Article

Investigating the floristic structure and composition of woodland forests in Godebe National Park, northwestern highlands of Ethiopia

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Abstract
Ethiopia is endowed with diversity of flora and fauna associated with its diverse topographical and climatic features. Protected areas have a great potential in preserving important flora and fauna resources. This study was conducted in Godebe National Park which is located in the dry lands of northwestern Ethiopia. The aim of this study was to investigate the woody species composition, diversity structure and regeneration status of Godebe National Park forest. Systematic random sampling technique was used to collect data following six line transects which were laid along vegetation types. The vegetation data were collected from 44 square plots each with a size of 400 m^2 (20 m × 20 m) for tree/shrub while subplots of size 100 m^2 (10 m × 10 m) and 25 m^2 (5 m × 5 m) for sapling and seedling respectively, were established in the main plots. Individual tree and shrub diameter at breast height (DBH) ≥2.5 cm and height ≥ 2 m were measured using caliper and hypsometer, respectively. DBH, frequency, density, and basal area were used for vegetation structure description while the density of mature trees, sapling, and seedling was used for analysis of regeneration. Microsoft Excel spread sheet programme and Shannon diversity and evenness indexes were used to analyze the vegetation data. Result revealed thata total of 59 woody species were identified; the total basal area and density of woody species were 47.16 m^2/ha and 6237 stems/ha, respectively. The structure of the study forest shows an inverted ‘J’ shape pattern which is an indication of its healthiness. The regeneration status of the study forest has also showed high regeneration capacity having higher density of seedlings and saplings than matured trees. Therefore, owing to strong potential of the park in terms of biodiversity conservation and tourism; preparation of management plan and promotion are needed; thereby sustainable park management can be ensured.

Keywords DBH; IVI; basal area; Godebe; diversity; structure; regeneration capacity; sustainable park management.

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1 Introduction

Ethiopia has a long history of biodiversity conservation. As depicted in the Ethiopian Wildlife Conservation Authority (EWCA, 2012) report, the first recorded indigenous conservation-oriented activity took place during the reign of Emperor Zerea Yacob (1434-1468) (Vreugdenhil et al., 2012). The Emperor noted the loss of forest cover on what is now known as 'Wachacha' Mountain near the capital, Addis Ababa. Seedlings and seeds were collected from Juniper forests areas elsewhere in the country, and the present 'Menagesha Suba' area was replanted. This occurred over 550 years ago, and the area is today known as the "Menagesha-Suba State Forest" (Eshetu, 2014). Indeed, this could be claimed as the oldest conservation area in Africa, or at least the oldest recorded formalized conservation effort on the continent Pankhurst (1989) cited in the works of (Vreugdenhil et al., 2012). But the country couldn't capitalize its effort on indigenous forest conservation practices which were started hundreds of years earlier than the world's establishment of Yellow stone National park in 1872 which was the first National Park in the world (Tilahun et al., 2017).

Ethiopia's Protected Area System is larger than the global average (12.6% of area of the earth's land surface), covering 15% of its landmass (Tilahun et al., 2017). The recently reformed Ethiopian Wildlife Conservation Authority (EWCA) is managing 52 protected areas covering 15% of the total area of the country (Abebe and Bekele, 2018). These includes 20 National Parks, 3 Sanctuaries, 2 wildlife reserves, 17 controlled hunting areas, 7 open hunting areas and 3 community conservation areas (Abebe and Bekele, 2018). Although, these protected areas conserve many spectacular habitats and species, they are under a severe threat of degradation by the anthropogenic factor (Tilahun et al., 2017). National parks are areas of land protected to conserve native plants and animals and their habitats, places of natural attractiveness, historic heritage and indigenous cultures. Also, these areas are centers of gene-banks and traditional ecological knowledge and have a direct economic and ecological benefit to the country; as well as bringing in international revenue from tourism and carbon trading (Abebe and Bekele, 2018). National parks safeguard habitats for vast range of indigenous plant and wildlife. They maintain biodiversity and endangered and endemic species or serves as in-situ conservation to ensure sustainability. However, these protected area in Ethiopia are facing challenges in meeting human and wildlife needs. These challenges are human trigger threats including grazing, settlement, agricultural expansion, fishing, fire and improper collection of non-timber forest products (Alelign et al., 2007). Most National parks and protected areas of Ethiopia are concentrated in the Dryland/wood land forests of the country; which harbors 77% of the protected areas (CIFOR, 2011). More than half of the oldest and established national parks including the Awash, Nech Sare, Omo, Gambella, Altash, Abijatashalla National Parks and many game reserves and sanctuaries are situated in drylands with huge potential for promoting ecotourism development in the country. As coined in the guidelines on sustainable forest management in dryland forests of Ethiopia, most of the vegetation resources are found in dry forests. They are an in separable part of the landscape, culture, and livelihoods (Atmadja and Eshete, 2019). Larger parts of dry land forests of Ethiopia categorized under the major forest classification of Acacia-Commiphora, and Combretum-Terminalia woodland and wooded grasslands (Friis, 2010). These woodland forests are characterized by a seasonal climate, with a dry season of 4-7 months (Arturo Sanchez et al., 2003). Above half of Ethiopia, the land surface is located in dry areas and associated tropical dry forests, which is being affected by ongoing deforestation (CIFOR, 2011). Thus, the floristic composition, regeneration status, and vegetation structure of National parks in the dryland forests of North western part of Ethiopia are crucial elements to clearly visualize the ongoing ecological dynamics affecting the vegetation of such an area.

Godebe National Park, hereafter (GoNP) was recognized as a national park in 2016. The park is rich in natural vegetation, although it is located in the dry lands of Ethiopia harbouring the Acacia-Commiphora, and Combretum-Terminalia woodlands and wooded grass lands which is known as a source of commercial forest products like frankincense and natural medicines (Eshete et al., 2011; Temesgen, 2020). Before it was designated as a park, GoNP has been used as a grazing area for local farmers and pastoralists for the last few decades and because of this the flora and fauna of the area became threatened. But, attributed to the considerable efforts made by the Amhara national regional state concerned officials, those threats are now reversed. Therefore, for effective management and conservation of the park, there is an urgent need to develop a sound management plan, and this required scientific information on species diversity, population structure and regeneration status of woody species in the park. However, GoNP to date lacks such scientific information on vegetation structure and regeneration status which is essential for sustainable management and conservation of the park. Hence, the main objective of this study was to fulfil the current information gap by investigating the floristic diversity, structure, composition, and regeneration status of GoNP woodland forests so as to convince decision makers for better management of the National Park.

2 Methodology

2.1 Description of the study area

GoNP is found in West Gondar Administrative Zone, West Armachiho District in Amhara Region. The park is 390 km far from Bahir Dar, the Capital city of Amhara region. The park is bordered with six rural kebeles from West Armachiho and Metema districts (on the East the park is bordered with ‘Dirmaga’ kebele, on the North with ‘Girarwuha’ and ‘Korhumer 01’ kebeles; on the West it is bordered with ‘Metema yohanis 01’ and ‘Zebachi Bahir’ kebeles, and on the South it is bordered with ‘Meshaha’ and ‘Shimelegara’ kebeles of Metema District). Geographically, it is located on $13^0$12’20.51’’ to $13^0$23’18.10’’ N latitude and $36^0$13’56.73’’ to $36^0$28’04.63’’ East longitudes with an altitudinal range of 718 m to 1229 m above sea level.

The park is situated under ‘Kolla’ agro ecological zone. The area is hotter throughout the year having annual temperature range of 38-48^{o}c and the area receives 600-1100 mm annual rain fall stayed from June – August (Hurni, 1998). Based on the long-term weather variable records of Global weather data records (1979 - 2013) calibrated with ground truth data from the nearest Abraha Jira Station, the mean annual rainfall is 780 mm with a Unimodal rainfall season ranges from June to August, which contributes about 82% of the annual rainfall of the study area (https://globalweather.tamu.edu).

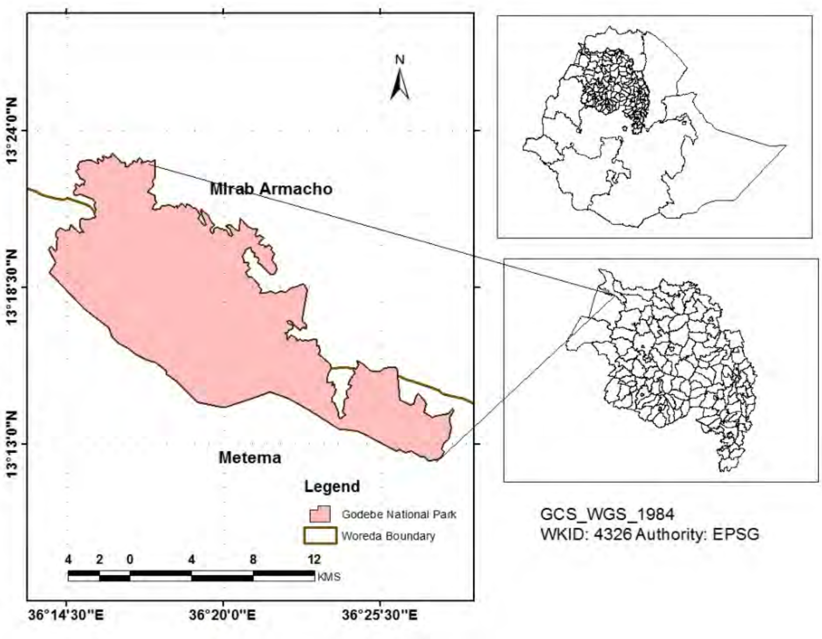


Fig. 1 Map of the study area.

