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FLORISTIC COMPOSITION, VEGETATION STRUCTURE AND REGENERATION STATUS OF WALDIBA NATURAL FOREST, NORTHERN ETHIOPIA

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ABSTRACT

A study was conducted in Waldiba natural forest, to investigate the floristic composition, vegetation structure and regeneration status, since there was lack of information in the forest. A total of 60 quadrats, measuring, 10 m x 10 m for trees and 5m*5m nested plots for saplings and seedlings at an interval of 300 m, were laid along three established transects at 500 m apart. Density, frequency, basal area, importance value index, Shannon diversity and evenness were computed. A total of 73 species, representing 32 families were recorded. Fabaceae was the dominant family followed by Combretaceae and Euphorbiaceae. The density was 1906.6 individuals/ha, of which, 35.7% was contributed by only three species. *Dichrostachys cinearea*, *Combretum fragrans* and *Combretum hereroense* hereroense were the most frequent species. The total basal area of the species was 5.52 m2 ha-1, which is lower compared to many other forests in Ethiopia. Dichrostachys cinearea (38%), Combretum fragrans (29%) and Combretum hereroense (26%) were the species with higher importance value index. The Shannon diversity and evenness were 3.17 and 0.74 respectively, indicating high diversity. The density of seedlings was higher than saplings and mature trees and the DBH and height distribution showed an inverted J shape, indicating active regeneration, with lack of taller and bigger trees, which may be as a result of anthropogenic factors. Hence, immediate conservation action must be taken and a research on soil seed bank and carbon storage potential of the forest is recommended.

KEYWORDS: Diversity, Forest, Regeneration, Species.

1. INTRODUCTION

Ethiopia hosts rich biological diversity due to its great geographical diversity with high and rugged mountains, flat-topped plateau and deep gorges, incised river valley and rolling plains (Tadesse et al., 2017). The flora of Ethiopia is very heterogeneous which is estimated to be 6000 species of higher plants, of which 10% are endemic (GebreEgziabher, 1991). These biodiversities have spiritual, economic, aesthetic, cultural and scientific functions (Moges et al., 2018). Forests form the major constituents of vegetation resources and thus conservation of forest genetic resources is among the priority areas of biodiversity conservation in Ethiopia (Tona, 2016). They have diverse economic importance, which can provide a variety of products in the form of food, fodder, fuel, medicine, timber, resins and oil (Naveed et al., 2012) and are also ecologically important in providing habitat for wildlife, influencing climate and maintaining global balances of carbon and atmospheric pollutants (Girma and Maryo, 2018).

Despite of all these vital importance, however, the forests in Ethiopia are being destroyed at an alarming rate, largely due to human related disturbances (Aynekulu, 2011). To minimize the loss of these forests, understanding the ecological and anthropogenic factors involved in the process are highly important (Senbeta et al., 2014). In particular, studies of plant species diversity are very important for prioritizing conservation activities (Lovett et al., 2000; Myers et al., 2000). Furthermore, According to Mohammed and Abraha (2013), investigating the floristic composition, structure and regeneration status of a forest could enable to properly manage and sustainably use the resources. Nonetheless, in Ethiopia, studies on plant diversity and composition of forests are inadequate (Senbeta et al., 2014). The same is true for Waldeba natural forest which is found in northern Ethiopia, one of the most environmentally degraded regions in the country, where mainly due to the difficulty of access to the forest site, studies regarding the existing type of tree species, diversity, density and regeneration potential of the forest are lacking. Thus, the present study was conducted to investigate the floristic composition, vegetation structure and regenerartion status of the forest.

2. MATERIALS AND METHODS

2.1. Study area description

The study was conducted in Waldiba natural forest found in Tselemti Woreda of Tigray National Regional State, Ethiopia. It is located in between 13o 73' 16''-13o 80'6'' North latitude and 37o 92' 18''-37o 95'29'' East longitude at an altitude of 1118 m a.s.l. It is bordered by Tekeze River, Zarima River and Ensaya River (Chercos, 2012). The major Kebelle nearby is May teklit in Tselemti district.

Five years (20122016) rain fall distribution shows that the minimum and maximum were 1003.7mm and 1307.6mm/year respectively. The maximum temperature ranges from 26.8°C in August to 38.6°C in April and the minimum temperature is 15.6°C in January to 21.7°C in April. The dry season occurs between November and April while the rainy season occurs between June and September (Tigray meteorological services center, 2016) (Fig 1).

The agroclimatic condition of the area is hot to dry semiarid lowland plains dictated by very hot temperature. The most dominant soil types of the study area are cambisols, nitosols, and Vertisols.

