant species diversity and forest structure in Arero dry Afromontane forest of Borena zone, South Ethiopia. *Tropical Plant Research*, *5*(2), 129–140. https://doi.org/10.22271/tpr.2018.v5.i2.018

Siyum, Z. G. (2020). Tropical dry forest dynamics in the context of climate change: syntheses of drivers, gaps, and management perspectives. *Ecological Processes*, 9(1). https://doi.org/10.1186/s13717-020-00229-6

Tesfaye, M. A., Gardi, O. and Blaser, J. (2019). *Temporal variation in species composition, diversity and regeneration status along altitudinal gradient and slope :* The case of Chilimo dry Afromontane forest in the Central Highlands of Ethiopia.

Tigabu, D. G. (2016). 'Deforestation in Ethiopia : Causes , Impacts and Remedy', *International Journal of Engineering Development and Research*, 4(2), pp. 204–209.

Tynsong, H., Dkhar, M., & Tiwari, B. (2022). "Tree diversity and vegetation structure of the tropical evergreen forests of the southern slopes of Meghalaya, North East India". *Asian Journal of Forestry*, *6*(1).

Tilahun, A. (2015). 'Structure and Regeneration Status of Menagesha Amba Mariam Forest in Central Highlands of Shewa, Ethiopia', *Agriculture, Forestry and Fisheries*, 4(4), p. 184. doi: 10.11648/j.aff.20150404.16.

Wassie, S. B. (2020). 'Natural resource degradation tendencies in Ethiopia: a review', *Environmental Systems Research*, 9(1), pp. 1–29. doi: 10.1186/s40068-020-00194-1.

Woldemariam, G., Demissew, S. and Asfaw, Z. (2016). 'Woody Species Composition, Diversity and Structure of Kumuli Dry Evergreen Afromontane Forest in Yem District, *Southern Ethiopia'*, 6(3), pp. 53–65. Available at: www.iiste.org.

Yahya, N., Gebre, B. and Tesfaye, G. (2019). 'Species diversity, population structure and regeneration status of woody species on Yerer Mountain Forest, Central Highlands of Ethiopia', *Tropical Plant Research*, 6(2), pp. 206–213. doi: 10.22271/tpr.2019.v6.i2.030.

Yemata, G. and Haregewoien, G. (2022). 'Floristic composition, structure and regeneration status of woody plant species in Northwest Ethiopia', *Trees, Forests and People*, 9(March), p. 100291. doi: 10.1016/j.tfp.2022.100291.

Yineger, H. *et al.* (2011). 'Floristic composition and structure of the dry Afromontane forest at Bale Mountains National Park, Ethiopia', *SINET: Ethiopian Journal of Science*, 31(2), pp. 103–120. doi: 10.4314/sinet.v31i2.66551.

APPENDICES

Appendix 1: Regeneration Status of Hurubu Forest, Ethiopia

No	Species Name	Number of Seedlings	Number of Saplings	Number of Matured Tree	Regeneration Status
1	*Acokanthera schimperi*	13	0	5	fair
2	*Albizia schimperiana*	19	10	11	fair
3	*Apodytes dimidiata*	0	0	3	not regenerating
4	*Bersama abyssinica*	3	8	12	fair
5	*Brucea antidysenterica*	0	0	24	not regenerating
6	*Buddleja polystachya*	0	0	13	not regenerating
7	*Calpurnia aurea*	56	45	4	good
8	*Carissa spinarum*	33	3	16	fair
9	*Croton macrostachyus*	23	12	11	good
10	*Dodonaea angustifolia*	40	11	70	fair
11	*Dombeya torrida*	0	0	6	not regenerating
12	*Dovyalis abyssinica*	14	23	20	fair
13	*Ekebergia capensis*	0	0	4	not regenerating
14	*Erica arborea*	0	0	81	not regenerating
15	*Ficus sur*	33	15	2	good
16	*Juniperus procera*	62	36	224	fair
17	*Maesa lanceolata*	0	3	2	poor
18	*Maytenus obscura*	44	0	27	fair
19	*Myrica salicifolia*	0	0	4	not regenerating
20	*Myrsine africana*	106	71	40	good
21	*Olea europaea*	11	0	30	fair
22	*Osyris quadripartita*	15	5	62	fair
23	*Pittosporum*	0	0	3	not regenerating

	viridiflorum				
24	*Podocarpus falcatus*	11	39	17	fair
25	*Pterolobium stellatum*	17	10	0	new
26	*Rhus glutinosa*	3	7	17	fair
27	*Rosa abyssincia*	10	5	16	fair
28	*Rytigynia neglecta*	0	3	32	poor
	Sum	513	306	756	

Source of data: from survey