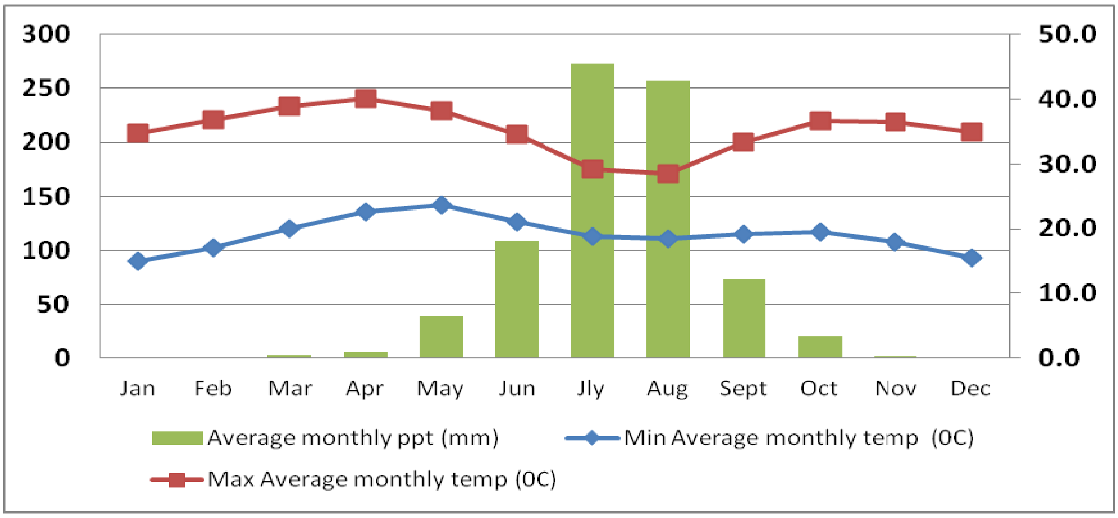


Fig. 2 Graphical representation of local meteorological data of the study area (Source: Global waether data for SWAT (https://globalweather.tamu.edu) and Calibrated with the mean annual ranfall of the nearest Abraha Jira Station.

Based on vegetation classification of Ethiopia Friis (2010) GoNP Forest communities are broadly categorized as Combretum-Terminalia and wooded grassland with *Terminalia brownii*, *Anogeissus leiococarrpa* and *Dalbergia melanoxylon* as frequent species; *Acacia-Commiphora* woodland and bushland proper with dominant *Acacia seyal*, *Acacia polycantha* and *Balanites aegyptiaca* species; and riparian/riverine forest with *Adansonia digitata*, *Diospyros mespiliformis* and *Tamarindus indica* as dominant species. The topography of GoNP forest is: 54.52% plain, 31.87% is sloppy, and 13.61% is gorgy lands. The major soil types of the area are *Eutric nitisols, Chromic vertisol*, and *Orthic luvisols*.

2.2 Method of vegetation data collection

The study area is selected purposively having extensive coverage of *Combretum-Terminalia* and *Acacia-Commiphora* wood land vegetation which is one of the very important vegetation in combating desertification, and having considerable potential to ecotourism and socio-economic benefits. Reconnaissance survey were done in the third week of November 2020, to collect some preliminary information, to have a mental picture and visual information on the study area in relation to its ecological attributes. During the preliminary surveying period, supportive information was collected from the GoNP office and local authorities of West Armachiho.

Systematic random sampling was employed for vegetation data collection to ensure sufficient representative samples from all gradient levels (Krebs, 1999; Kent, 2012). Following the procedure used in (Senbeta and Teketay, 2001; Fisaha et al., 2013; Temesgen, 2020). Transect lines were laid in the forest following vegetation distribution that may include the *Combretum-Terminalia*, the *Acacia-Commiphora* woodland, and bushland community, and the Riparian/ riverine vegetation community following the methodology used by Temesgen (2020). Species accumulation curve was used to determine minimal sample plot sizes as species accumulation curve illustrate the rate at which new species are found (Magurran, 2004). The adequacy of sample size was estimated by stopping sampling the point at which additional quadrats did not significantly affect the mean of species (Ellenberg, 1974). Based on the above principles 44 square sample quadrats (Fig. 3) with a size of 20 m by 20 m, 10 m by 10 m and 5 m by 5 m for mature trees/shrub, saplings and seedlings respectively, were laid down alternatively along the line transects at 200 m intervals along the linear transects using hand held GPS following (Taju et al., 2021). The first sampling plot was located randomly, and the subsequent plots were established at fixed intervals systematically.

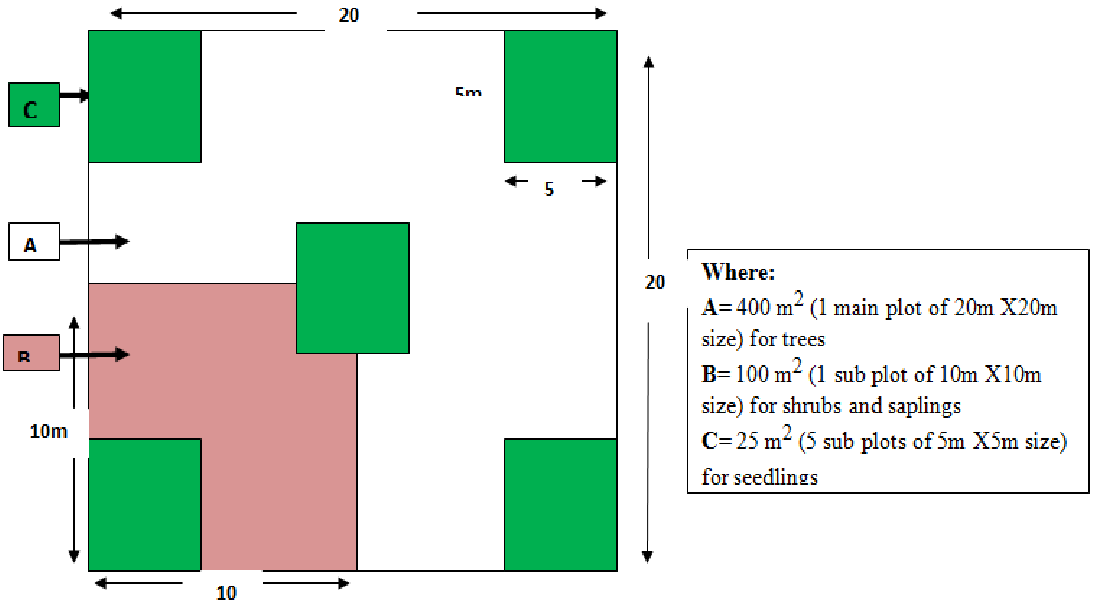


Fig. 3 Simple sketch of vegetation data collection designs.

To study the species composition and population structure of the forest, data on species identity, density, frequency, diameter at breast height and height were recorded for trees, tree/shrub, shrub and Seedlings/saplings in all sample quadrants following the procedures (Tilahun, 2015; Temesgen, 2020). All tree/shrub species rooted within the main plot and saplings and seedlings of woody species within the subplots were recorded. In each sampling plots, the diameter at breast height (DBH) (1.3 m above the ground) of each tree/shrub were measured using tree Caliper/diameter tape. The height and diameter were measured using a hypsometer and a diameter tape/Caliper respectively. For this study, the plants were categorized as seedling (height≤1 m), sapling (height between 1 m and 3 m) and tree/ shrub (height ≥2 m and DBH≥2.5 cm) following (Senbeta and Teketay, 2001; Fisaha et al., 2013; Melese and Ayele, 2017; Taju et al., 2021). In cases where a tree/shrub bole branched at breast height or below, the diameters were measured separately and considered as two trees and in cases where tree/shrub boles buttressed, DBH were measured from the point just above the buttresses.