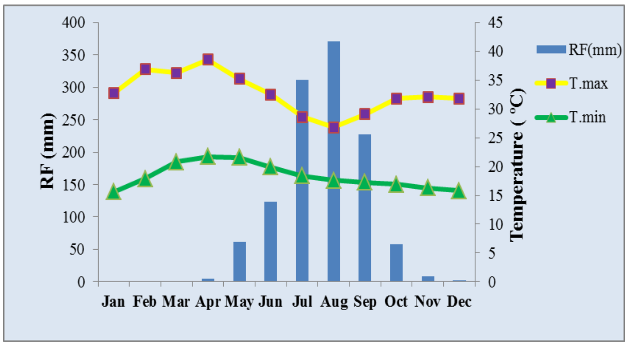


Figure 1: Five years (2012–2016) mean monthly rainfall (mm) and maximum and minimum mean monthly temperatures of the study area (Source: Tigray meteorological services center).

2.2. Vegetation data sampling

To compute the vegetation survey, three lines transects, parallel to each other were laid systematically at 500 meters interval (Shiferaw et al., 2018). Along each transect line, 20 sample plots, measuring 10m×10m for trees and 5m*5m nested plots for saplings and seedlings (Dhaulkhandi et al., 2008) were laid down systematically at 300 meters intervals. Accordingly, a total of 60 plots were use to collect data. The first plot was laid down randomly and the other plots systematically at equal interval in each of the transects. The plots were marked using strings and wooden pegs and the counted and recorded species were marked using a chalk not to miss or count an individual twice. All species were identified, counted, recorded by their local name and measured in each plot. Height and DBH measurements were made using Clinometer and diameter tape respectively. For species that were difficult to identify in the field, herbarium specimens were collected, pressed, dried and transported to the National Herbarium in the Department of Biology, Addis Ababa University, for proper identification.

2.3. Data analysis

The vegetation data were analyzed by computing the density, frequency, dominance, diversity indices and importance value index (IVI).

2.3.1. Density: Which refers to the total number of individuals of a species/ha was computed by summing up all the individuals from all sample plots and translated to hectare base for all the species. Two sets of density were calculated: density/ha of each species and relative density, calculated as the ratio of the density of a given species to the sum total of the density of all species (Eq 1).

$$\textbf{Relative density} = \frac{\text{Density of species A in hectare base}}{\text{Density of all species in hectare base}} * 100$$

...... Eq (1)

2.3.2. Frequency: It shows the presence or absence of a given species in each sample quadrant. Two sets of frequency were calculated, Absolute frequency, which refers to the number of plots in which the species encountered and relative frequency, calculated as the ratio of the absolute frequency of a given species to the sum total of the frequency of all species (Eq. 2).

$$\textbf{Relative frequency} = \frac{\text{Freqency of species A}}{\text{Frequency of all species}} * 100$$

...........Eq (2)

2.3.3. Dominance: 2.1.1: It refers to the degree of coverage of a given species expressed by a space it occupied in a given area. Two sets of dominance were calculated: absolute dominance (the sum of basal areas of the stems in m2/ha), and relative dominance: ratio of the total basal area of a given species to the sum of total stem basal areas of all species. Dominance was calculated for individual stems with diameter > 2.5cm (Eq 3) (Worku, 2006).

$$\textbf{Relative dominance} = \frac{\textit{Dominanceofspecies}A}{\textit{Dominanceofallspecies}} * 100 \cdots\cdots$$

Eq (3)

Basal area (BA) was computed using the formula (Eq 4):-

$$BA = \frac{\pi d^2}{4} \ldots\ldots\ldots\ldots\text{Eq (4)}$$

Where BA= basal area in m^2; π=3.14; D=diameter

2.3.4. Importance Value Index (IVI)

The IVI refers to the relative ecological importance of each species in a given area. It was calculated by summing up the relative dominance, relative density and relative frequency of the species (Mata et al., 2011) as follows:

IVI=Rd+ RD+ RF..............................Eq (5)

Where Rd is relative density, RD is relative dominance and RF is relative frequency.

2.3.5. Diversity indices

Species diversity was estimated using Shannon Wiener Diversity Index and evenness (Kent & Coker 1992):

H'= $-\sum_{i=1}^{s}$ pi ln pi……………………. (eq. 6)

Where:
H'= Shannon diversity index
s = number of species
Pi=the proportion of individuals or the abundance of the ith
species expressed as a proportion of the total
ln= natural logarithm

Evenness: was calculated using the formula:

Evenness (J') = $-\sum_{i=1}^{s}$ pi ln pi /lns…….. (Eq 7).

Where: S = number of species and ln is a natural log.