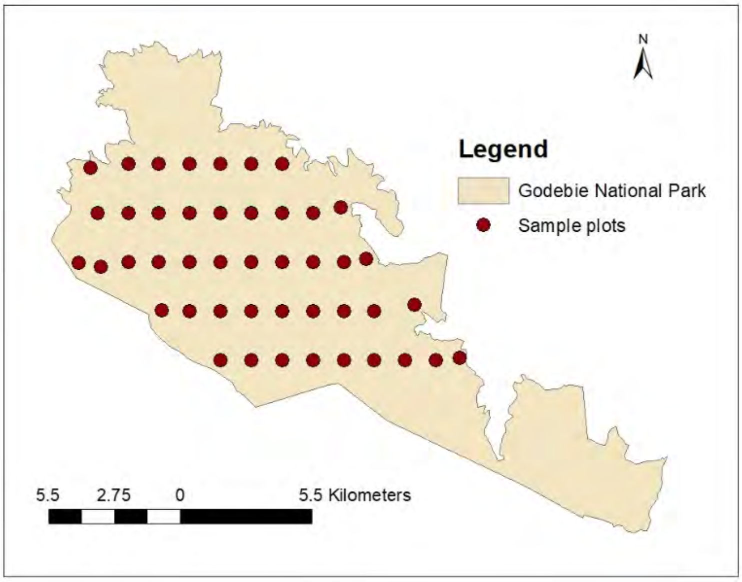


Fig. 4 Data collection transects and plots.

The identity of all species in the entire quadrate were identified and recorded in the field using Published volumes of Flora of Ethiopia (Edwards et al., 1995, 1997, 2000; Hedberg and Edwards, 1989; Hedberg et al., 2003; Bekele, 2007). Natural Database for Africa (NDA) virsion-2.0, August 2011 CD-ROM was also used for species identification. For species that was difficult to identify in the field, their local names were recorded, herbarium specimens were collected, pressed and dried properly using plant presses and identified in the office helped by botanists in the University of Gondar.

2.3 Method of data analysis

The species diversity of the forest are being computed using the Shannon Wiener's Diversity Index (*H'*), Simpson's Evenness or Equitability Index (*E*) using (Magurran, 1988). Frequency of a species was computed as the proportion of samples within which a species is found, and density were computed by converting the count from the total quadrats into a hectare basis as indicated in (Fisaha et al., 2013; Temesgen, 2020). All individuals of trees and shrubs with a DBH greater than 2 cm, and height greater than 2 m were measured (Girmay et al., 2020). Individuals were counted as seedlings (≤1 m and DBH≤2 cm) and saplings (height>1 m and DBH≤2 cm) following (Peters, 1996; Taju et al., 2021). The regeneration status of woody species were summarized based on the total count of seedlings and saplings of each species across all the sub quadrats (Senbeta and Teketay, 2001). The forest structure was described in terms of frequency, dominance, basal area per hectare (BA/ha) calculated from DBH≥2 cm. The Importance Value Index, hereafter (IVI) of each species were converted into a 100 percent scale. Different mathematical computations were employed for computing the raw data using the following equations and indexes:

$$\text{Species Diversity } (H') = -\sum_{i=1}^{s} \text{Pi} \ln(\text{Pi}) \quad (1)$$

$$Eveness \quad (J) = \frac{\sum_{i=1}^{S} pi \ln(pi)}{\ln(s)} \quad (2)$$

where

s = the number of species
pi= the proportion of individuals of the i^th^ species expressed as a proportion of the total abundance
ln= natural logarithm

$$\text{Frequency of species} = \frac{\text{Number of plots with that species}}{\text{Total number of plots}} \times 100 \quad (3)$$

$$\text{Relative frequency} = \frac{\text{Frequency of species species A}}{\text{Total frequency of all species}} \times 100 \quad (4)$$

$$\text{Density of species} = \frac{\text{Number of individuals of that species}}{\text{Area sampled}} \times 100 \quad (5)$$

$$\text{Relative density} = \frac{\text{Density of species A}}{\text{Total density of all species}} \times 100 \quad (6)$$

$$\text{Basal area (m)}^2 = \pi \frac{\text{DBH}^2}{4} \quad (7)$$

where

BA = basal area per tree in m^2
π = 3.1416
DBH = diameter at breast height in cm

$$\text{Dominance} = \frac{\text{Total basal area}}{\text{Area sampled}} \quad (8)$$

$$\text{Relative dominance} = \frac{\text{Dominance of species A}}{\text{Total dominance of all species}} \times 100 \quad (9)$$

Importance Value Index (IVI) = Relative density+ Relative frequency+ Relative dominance

$$IVI_i = \left[\frac{B_i}{\sum B_j} \times 100\right] + \left[\frac{n_i}{\sum n_j} \times 100\right] + \left[\frac{f_i}{\sum f_j} \times 100\right] \quad (10)$$

where
IVI_i = the Importance Value Index (IVI) of the i^th^ species
n_i = the number of individuals of the i^th^ species
n_j = the sum of individual trees of all species
B_i = the basal area of the i^th^ species
B_j = the total basal area (m^2) of all specie
f_i = the absolute frequency of the i^th^ species
f_j = the total sum of the absolute frequencies of all species.

The regeneration status of the major study species in the study area were summarized based on the total count of seedlings and saplings of each species across all quadrats and presented in tables, graphs and frequency histograms (Temesgen, 2020). Individuals were counted as seedlings with a height of ≤1 m and DBH of ≤2 cm) and saplings (with a height > 1 m and with a DBH≤2 cm). The regeneration status of the forest was assessed using the following categories used by Fisaha et al. (2013). ‘Good’, if presence of seedling > sapling > adult trees; ‘Fair’, if presence of seedling > sapling < adult trees ‘Poor’, if a species survives only in the sapling stage, but not as seedlings (even though saplings may be <, >, or = mature trees); ‘None’, if a species is absent both in sapling and seedling stages, but present as mature; and ‘New’, if a species has no mature, but only sapling and/or seedling stages.

3 Results

3.1 Woody species richness, composition and diversity

A total of59 woody species belonging to 43 genera and 29families were identified in GoNP Forest. Regarding the habits of the species, 29 (49%) were trees, 28 (47%) trees/shrubs and 2 (4%) were shrubs, as shown in (Table 2) and (Fig. 5). *Fabaceae* was the dominant family with 12 species (20.33%) followed by *Combretaceae* with 7 species (11.9%); *Rhamnaceae, Euphorbiaceae*, and *Moraceae* have equally three species (15.25%); *Anacardiaceae*, *Rubiaceae*, *SterculiaceaeTiliacea*, *Bigonaseae*, *Celastrraceae*, and *Opiliacea* have two species each (23.72%); from total; and the rest 17families represented by a single species each (28.81% from total species). Out of 59 species, 7 species were not represented in tree life forms; but in seedling and sapling life forms (Table 1).

Table 1 Woody species identified in the study forest.

No.	Species name	Family name	Vernacular name (Amharic)	Habit
1	*Acacia polyacantha Willd.*	*Fabaceae*	Gimarda Girar	T
2	*Acacia Senegal*	*Fabaceae*	Sebansa Girar	S/T
3	*Acacia seyal Del.*	*Fabaceae*	Key Girar	T
4	*Acacia sieberiana Dc.*	*Fabaceae*	Nechi Girar	T
5	*Adansonia digitata*	*Bombacaceae*	Diza	T
6	*Albizia amara*	*Fabaceae*	Tiya	S/T
7	*Albizia malacophylla (A. Rich.)*	*Leguminosae*	Tifasha/Nfasha	T
8	*Allophylus rubifolius*	*Sapindaceae*	Tatesa	S/T
9	*Anogeissus leiocarrpa (A. Rich)*	*Combretaceae*	Kirkira	T
10	*Asparagus Africanus Lam.***	*Asparagaceae*	YesetKest	S
11	*Azadiractha indica A.Juss.**	*Meliaceae*	Neem, Kinin	T
12	*Balanites aegyptiaca (L.) Del.*	*Balanitaceae*	Lalo	T
13	*Boscia angustifolia A. Rich.*	*Capparidaceae*	Shisha	T
14	*Boswellia papyrifera Hochst. ex A. Rich*	*Burseraceae*	Walia Meker	T
15	*Breonadias alicina*	*Rubiaceae*	Dembeka	S/T
16	*Calotropis procera*	*Asclepiadaceae*	Tobiya	S
17	*Cobretum adenogonium Steud. ex A. Rich*	*Combretaceae*	TikurAbalo	T
18	*Cobretum Molle*	*Combretaceae*	Nech Abalo	T
19	*Combretum aculeatum Vent.**	*Combretaceae*	sebaha	S/T
20	*Combretum collinum Fresen*	*Combretaceae*	Chamda	T
21	*Dalbergia melanoxylon Guill. & Perr*	*Fabaceae*	Zobi	S/T
22	*Dichrostachys cinerea Wight & Am*	*Fabaceae*	Gorgoro/ Ader	S/T
23	*Diospyros mespiliformis*	*Ebenaceae*	Serkin	T
24	*Dombeya Kirikii*	*Sterculiaceae*	Neftelo	S/T
25	*Erythrina abyssinica*	*Fabaceae*	Quara	S/T
26	*Ficus sur*	*Moraceae*	shola	T
27	*Ficus sycomorus L.*	*Moraceae*	Bamba	T
28	*Ficus thonningii Blume.*	*Moraceae*	Chibaha	T
29	*FlueggeavirosaGuill. & Perr.*	*Euphorbiaceae*	Ayahada	S/T
30	*Gardenia ternifolia Schumach & Thonn*	*Rubiaceae*	Gambilo	T
31	*Grewia bicolar*	*Tiliaseae*	Sumaya	S/T
32	*Grewia mollis*	*Tiliaseae*	Lenquata	S/T
33	*Jatropha curcas L.**	*Euphorbiaceae*	Jatropha	S/T
34	*Kigelia africana*	*Bignoniaceae*	Adendin	T
35	*Lanneafruticosa (Hochst. ex A. Rich) Engl***	*Anacardiaceae*	Digunguna	T

No.	Species name	Family name	Vernacular name (Amharic)	Habit
36	*Lannea welwitschii*	*Anacardiaceae*	Dergeja	T
37	*Lonchocarpus laxiflorus Guill. & Perr.***	*Fabaceae*	Zengerifa/Hameja	T
38	*Maytenus senegalensis Forssk*	*Celastraceae*	Dingayseber	S/T
39	*Maytenus undata (Thunb.)*	*Celastraceae*	YeberehaAtata	S/T
40	*Ocimum lamiifolium***	*Lamiaceae*	Damakessie	S
41	*Opilia campestris*	*Opiliaceae*	Arina	S/T
42	*Osyris quadripartite***	*Santalaceae*	Keret	S/T
43	*Oxytenanthera abyssinica**	*poaceae*	Shimel	T
44	*Pavonia burchelli***	*Malvaceae*	Nechilo	S
45	*Piliostigma thonningii Milne-Redth*	*Fabaceae*	YekolaWanza	T
46	*Pterocarpus lucens Guill. & Perr*	*Fabaceae*	Charia	T
47	*Rhus glutinosa*	*Anacardiaceae*	Embus/Kemo	S/T
48	*Salix spp.*	*Salicaceae*	WonzAdmik/Haya	S/T
49	*Securidaca longepedunculata*	*Polygalaceae*	Etsemenahay	S/T
50	*Securinega virosa (Roxb.) Baill.*	*Euphorbiaceae*	Ashama	S/T
51	*Sterculea setigera Del.*	*Sterculiaceae*	Derlie	T
52	*Stereospermum kunthianum Cham*	*Bignoniaceae*	Zana	S/T
53	*Tamarindus indica L.*	*Fabaceae*	Kumer	T
54	*Terminalia browni*	*Combretaceae*	Woyiba	T
55	*Terminalia laxiflora Engl. & Diels*	*Combretaceae*	Wombella	T
56	*Ximenia americana L.*	*Olacaceae*	Enkoy	S/T
57	*Ziziphus abyssinica Hochst. ex A. Rich***	*Rhamnaceae*	Abeterie	S/T
58	*Ziziphus mauritiana*	*Rhamnaceae*	Yahya Gava	S/T
59	*Ziziphus spina-christi (L.) Desf.*	*Rhamnaceae*	Geva	S/T

*Species recorded out of sample plots;
**Species which are represented only in seedling and sapling life form.

A measure of species diversity is an important parameter of a plant community that plays a vital role in ecology and conservation biology (Mesfin, 2018). The overall Shannon-Wiener diversity (*H'*) and equitability (evenness) index values of woody species in the GoNP were 3.64 and 0.93 respectively. As the result shows the species diversity index of GoNP forest falls in to the higher diversity index as the normal range of Shannon-Wiener diversity index is 1.5-3.5 and rarely exceeded to 4.5 (Kent, 2012). The higher woody species diversity in the study forest is attributed to the equitable distribution of woody species in the entire area of the study forest.

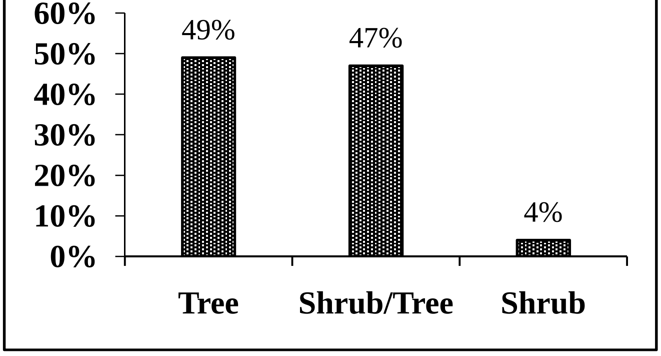


Fig. 5 Forest composition of GoNP forest.

3.2 Vegetation structure

3.2.1 Density and frequency of woody species

The overall density of woody species in GoNP forest was 6237 stems /ha in the study quadrates. The woody species having highest density were *Acacia seyal, Dalbergia melanoxylon, Acacia Senegal, Allophylus rubifolis, Pavonia burchelli,* and *Combretum molle* which covers 37% of the total density of the forest (Table 3). Coming to the frequency of species: *Acacia polycantha, Combretum collinum, Anogeissus leiocarpa, Dalbergia melanoxylon, Acacia seyal*, and *Ziziphus spina christ* which was found in 58.8%, 56.8%, 54.54%, 38%,34.09% and 34% of the study quadrates respectively (Table 1). Frequency contributes to indicate homogeneity and heterogeneity of vegetation of a given species (Temesgen, 2020). The study forest has lower species heterogeneity because the higher percentage of species were found in the higher frequency class than in the lower class (Fig. 6). According to Burju et al. (2013) cited in Temesgen (2020), low value in lower frequency and high value in higher frequency class indicate similar species composition. The lower species heterogeneity may be attributed to similarity in different biophysical parameters like elevation and Agro-ecology and species preferences in the area; since the forest is *Combretum terminalia* dominated woodlands.

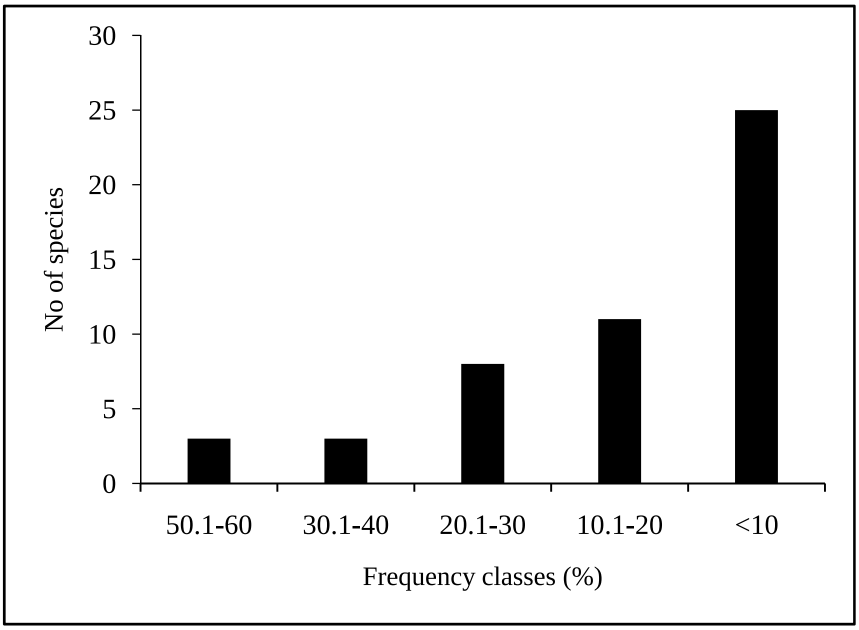


Fig. 6 Woody species frequency class distribution of GNP (1) 50.1–60%, (2) 30.1–40%, (3) 20.1–30%, (4) 10.1–20%, and (5) ≤10%.

3.2.2 Basal area of the study forest

The overall basal area of woody species with a diameter at breast height of (DBH) ≥2.0 cm in the study forest was 47.16 m^2/ha and much of the basal area were contributed by few woody species which are found in lower relative density and frequency like *Adansonia digtate, Diospyros mespiliformis, Tamarindus indica, Anogeissus leiocarpa,* and *Sterculia setigera* which contributes (63%) of the total basal area of the study forest. This was happened because, these woody species are few in number but exhibits higher individual girth/DBH as they are a riverine type of woody species. For example, if we take *Adansonia digitate* it has 1.4 and 1.5 relative density and frequency respectively; but, has 18m^2/ha of basal area which accounted 38.16% of the total basal area of the study forest (Table 2).

Table 2 Density, frequency,dominance and importance value index of woody species.