2.3.6. Population Structure and Regeneration Status

To assess the regeneration status, seedlings and saplings of the species encountered in the sample plots were counted. Species having height of < 0.5m, 0.5-3m and > 3m were counted as seedlings, saplings and trees respectively. To assess the vegetation structure of the plants, all individuals encountered in the quadrats were grouped arbitrarily into diameter and height class distributions at an interval of 2.5cm and 2m respectively. Then, histograms were drawn.

3. RESULTS AND DISCUSSION

3.1. Floristic Composition

A total of 73 plant species which belong to 32 families were recorded in the forest (Table1). Of these plant species, 49 species (67.12 %) were trees, 21 species (28.76 %) were shrubs, 2 species (2.74 %) were lianas and 1 species was a grass (1.37%). Furthermore, 72 species were indigenous and 1was exotic. The number of species and families encountered in this forest was higher relative to some other natural forests in Ethiopia such as Yemrehane Kirstos church forest, 39 species and 29 families (Ayanaw and Dalle, 2018), Kurib forest, 39 species (Belay, 2016), Keja Araba and Tula forests, 51 species and 25 families (Yakob and Fekadu, 2016) and Metema dry land forest which has similar Agroeclogy (low-land) with Waldiba natural forest, 36 species (Habtie, 2015), implying that Waldiba forest is floristically richer than these forests. However, higher number of species were recorded in Hugumbirda Gratkhassu national forest, Northern Ethiopia, 102 species and 50 families (Woldemichael et al, 2010) and Sesa Mariam Monastery, Northwestern Ethiopia, 113 species and 54 families (Meshesha et al, 2015) than in Waldiba. The difference in species and families number among the different forests could be attributed to their difference in vulnerability to anthropogenic effects, climatic conditions as well as location.

Fabaceae was the family with relatively higher number of species represented by 13 species. Combretaceae and Euphorbiaceae were the second diverse families represented by six species each (Table 2). The three families contributed to 34.2% of the species composition of the natural forest. Moraceae was the third diverse family represented by 5 species, while 17 families were represented by a single species each. This shows that the forest was dominated by few families. Similar result was reported by Alemu et al. (2015) in which twenty out of 44 families were represented by only a single spec ies each in Gelesha forest. Similarly Kuma and Shibru (2015) from Oda forest, Ethiopia, reported that 58.8% of the families were represented by one species each.

The dominance of Fabaceae might be due to its efficient pollination and a successful seed dispersal mechanism that helps them adapt to a wide range of environmental conditions (Kelbessa and Soromessa, 2008). The dominance of this family was reported from similar studies conducted in the different parts of the country like Yemrehane Kirstos Church forest by Ayanew and Dalle (2018), Riverine forest at Nech Sar national park (Kebebew and Demissie, 2017) which has similar altitude (1,108-1,650 m.a.s.l) with the study area, Oda forest (Kuma and Shibru, 2015) and Berbere forest (Bogale et al., 2017). This may indicate that the ecological conditions in these areas are more favorable for the family. Whereas, Euphorbiaceae was reported as the most diverse family in Gelesha forest, South West Ethiopia (Alemu et al., 2015) and Rosaceae in Gemechis Natural Forest (Chimdessa et al., 2018). This may be due to the variation of different places in their Agroecology and suitability of the different environments for different families.

Table 1: List of species encountered in Waldiba natural forest D/ha=Density/ha, RD(%)=Relative density(%), BA (m2/ha)=Basal area(m2/ha), R.DO (%) = Relative dominance (%), FR(No)= frequency (No), No refers to the number of plots in which the species encountered, RF(%)= relative frequency(%), IVI (%)= Importance value index(%) of species in Waldiba natural forest.

Scientific name	Vernacular name	Family	D/ha	RD(%)	BA(m^2/ha)	RDO%	FR (No).	RF(%)	IVI(%)
Cassia singueanea	Hambohambo	Caesalpinioideae	105.00	5.51	0.08	1.52	16.00	4.88	11.91
Anogeisus leocarpus	Hanse	Combretaceae	86.67	4.55	0.03	0.52	4.00	1.22	6.29
Gardinea lutea	Hatsinay	Rubiaceae	50.00	2.62	0.03	0.46	10.00	3.05	6.14
Tamarindus indica	Humer	Caesalpinioideae	21.67	1.14	0.02	0.28	4.00	1.22	2.64