Species	D	RD	F	RF	DO	RDO	IVI
Acacia polycantha willd	139.00	2.23	56.82	7.53	0.81	1.72	11.48
Acacia senegal	237.50	3.81	4.55	0.60	0.10	0.20	4.62
Acacia seyal Del.	518.33	8.31	34.09	4.52	1.33	2.82	15.65
Acacia sieberiana Dc.	139.29	2.23	15.91	2.11	0.13	0.28	4.62
Adansonia digitata	90.00	1.44	11.36	1.51	18.00	38.17	41.12
Albizia amara	75.00	1.20	4.55	0.60	0.08	0.17	1.98
Albizia malacophylla (A. Rich.)	25.00	0.40	2.27	0.30	0.00	0.00	0.71
Allophylus rubifolis	320.83	5.14	13.64	1.81	0.77	1.64	8.59
Anogeissus leiocarrpa (A. Rich)	180.21	2.89	54.55	7.23	3.28	6.96	17.08
Balanites aegyptiaca (L.) Del.	80.77	1.30	29.55	3.92	0.70	1.49	6.70
Boscia angustifolia A. Rich.	75.00	1.20	6.82	0.90	0.05	0.10	2.20
Boswellia papyrifera Hochst. ex A.Rich	222.22	3.56	20.45	2.71	0.44	0.94	7.21
Breonadia salicina	93.75	1.50	9.09	1.20	0.14	0.29	3.00
Calotropis procera	66.67	1.07	6.82	0.90	0.05	0.10	2.07
Cobretum adenogonium Steud.ex A. Rich	45.83	0.73	13.64	1.81	0.47	1.00	3.55
Cobretum Molle	275.00	4.41	4.55	0.60	0.14	0.30	5.31
Combretum collinum Fresen	112.00	1.80	56.82	7.53	1.35	2.86	12.18
Dalbergia melanoxylon Guill. & Perr	444.12	7.12	38.64	5.12	1.43	3.02	15.27
Dichrostachys cinerea Wight & Am	136.36	2.19	25.00	3.31	0.05	0.10	5.60
Diospyros mespiliformis	190.91	3.06	25.00	3.31	6.57	13.93	20.30
Dombeya Kirikii	158.33	2.54	6.82	0.90	0.01	0.03	3.47
Erythrina abyssinica	25.00	0.40	2.27	0.30	0.00	0.00	0.71
Ficus sur	50.00	0.80	11.36	1.51	0.02	0.05	2.36
Ficus sycomorus L.	25.00	0.40	2.27	0.30	0.21	0.45	1.15
Ficus thonningii Blume.	93.75	1.50	9.09	1.20	2.01	4.25	6.96
Flueggea virosa Guill. & Perr.	109.38	1.75	18.18	2.41	0.03	0.07	4.23
Gardenia ternifolia Schumach & Thonn	33.33	0.53	6.82	0.90	0.02	0.04	1.48
Grewia bicolar	100.00	1.60	9.09	1.20	0.03	0.05	2.86
Grewia mollis	75.00	1.20	4.55	0.60	0.08	0.17	1.97
Kigelia africana	125.00	2.00	2.27	0.30	0.37	0.78	3.09
Lannea fruticosa (Hochst. ex A. Rich) Engl	121.88	1.95	18.18	2.41	0.57	1.20	5.57
Lannea welwitschii	33.33	0.53	6.82	0.90	0.05	0.11	1.54
Maytenus senegalensis Forssk	200.00	3.21	9.09	1.20	0.15	0.32	4.73
Maytenus undata (Thunb.)	25.00	0.40	9.09	1.20	0.01	0.02	1.62
Opilia campestris	200.00	3.21	2.27	0.30	0.01	0.01	3.52
Pavonia burchelli	283.33	4.54	6.82	0.90	0.11	0.23	5.68
Piliostigma thonningii (Schumach.)Milne-Redth	25.00	0.40	11.36	1.51	0.13	0.27	2.17
Pterocarpus lucens Guill. & Perr	108.33	1.74	13.64	1.81	0.70	1.48	5.03
Rhus glutinosa	50.00	0.80	2.27	0.30	0.00	0.00	1.11
Salix spp.	50.00	0.80	2.27	0.30	0.01	0.03	1.13
Securidaca longepedunculata	50.00	0.80	2.27	0.30	0.01	0.01	1.11
Securinega virosa (Roxb.) Baill.	150.00	2.41	4.55	0.60	0.00	0.01	3.02
Sterculea setigera Del.	95.83	1.54	13.64	1.81	1.39	2.94	6.28
Stereospermum kunthianum Cham	60.00	0.96	22.73	3.01	0.25	0.52	4.50

Species	D	RD	F	RF	DO	RDO	IVI
Tamarindus indica L.	55.00	0.88	22.73	3.01	3.49	7.41	11.30
Terminalia browni	125.00	2.00	20.45	2.71	0.59	1.24	5.96
Terminalia laxiflora Engl. & Diels	58.33	0.94	13.64	1.81	0.47	1.00	3.75
Ximenia Americana L.	50.00	0.80	9.09	1.20	0.01	0.01	2.02
Ziziphus mauritiana	80.00	1.28	22.73	3.01	0.09	0.19	4.48
Ziziphus spina-christi (L.) Desf.	153.33	2.46	34.09	4.52	0.48	1.01	7.99
	6237.00	100	754.55	100	47.16	100	300

D=Density; RD= relative density; F=frequency; RF= Relative frequency; DO=dominance; RDO= Relative dominance; IVI= Importance value index.

3.2.3 The importance value index of the study forest

The importance value index hereafter (IVI) of woody species in GoNP forest ranged from 0.70% to 41.12%. The highest IVI was documented for *Adansonia digitata* (41.12%) followed by *Diospyros mespiliformis* (20.3%), *Anogeissus leiocarrpa* (17.08%), *Acacia seyal* (15.65%), *Dalbergia melanoxylon* (15.27%), *Combretum collinum* (12.18%), *Acacia polycantha*(11.48%), *Tamarindus indica* (11.3% each), *Allophylus rubifolis* (8.59%), *Ziziphus spina-christi* (7.9%), and *Boswellia paprifera* (7.2%) had their IVI value above 7% which were the most ecologically important species in the study forest. The tree species in the forest were grouped into five classes based on their IVI values for conservation priority as follows: (1)>15.1%, (2) 10.1–15%, (3) 5.1–10%, (4) 1.1–5%, and (5) ≤1%. 28% of species were found in importance value index (IVI) class 1.1-5% while the lowest importance value index (IVI) was in class of ≤1% (Fig. 7).

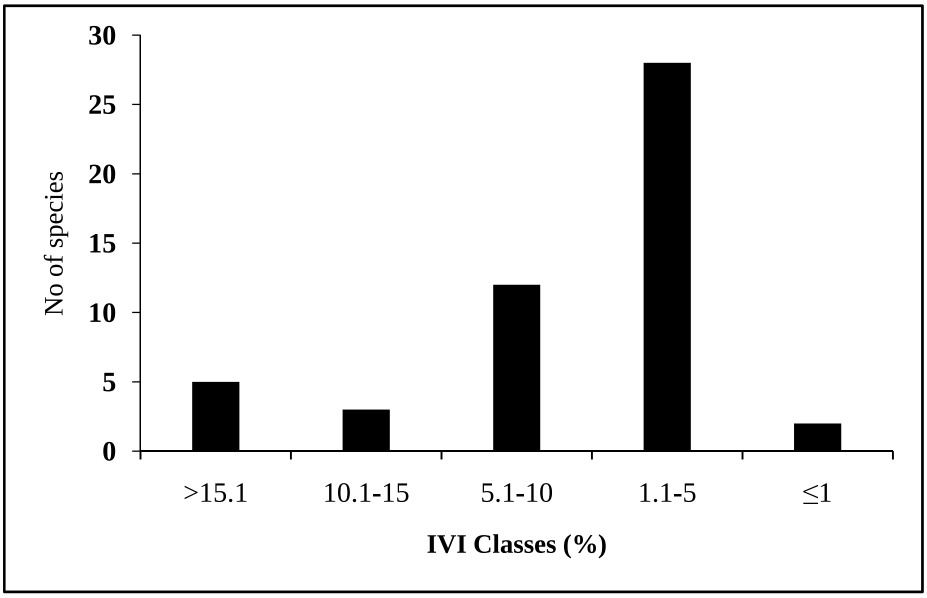


Fig. 7 Importance Value Index classes (%).

3.2.4 Horizontal population structure of GoNP forest

The cumulative diameter class distribution pattern of GoNP Forest reveals an inverted -J-shape. However, the density of woody plants generally declined with increasing diameter classes. The distribution of trees and shrubs was categorized in to eight DBH classes: 2–10 cm,10.1–20 cm, 20.1–30 cm, 30.1–40 cm, 40.1–50 cm, 50.1–60 cm, 60.1–70 cm, 70.1–80 cm, and >80.1 cm. The majority (92%) of the total tree density was distributed between the first and third diameter classes, whereas, 8% of tree density was found to be between fourth to eighth diameter classes (Fig. 8). In GoNP, the highest diameter at breast height was recorded for eight individuals of *Adansonia digitata* (108–375 cm). As the result revealed the population structure of the study forest was in a good recruitment level and hence it is a healthy forest. But there is a problem of mother tree disappearance if a strict measure was not taken to stop selective logging of big trees and recurrent fire incidences which is common to the area.

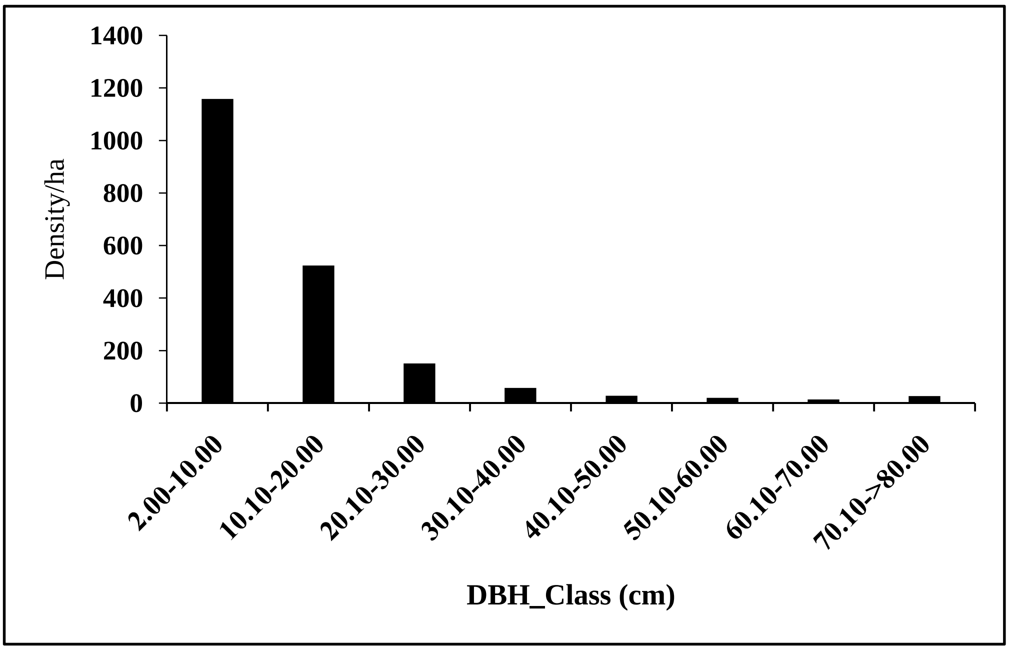


Fig. 8 Horizontal population structure of GoNP forest.

3.2.5 Height class distribution of tree and shrub species in GoNP

Tree height distribution was classified into seven classes: ≤10 m, 10.1–20 m, 20.1–30 m, 30.1–40 m, 40.1–50 m, 50.1–60 m, and >60.1 m. There was a higher number of tree and shrub individuals in the height class ≤10 m, which accounts for about 1549 stems/ha (78%) of the total height classes. Species such as *Diospyros mespiliformis*, *Adansonia digitate*, *Ficus sur*, *Ficus thoningii*, *Boswellia paprifera*, and *Combretum adengonium* had 66 individuals having above 20m height. The highest height was recorded for a species *Diospyros mespiliformis* (66 m) (Fig. 9).

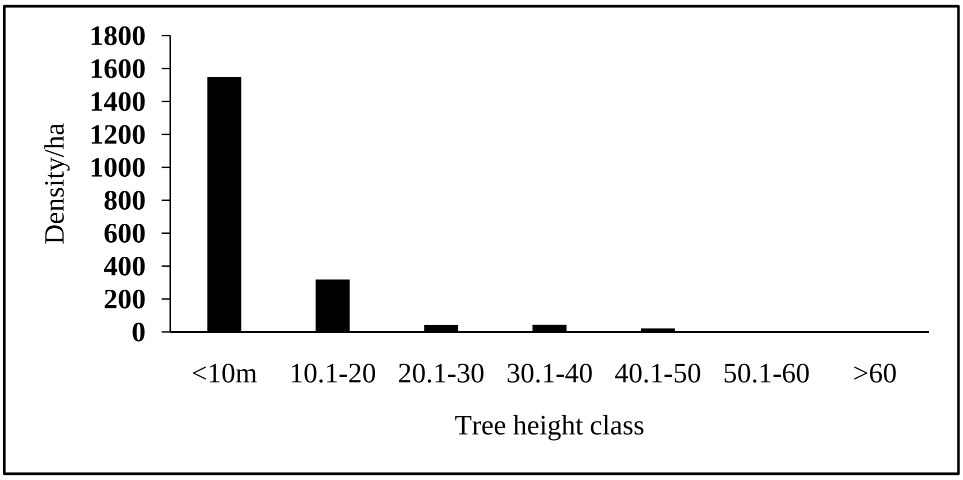


Fig. 9 Height class distribution of woody species in GoNP forest.

Table 3 The ten most dominant woody species to basal area (BA) in GoNP forest.

No	Scientific name	Density (stems ha^{-1})	Average DBH (m)	Basal area ($m^2.ha^{-1}$)	Relative BA (%)
1	*Adansonia digitate*	90	98.4	18	38.17
2	*Diospyros mepiliformis*	191	34.58	6.57	13.93
3	*Tamarindus indica*	55	53.93	3.49	7.41
4	*Anogeissus leiocarpa*	180	13.25	3.28	6.96
5	*Ficus thonningi*	94	42.05	2	4.25
6	*Dalbergia melanoxylon*	444	8.8	1.43	3.02
7	*Sterculea setigera*	96	33.26	1.38	2.94
8	*Combretum collinum*	112	13.34	1.34	2.86
9	*Acacia seyal*	518	9.05	1.32	2.82
10	*Acacia polycantha*	139	9.1	0.81	1.72

3.2.6 Population structure of selected tree species

The analysis of population structure of GoNP forest individual tree species divided in to eight diameters at breast height (DBH) classes dominantly showed five patterns of population structure:

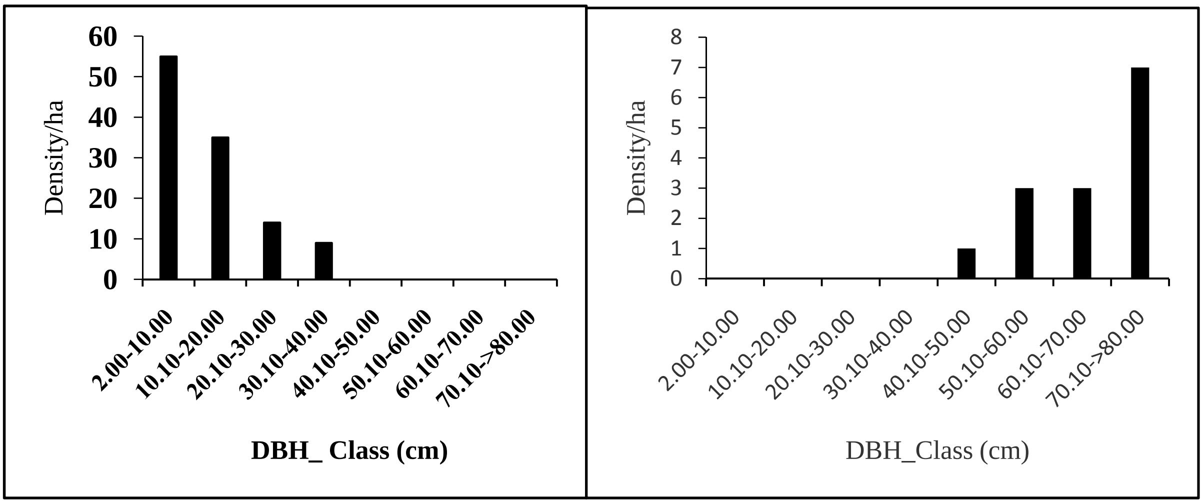
(1) The distribution showed inverted ‘J’ shaped structure in which the highest proportion of individuals were present in lower diameter at breast height classes and those species represented in such pattern were *Combretum collinum, Acacia polycantha, Acacia seyal*, and *Anogeissus leiococarpus* (Fig. 10(a)).

(2) The distribution showed a J-shaped structure in which a higher proportion of individuals were present in higher diameter at breast height classes and the trend decreased towards the lower diameter classes. Species in this pattern were *Adansonia digitata, Ficus thonningii* and *Tamarindus indica* (Fig. 10(b)).