Scientific name	Vernacular name	Family	D/ha	RD(%)	BA(m^2/ha)	RDO%	FR (No).	RF(%)	IVI(%)
Syzygium guineense	Liham	Myrtaceae	18.33	0.96	0.08	1.47	3.00	0.91	3.35
Grewia bicolor	Mesoqa	Tiliaceae	35.00	1.84	0.01	0.17	7.00	2.13	4.14
Boswellia papyrifera	Meker	Burseraceae	53.33	2.80	0.30	5.46	5.00	1.52	9.78
Steganotaenia araliacea Hochst	Mender-gihilay	Umbelliferae	1.67	0.09	0.01	0.12	1.00	0.30	0.51
Pseudocedrela kotschyi Harms	Mizan	Meliaceae	10.00	0.52	0.02	0.33	3.00	0.91	1.76
Ficus ingens (Miq.) Miq.	Mitsa	Moraceae	8.33	0.44	0.05	0.87	1.00	0.30	1.61
Ximenia americana	Mili'o	Olacaceae	70.00	3.67	0.16	2.85	10.00	3.05	9.57
Combretum molle	Sesewe	Combretaceae	15.00	0.79	0.05	0.86	6.00	1.83	3.48
Combretum hereroense	Sebi'a	Combretaceae	140.00	7.34	0.53	9.56	29.00	8.84	25.74
Ficus sycomorus	Sagla	Moraceae	10.00	0.52	0.13	2.29	2.00	0.61	3.43
Phoenix reclinata	Sye	Palmae	1.67	0.09	0.02	0.39	1.00	0.30	0.78
Erythrina abyssinica	Shtene-hbey	Fabaceae	10.00	0.52	0.05	0.86	2.00	0.61	2.00
Ozoroa insignis	Shtara	Anacardiaceae	1.67	0.09	0.02	0.41	1.00	0.30	0.81
Acacia abyssinica	Keyih-chea	Fabaceae	1.67	0.09	0.01	0.21	1.00	0.30	0.60
Maerua angolensis DC	Qaremo	Capparidaceae	10.00	0.52	0.03	0.50	4.00	1.22	2.24
Grewia villosa Willd.	Qa'eto	Tiliaceae	3.33	0.17	0.02	0.37	6.00	1.83	2.38
Euphorbia tirucalli	Qinchib	Euphorbiaceae	1.67	0.09	0.01	0.22	1.00	0.30	0.61
Euphorbia abyssinica	Qolqal	Euphorbiaceae	1.67	0.09	0.00	0.05	1.00	0.30	0.45
Pterolobium stellatum	Qonteftefe	Fabaceae	1.67	0.09	0.00	0.06	1.00	0.30	0.45
Eucalyptus camaldulesis	Baharzaf	Myrtaceae	1.67	0.09	0.02	0.45	1.00	0.30	0.84
Milletia ferruginea	Birbra	Fabaceae	1.67	0.09	0.02	0.35	1.00	0.30	0.74
Acacia persiciflora	Trmi	Fabaceae	1.67	0.09	0.01	0.14	2.00	0.61	0.84
Albizia malacophylla	Tnfasha	Fabaceae	1.67	0.09	0.05	0.83	2.00	0.61	1.52
Ormocarpum pubescens	Alendya	Fabaceae	1.67	0.09	0.03	0.63	1.00	0.30	1.02
Piliostigma thoningii	Ami'am-gimel	Fabaceae	1.67	0.09	0.01	0.21	1.00	0.30	0.60
Oxytenanthera abyssinica	Arqay	Poaceae	1.67	0.09	0.00	0.04	1.00	0.30	0.43
Maytenus senegalensis	Argudi	Celastraceae	26.67	1.40	0.01	0.15	4.00	1.22	2.77
Ziziphus jujube	Abetere	Rhamnaceae	53.33	2.80	0.11	2.08	9.00	2.74	7.62
Lannea triphylla	Abde-abde	Anacardiaceae	5.00	0.26	0.04	0.73	4.00	1.22	2.22
Nuxia congesta	Atkaro	Loganiaceae	1.67	0.09	0.04	0.66	1.00	0.30	1.05
Commiphora africana	Anqu'a	Burseraceae	43.33	2.27	0.02	0.45	2.00	0.61	3.33