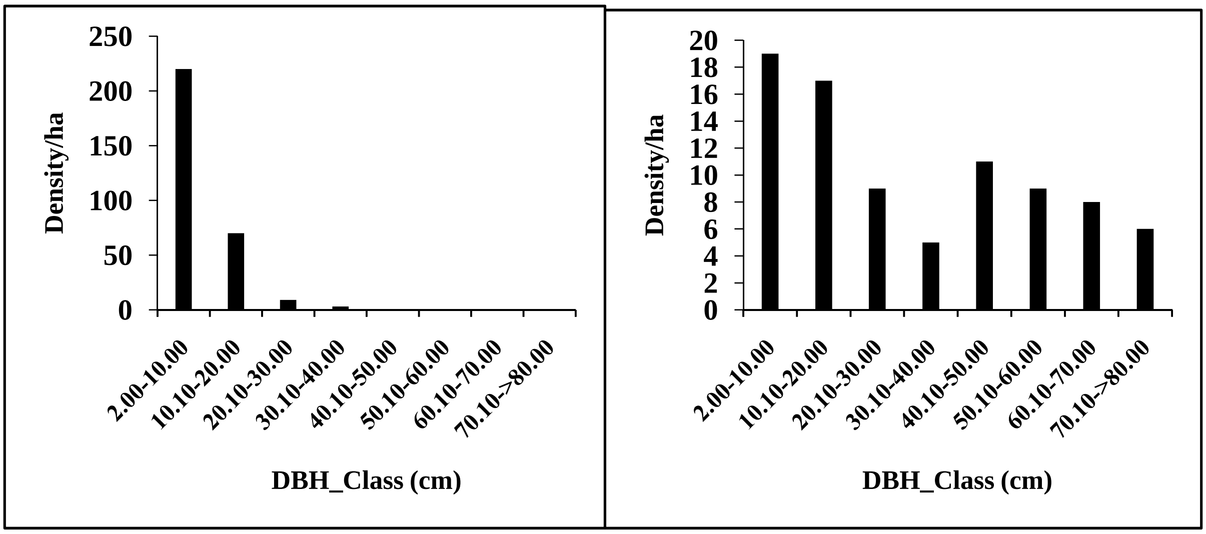
(3) The distribution showed an inverted ‘F’ shaped a higher proportion of individuals were concentrated in the first, second, and third diameter at breast height classes while absent in the rest of DBH classes and the only species represented in such a pattern is *Dalbergia melanoxylon* species (Fig. 10(c)).

(4) The distribution showed uniform shaped in which considerable number of individuals represented in all diameter at breast height classes. The representative species in this pattern is *Diospyros mespiliformis* (Fig. 10(d)).

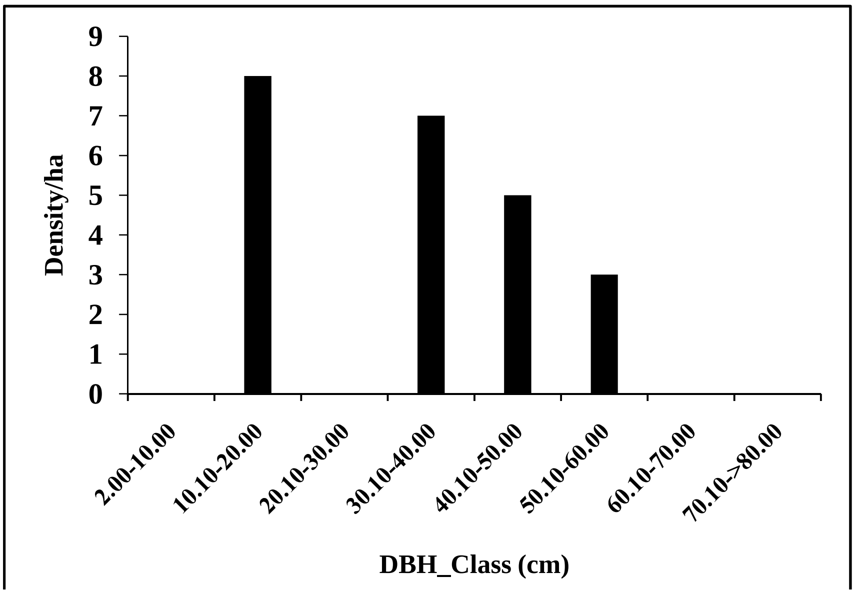
(5) Irregular distribution over diameter classes. Some of diameter classes had a small number of individuals while other diameter classes had a large number of individuals and even some of them were missed. The species represented in this pattern of distribution is *Sterculia setigeria* (Fig. 10(e)).



(a) (b)



(c) (d)



(e)

Fig. 10 Representative population structure patterns of each tree species in Godebe National Park (a) *Combretum collinum*, (b) *Ficus thonningii*, (c) *Tamarindus indica*, (d) *Diospyros mespiliformis*, and (e) *Sterculia setigeria*.

3.3 Regeneration status of woody species in GoNP forest

Out of the total 59 woody species encountered in the study area the density of seedling sapling, and mature trees were 18312, 6578, and 6237 respectively (Fig. 12). Ten woody species namely *Ficus sur, Ficus sycomorus, Ficus thonningii, Grewia bicolar, Kigelia Africana, Lannea fruticose, Opilia campestris, Rhus glutinosa, Securidaca longepedunculata*, and *Terminalia laxiflora* had never represented with seedling and sapling life stages. Which means almost 17% of those woody species found in GoNP forest were not represented with both seedlings and saplings stages and hence they are in verge of disappearance. Similarly, species like *Adansonia digitata, Albizia amara, Breonadia salicina,* and *Erythrina abyssinica* were not represented with seedling life stages. *Flueggea virosa* and *Sterculea setigera* were also had not saplings at all. Relatively higher sapling density was exhibited by species such as *Acacia seyal*, *Dichrostachys cinerea*, *Anogeissus leiocarrpa*, *Acacia sieberiana,* and *Maytenus senegalensis*. And those woody species having highre density of seedlings were *Dichrostachys cinerea,Maytenus senegalensis*, *Acacia polycantha*, *Pavonia burchelli*, and *Acacia seyal* (Table 4).The absence of seedling and sapling may be attributed to anthropogenic disturbance and seed predation (Temesgen, 2020).

Table 4 Density of woody species along life forms.

Species	**Density of trees/ha**	**Density of Saplings/ ha**	**Density of Seedlings/ ha**	**Aggregated Density/ ha of the forest in all life forms**
Acacia polycantha willd	139.00	259.52	1082.67	1481.19
Acacia senegal	237.50	0.00	491.43	728.93
Acacia seyal Del.	518.33	430.77	886.67	1835.77

Species	**Density of trees/ha**	**Density of Saplings/ ha**	**Density of Seedlings/ ha**	**Aggregated Density/ ha of the forest in all life forms**
Acacia sieberiana Dc.	139.29	325.00	377.14	841.43
Adansonia digitata	90.00	0.00	0.00	90.00
Albizia amara	75.00	0.00	0.00	75.00
Albizia malacophylla (A. Rich.)	25.00	0.00	160.00	185.00
Allophylus rubifolis	320.83	300.00	620.00	1240.83
Anogeissus leiocarrpa (A. Rich)	180.21	387.50	411.43	979.14
Asparagus Africanus Lam.	0.00	0.00	160.00	160.00
Balanites aegyptiaca (L.) Del.	80.77	222.22	628.57	931.56
Boscia angustifolia A. Rich.	75.00	275.00	651.43	1001.43
Boswellia papyrifera Hochst. ex A.Rich	222.22	120.00	368.00	710.22
Breonadiasalicina	93.75	0.00	0.00	93.75
Calotropis procera	66.67	0.00	120.00	186.67
CobretumadenogoniumSteud.exA.Rich	45.83	0.00	160.00	205.83
CobretumMolle	275.00	100.00	80.00	455.00
Combretum collinum Fresen	112.00	238.89	320.00	670.89
Dalbergia melanoxylon Guill. & Perr	444.12	270.00	320.00	1034.12
Dichrostachys cinerea Wight & Am	136.36	417.86	1244.44	1798.67
Diospyros mespiliformis	190.91	308.33	880.00	1379.24
Dombeya Kirikii	158.33	90.00	186.67	435.00
Erythrina abyssinica	25.00	0.00	0.00	25.00
Ficus sur	50.00	0.00	0.00	50.00
Ficus sycomorus L.	25.00	0.00	0.00	25.00
Ficus thonningii Blume.	93.75	0.00	0.00	93.75
FlueggeavirosaGuill. &Perr.	109.38	0.00	560.00	669.38
Gardenia ternifolia Schumach &Thonn	33.33	50.00	160.00	243.33
Grewia bicolar	100.00	0.00	0.00	100.00
Grewia mollis	75.00	150.00	240.00	465.00
Kigelia africana	125.00	0.00	0.00	125.00
Lannea fruticosa	0.00	0.00	0.00	0.00
Lannea fruticosa (Hochst. ex A. Rich) Engl	121.88	87.50	230.00	439.38
Lannea welwitschii	33.33	0.00	160.00	193.33
Lonchocarpus laxiflorus Guill. & Perr	0.00	75.00	160.00	235.00
Maytenus senegalensis Forssk	200.00	300.00	1200.00	1700.00
Maytenusundata (Thunb.)	25.00	100.00	640.00	765.00
Ocimum lamiifolium	0.00	0.00	0.00	0.00
Opilia campestris	200.00	0.00	0.00	200.00
Osyris quadripartita	0.00	50.00	200.00	250.00
Pavonia burchelli	283.33	200.00	1040.00	1523.33
Piliostigma thonningii (Schumach.)Milne-Redth	25.00	183.33	320.00	528.33
Pterocarpus lucensGuill. & Perr	108.33	280.00	560.00	948.33
Rhus glutinosa	50.00	0.00	0.00	50.00
Salix Spp.	50.00	150.00	160.00	360.00
Securidaca longepedunculata	50.00	0.00	0.00	50.00
Securinega virosa (Roxb.) Baill.	150.00	100.00	360.00	610.00