Capparis micrantha	Andel	Caparidaceae	43.33	2.27	0.01	0.14	5.00	1.52	3.94
Combretum spp.	Akuma	Combretaceae	28.33	1.49	0.15	2.79	13.00	3.96	8.24
Cordia africana	Awhi	Boraginaceae	3.33	0.17	0.05	0.87	1.00	0.30	1.35
Acalypha sp.	Awneta	Euphorbiaceae	1.67	0.09	0.03	0.48	2.00	0.61	1.18
Boscia salicifolia	Awo	Capparaceae	28.33	1.49	0.05	0.94	5.00	1.52	3.95
Diospyros mespiliformis	Aye	Ebenaceae	40.00	2.10	0.05	0.94	3.00	0.91	3.96
Dovyalis abyssinica	Ayahada	Flacourtiaceae	36.67	1.92	0.02	0.43	6.00	1.83	4.18
Sterospermum kunthianum	Adgi-Zana	Bignoniaceae	70.00	3.67	0.04	0.66	3.00	0.91	5.24
Carissa edulis	Agam	Apocynaceae	1.67	0.09	0.04	0.66	2.00	0.61	1.35
Ficus hochstettelri	Afekemo	Moraceae	16.67	0.87	0.07	1.28	6.00	1.83	3.98
Bridelia scleroneura	Enchet-dmu	Euphorbiaceae	5.00	0.26	0.01	0.25	2.00	0.61	1.12
Boscia angustifolia	Kermed	Capparidaceae	1.67	0.09	0.03	0.48	1.00	0.30	0.87
Mimusops kummel	Kumel	Sapotaceae	8.33	0.44	0.01	0.23	1.00	0.30	0.97
Ehretia cymosa	Kirah	Boraginaceae	1.67	0.09	0.01	0.20	1.00	0.30	0.59
Terminalia brownii	Weiba	Combretaceae	11.67	0.61	0.06	1.03	3.00	0.91	2.55
Dalbergia melanoxylon	Zbe	Fabaceae	10.00	0.52	0.03	0.62	3.00	0.91	2.06
Grewia bicolor Juss	Derech-merech	Tiliaceae	68.33	3.58	0.07	1.21	9.00	2.74	7.54
Acacia seyal	Tsaeda-chea	Fabaceae	8.33	0.44	0.02	0.31	4.00	1.22	1.96
Adansonia digitata	Dima	Bombacaceae	1.67	0.09	0.53	9.63	2.00	0.61	10.33
Ficus vasta	Daero	Moraceae	1.67	0.09	0.59	10.62	1.00	0.30	11.01
Lannea fruticosa	Dguidugugni	Anacardiaceae	5.00	0.26	0.00	0.09	3.00	0.91	1.26
Vangueria edulis	Guramayle	Rubiaceae	1.67	0.09	0.03	0.60	2.00	0.61	1.30
Acacia bussei	Gomoro	Fabaceae	66.67	3.50	0.38	6.91	14.00	4.27	14.67
Dichrostachys cinearea	Gonoq	Fabaceae	388.33	20.37	0.37	6.73	36.00	10.98	38.08
Combretum fragrans	Tenkeliba	Combretaceae	151.67	7.95	0.64	11.55	32.00	9.76	29.26
Astralagus atropilosulus	Tetem-agazen	Leguminosae	3.33	0.17	0.00	0.09	1.00	0.30	0.57
Ozoroa insignis Del.	Tetera	Anacardiaceae	8.33	0.44	0.03	0.59	2.00	0.61	1.64
Ficus thonningii Blume	Tsekente-milihto	Moraceae	3.33	0.17	0.05	0.93	1.00	0.30	1.41
Pterocarpus lucens	Tsara	Fabaceae	1.67	0.09	0.02	0.29	1.00	0.30	0.68
Bridelia scleroneura	Tsfri-nebri	Euphorbiaceae	5.00	0.26	0.04	0.77	2.00	0.61	1.64
Bridelia sp.	Sebari-mahtse	Euphorbiaceae	8.33	0.44	0.01	0.26	1.00	0.30	1.00
Cissus petiolata	Alke	Vitaceae	6.67	0.35	0.00	0.09	1.00	0.30	0.74

Scientific name	Vernacular name	Family	D/ha	RD(%)	BA(m^2/ha)	RDO%	FR (No).	RF(%)	IVI(%)
Heteromorpha arborescens	Eshok-zibie	*Umbelliferae*	6.67	0.35	0.02	0.30	1.00	0.30	0.96
Ziziphus spina-christi	Gaba	Rhamnaceae	20.00	1.05	0.01	0.13	3.00	0.91	2.09
Grewia ferruginea	Tsanqayt	Tiliaceae	15.00	0.79	0.02	0.39	3.00	0.91	2.09
Solanum incanum	Engule	Solanaceae	6.67	0.35	0.00	0.00	1.00	0.30	0.65
Calotropis procera	Gindae	*Asclepiadaceae*	13.33	0.70	0.00	0.00	2.00	0.61	1.31
Diospyros abyssinica	Tselimo	Ebenaceae	6.67	0.35	0.00	0.00	1.00	0.30	0.65
	Total		**1906.6**	**100**	**5.52**	**100**	**328**	**100**	

Table 2: Proportions of families species composition.

Family	Number of species	Proportion (%)
Fabaceae	13	17.81
Combretaceae	6	8.22
Euphorbiaceae	6	8.22
Moraceae	5	6.85
Tiliaceae	4	5.48
Anacardiaceae	4	5.48
Caesalpinioideae	2	2.74
Rubiaceae	2	2.74
Myrtaceae	2	2.74
Burseraceae	2	2.74
Umbelliferae	2	2.74
Capparidaceae	2	2.74
Rhamnaceae	2	2.74
Boraginaceae	2	2.74
Ebenaceae	2	2.74
Meliaceae	1	1.37
Olacaceae	1	1.37
Palmae	1	1.37
Poaceae	1	1.37
Celastraceae	1	1.37
Loganiaceae	1	1.37
Caparidaceae	1	1.37
Capparaceae	1	1.37
Flacourtiaceae	1	1.37
Bignoniaceae	1	1.37
Apocynaceae	1	1.37
Sapotaceae	1	1.37
Bombacaceae	1	1.37
Leguminosae	1	1.37
Vitaceae	1	1.37
Solanaceae	1	1.37
Asclepiadaceae	1	1.37
Total	**73**	**100**

3.2. Density, Frequency, Dominance and Importance Value Index

The overall density of the forest was found to be 1906.6 individuals/ha. The density of few species, for instance, *Dichrostachys cinearea*, *Combretum fragrans* and *Combretum hereroense* was higher in the forest with 388.3stems/ha, 151.6 stems/ ha and 140stems/ ha respectively. These three species contributed to 35.7 % of the total density which implies that there was a high variation in density among species. In contrast, 27 species were found to be the least abunda-nt with density of less than 5 stem ha-1 each (Table 1). This high abundance of a few species in a forest could be due to overharvesting of some species and difference in survival strategies of the species (Wakjira, 2006).

The forest had relatively high density compared to that of Gera moist Montane forest, 1778 individuals/ha (Mulugeta et al., 2015) and Yegof Mountain Forest, South Wollo, Ethiopia (1685 stems/ha) (Mohammed and Abraha, 2013). On the other hand, it was lower compared to some other forests in the country such as Amoro Forest in North Western Ethiopia, 2860stems/ha (Birhanu et al, 2018) and Arero dry Afromontane forest, South Ethiopia, 5049 stems ha-1 (Shiferaw et al., 2018). The difference in density of species across different forests could be attributed to difference in habitat preferences of species of a forest and the extent of anthropogenic disturbances.

Frequency analyses showed that most of the species were found to have low distribution across the plots and few species in high distribution, indicating that there was a high variation among species. For instance, most frequent species were *Dichrostachys cinearea, Combretum fragrans* and *Combretum hereroense* recorded in 36, 32 and 29 out of the 60 sample plots respectively, followed by *Cassia singueanea* which was recorded in 16 quadrates. In contrast, 27 species were encountered only in a single plot and 13 species in two plots (Table 1). The wider distribution of some few species across studied plots was reported from Amoro forest in North Western Ethiopia (Birhanu et al., 2018).

The total basal area of species in the forest was 5.52 m^2 ha^{-1} (Table 1) This was comparable to Ylat Forest **(**1m^2 ha^{-1}) (Tegegne and Workineh, 2017); Tara-Gedam natural forest, 6.81 m^2 ha^{-1} (Gebrehana, 2015) and Kuneba forest (6.8m^2/ha) (Tefera et al., 2015). On the other hand, it was much smaller to most of reports from Ethiopia such as Amoro forest (Birhanu et al., 2018); Nech Sar national park, 46.04 m^2 ha^1 (Kebebew& Demissie, 2017) and Yegof forest (25.4 m^2/ha). The low basal area of the forest compared to these forests could be due to the dominance of the forest by seedlings and saplings with low diameter. In addition to this, low basal area of the forest could be due to cutting down matured trees and in turn influenced the basal area by reducing the number of matured stems having higher diameter (Figure 2).

Figure 2. Illegal cutting of trees in Waldiba Natural Forest.

A high variation was observed among species in their basal area in the forest. The dominant species were *Combretum fragrans* (11.55%), *Ficus vasta* (10.62%), *Adansonia digitata* (9.63%), *Combretum hereroense* (9.56%) and *Acacia bussei* (6.9%) These five dominant species contributed to 48.3% of the total basal area in the forest whereas the remaining 68 species contributed to 51.7% of the total basal area (Table 1).