Species	Density of trees/ha	Density of Saplings/ ha	Density of Seedlings/ ha	Aggregated Density/ ha of the forest in all life forms
Sterculea setigera Del.	95.83	0.00	160.00	255.83
Stereospermum kunthianum Cham	60.00	50.00	100.00	210.00
Tamarindus indica L.	55.00	208.33	493.33	756.67
Terminalia browni	125.00	183.33	460.00	768.33
Terminalia laxiflora Engl. & Diels	58.33	0.00	0.00	58.33
Ximenia Americana L.	50.00	133.33	520.00	703.33
Ziziphus abyssinica Hochst. ex A. Rich	0.00	300.00	160.00	460.00
Ziziphus mauritiana	80.00	237.50	506.67	824.17
Ziziphus spina-christi (L.) Desf.	153.33	244.44	773.33	1171.11
Total	6236.96	6827.87	18311.78	31376.61

As the result revealed in (Fig. 11) below the regeneration status of GoNP is good as the density of seedlings exceeds the density of saplings and mature trees and hence the forest is in a good recruitment level. But, the recruitment capacity of seedlings to saplings and mature trees were two-fold lower and this may be due to the recurrent forest fire occurs every year in the areamay damage seedlings before recruited to saplings and mature trees. Moreover, higher density of seedlings was contributed by few fire resilient and high seed producing species like *Dichrostachys cinera*, *Acacia polycantha*, and *Acacia seyal*. And sometimes the occurrence of fire may facilitate the seed germination of the aforementioned woody species.

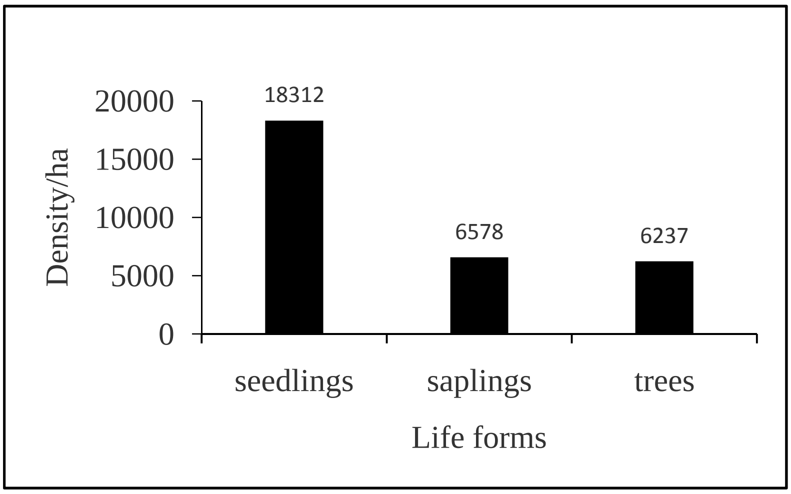


Fig. 11 Regeneration status of GoNP forest.

4 Discussion

Establishing National park/protected areas is generally considered among the most effective strategies for biodiversity conservation (Utaile et al., 2020). However, concerns over the effectiveness of protected areas in achieving their management objectives have been growing. GoNP has been considered to be among the newly established national park having considerable biodiversity resources. Result shows the species composition of the study forest was much resembled with Nechisar national park forest Utaile et al. (2020); Yabello forest

Worku (2006); Metema forest Dalle (2012); Kafta Sheraro National Park forest Temesgen (2020), and Hirmi Forest Girmay et al. (2020) having shrub dominated woodland species composition as those forests are situated in a similar woodland vegetation zones. But, the species richness of the study forest was less than Metema, Hirmi, Nechisar national park and Kafta sheraro national park forests having 87, 89, 171 and 70 woody species respectively. This may attribute to the forest protection efforts of the study forest as it was a recently demarcated park and was open access forest in the recent past seven years. Moreover, the nature of woodland forest is shrub dominated and the very reason for being shrub dominated may be due to the ongoing selective logging and the recurrent fire that are drying and destroying bigger mother trees.

Compared with other similar forests the species diversity and evenness indexes GoNP forest were almost similar with Metema dryland forest Dalle (2012) having *H'*=3.67 and *E*=0.82 and Kafta Sheraro National Park Forest Temesgen (2020) having *H'*= 3.2 and *E*=0.77 respectively having similar Agro-ecological zones. But, the species diversity and evenness indexes of the study forest exceeds Yabello dryland forest by Worku (2006) having *H'*= 2.26 and *E*=0.82; Taragedam forest by Zegeye et al. (2011) having *H'*=2.98 and E= 0.65; Dello Menna dry forest by Motuma et al.(2010) having *H*=3.304 and *E*=0.76; Nechisar National Park forest by Kebebew (2017) having *H'*=2.92 and *E*=0.68. This may be attributed by its location situated far from settlement areas and the recent forest protection effort of the local authorities.

The density of tree species in the study forest is 6237 stems/ha which is relatively higher than Yabello dry land forest Worku (2006) with (830 stems/ha), Abergelle forest Eshete et al. (2011) with 364 stems/ha; Taragedam forest Zegeye et al. (2011) with (3001 stems/ha); and Kafta Sheraro National Park forest Temesgen (2020) with (466 stems/ha); Nechisar National Park forest by Kebebew (2017) with (1815 stems/ha). Moreover, GoNP forest has higher density of seedlings and saplings that shows the significance of the establishment of Godebe forest as a national park that has positive contribution to the restoration of woody species as the anthropogenic pressures may be minimized. Also, the variation in density of life forms and between species may be attributed to habitat differences, habitat preferences among the species characteristics for adaptation, degree of exploitation, and conditions for regeneration (Temesgen, 2020).

Basal area is a substantive structural attribute that is often used as a measure of stand productivity (Utaile et al., 2020). Referring to this study result, the basal area of all woody vegetation of GoNP Forest (47.16 m^2/ha) is lower than Chilimo-Gaji Forest (454.52 m^2/ha) Siraj and Zhang (2018); Kafta Sheraro National Park (79.3 m^2/ha) Temesgen (2020); Wurg forest (126.47 m^2/ha) Boz and Maryo (2020). But it was higher than some of the dryland forest areas of Ethiopia like: shrub dominated forest of Babile Elephant Sanctuary(13.9 m^2/ha) (Belayneh, 2014); Hallideghie wildlife reserve (0.997 m^2/ha) Endris et al. (2017); and Hirmi woodland vegetation (14 m^2/ ha) Girmay et al. (2020). The most important contributor of basal area for the study forest are *Adansonia digtate, Diospyros mespiliformis, Tamarindus indica, Anogeissus leiocarpa*, and *Sterculia setigera* which contributes (63%) of the total basal area of the study forest and hence these species are ecologically the most important species.

Diameter at breast height (DBH) and height are important indicators of forest reproduction and health status (Worku, 2006). The general pattern of the study forest structure showed an inverted J-shaped distribution where species frequently had the highest frequency in low diameter classes and a gradual decrease towards the higher diameter classes. Inverted J-shape pattern is a normal population structure and shows the existence of species in healthier condition. Similar results were reported in Ethiopia; (Motuma et al., 2010; Belayneh, 2014; Endris et al., 2017; Girmay et al., 2020). This population structure also shows this forest has higher regeneration capacity as the density of seedlings greater than saplings and the density of saplings exceeds the density of trees.

5 Conclusion and Recommendation

Godebe National Park Forest has high biodiversity potential comprising about 59 woody species from 29 families and 43 genera of woody plant species. And the species diversity and richness of this forest is among the highest compared with similar dryland forests of Ethiopia and even its diversity is higher than the standard woody species diversity ranges. Moreover, those identified species are equitably distributed in the entire forest area. The overall population structure of the GoNP forest showed an inverted 'J' shaped pattern which is a good indicator of healthiness of the forest. But some common species of trees and shrubs revealed different types of patterns, addressing a high variation among species population dynamics within the forest. The finding also showed that some species like *Adansonia digitata, Ficus thonningii* and *Tamarindus indica* had low regeneration capacity exhibiting 'j' shaped pattern where the number of smaller diameter trees are almost absent. This clearly shows tree species in different stages of development are the abnormal status of population structure. The regeneration status of the tree species of the study site dominantly showed "Good" as the density of Seedlings>sapling>mature trees. Although the park is a newly designated national park, it has higher woody species diversity, high ecological and economic importance like *Boswellia paprifera, Acacia Senegal, Adansonia digitata, Dalbergia melanoxylon* and *Tamarindus indica*. Therefore, proper documentation of floral resources in the park followed by preparation of management plan are vital for biodiversity conservation and tourism development in the study area. On top of this, further promotion is required to give attention by decision makers.

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