Importance value index (IVI) reflects the extent of the relative dominance, relative frequency and relative density of a given species. The species with relatively higher dominance, frequency and density were found to be more important species since IVI was analyzed by summing up the relative density, relative frequency and relative dominance. Thus, *Dichrostachys cinearea* (38%), *Co-mbretum fragrans* (29%) and *Combretum hereroense* (26%) were the most important species. Whereas, 48 species were found to be less important with importance value index of less than 3% each (Table 1). This dominance of few species could be due to rapid reproduction strategies of some plant species, whereas slow reproduction strategies of another species. Moreover, the low IVI value of some species could also be due to livestock grazing or trampling of some selected species. The low IVI value of the species indicates that they are endangered and need immediate conservation.

3.3. Species Diversity

The Shannon Wiener Diversity index (H') and evenness (J’) values of the forest were 3.17 and 0.74 respectively. The Shannon-Wiener Diversity index (H') normally varies between 1.5 and 3.5 and rarely exceeds 4.5 (kent and coker 1992). According to Cavalcanti and Larrazábal (2004) cited in Atsbeha etal. (2019), it is considered as high when the calculated value is ≥ 3.0, medium when it is between 2.0 and 3.0, low between 1.0 and 2.0, and very low when it is ≤ 1.0. For that reason, the Shannon index of Waldiba forest is categorized under ‘’high’’ diversity value.

In comparison to other forests, the Shannon index of Waldiba was higher than that of Arero dry Afromontane forest, South Ethiopia, (H') =2.67 (Shiferaw et al., 2018) and Kuneba forest, Afar region, Ethiopia (H') =2.26 (Tefera et al., 2015,) which has more or less similar agroecology with the study area. This shows that Waldiba is more diverse than these forests. However, the diversity index was low as compared to natural forests such as Yegof Mountain Forest (H') =3.73 (Mohammed & Abraha, 2013) and Sesa Mariam Monastery vegetation, Northwestern Ethiopia (Meshesha et al, 2015). These differences in species diversity could be attributed to heterogeneity in edaphic, biotic and abiotic factors of the different forest sites. According to Ramakrishnanb (1992), these factors play a vital role in both species as well as genetic diversity through their impact on seed germination.

3.4. Population Structure and Regeneration Status

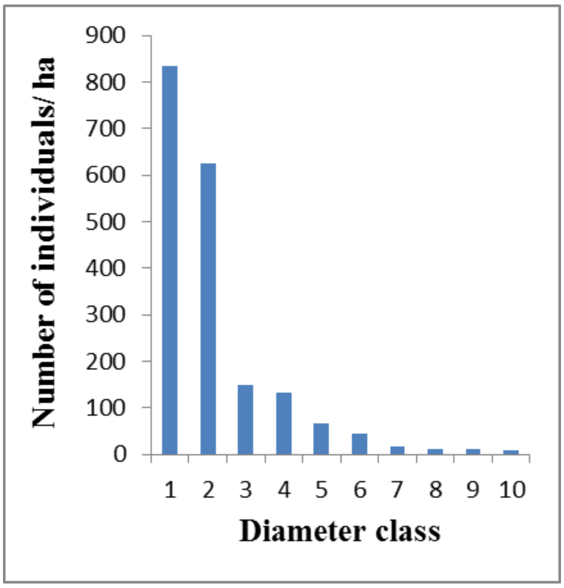
The diameter and height distribution of the community of overall species showed an inverted J –shape (Figure 3). In this distribution pattern, most of the individuals are in the lower diameter and height classes and the number is subsequently decreasing so that the higher classes are represented by very few individuals. For instance, in this study, abundance of species at different diameter classes with decreasing order were < 2.5cm (833 stems ha^{-1}), 2.5-5cm (626 stems ha^{-1}), 5-7.5cm (150 stems ha^{-1}), 7.5-10cm (133 stems ha^{-1}), 10-12.5cm(68 stems ha^{-1}), 12.5-15cm (45 stems ha^{-1}), 15-17.5cm (17 stems ha^{-1}), 17.5-20cm (13 stems ha^{-1}), 20-22.5cm (13 stems ha^{-1}) and > 22.5cm (8 stems ha^{-1}). This distribution indicated that 76.5% of species in the forest had a diameter of less than 5cm. whereas, the two largest diameter classes (20-22.5cm and >22.5cm) encountered for only 1.1% of the total stand.

Height class distribution follows similar trend to diameter class distribution. Hence, the denser class was <2m (1128 individuals ha-1), followed by 2-4m (415 individuals ha-1), 4-6m (77 individuals ha-1), 6-8m (93 individuals ha-1), 8-10m (80 individuals ha-1), 10-12m (65 individuals ha-1) and > 12.5m (48 individuals ha-1). This shows that 81% of species in the forest were less than 4m tall. The stems within higher height class (>12.5m) accounts for only 2.5% of the total stand. The trend of decreasing number of stands with increasing height and diameter may be due to the illegal cutting of bigger and taller stems for various purposes (Fig. 2). According to Lalfakawma (2010), disturbances, whether natural or man made have much influence on community composition and tree population structure of forest ecosystems. Moreover, the total seedling, sapling and mature plants densities were 833.3, 626.6 and 446.6 individual-s per hectare respectively (Table 3). This reveal that the density of seedling is greater than both sapling and mature trees (i.e. density of seedling > density of sapling > density of mature tree) in the forest.

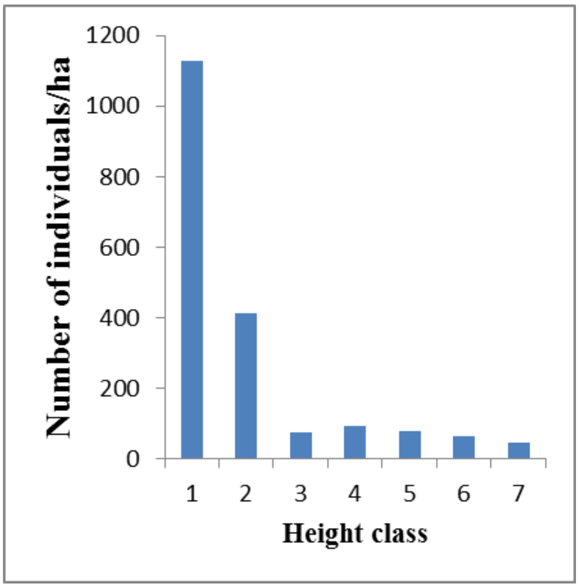
Table 3: Density of species with different plant categories.

Categories	**Density/ha**	**Proportion (%)**
Mature tees	446.6	23.42
Saplings	626.6	32.87
Seedlings	833.3	43.71
Total	**1906.6**	**100**

Investigating the population size of seedlings, saplings and mature trees is used to determine the regeneration status of a forest (Khan et al., 1987; Lalfakawma, 2010). According to Dhaulkhadi et al. (2008), If a forest has seedlings >saplings >adults, it is in a good regeneration; if seedlings> or ≤ saplings ≤ adults, fair regeneration; if the species survives only in sapling stage, but no seedlings (saplings may be or = adults), poor regeneration; If a species is present only in an adult form it is considered as not regenerating. In view of this, the pattern in Waldiba natural forest indicated that the forest had active and uniform regeneration and recruitment potential. The success of plant regeneration in the forest could be due to successful seed production, dispersal to safe sites, germination and seedling emergence and seedling establishment (Barik et al., 1996). In addition to regeneration from seeds, Resprouting may also contribute to the encouraging regeneration status of the forest, since it is other possible option of regeneration and is an important life characteristic of species in tropical forests (Bond and Midgley, 2001) and has contribution to maintain and conserve flora and fauna (Evans, 1992). The promising regeneration status in this forest was similar for those of Amoro Forest (Birhanu et al., 2018), Nech-Sar national park (Kebebew and Demissie, 2017) and Gra-Kahsu natural vegetation, Northern Ethiopia (Atsbeha et al., 2019).



(a)



(b)

Fig 3: (a)= Diameter class distributions at an interval of 2.5cm.1=<2.5cm, 2=2.5 5cm……..10=>22.5; (b) = Height class distributions at an interval of 2m. 1=<2m, 2=2-4m, 3=4 6m……………..7=>12m.

CONCLUSIONS AND RECOMMENDATIONS

Waldiba natural forest was found to be floristically among diverse forests with regard to species composition and diversity. Most of the species were trees followed by shrubs, lianas and grass in the forest. Fabaceae was the most dominant family with 13 species and contributes 17.8% of the species composition. The forest was dominated by stems having small diameter and height classes. The distribution of species showed a decrement trend from lower to higher diameter and height classes. Furthermore, in this study, the regeneration of wood species has shown that contribution of seedlings density was highest followed by saplings and adult trees, which is an indication of healthy regeneration of the species in the forest. The analyses of vegetation composition revealed that density, basal area, frequency and importance value index vary considerably among species which indicated that the forest was found to be dominated by few species. Similarly, few families dominate the species composition of the forest and most of the families were represented by small number of species.

Accordingly, urgent research and development works are required to address the problems of the species with low density, basal area, frequency and importance value index. These species must also be prioritized for conservation. The seedling establishment mechanisms of the species with low distribution, soil seed banks and carbon storage potential of the forest have to be studied. In addition to this, it is necessary to take measures against the human interference.

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Conflict of interests
The authors have not declared any conflict of interests.

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