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Diversity, Structure, and Regeneration of Bishan Gari Forest, West Arsi Zone, Ethiopia: Implication for Conservation of Woody Species

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***Abstract*—T**he study was conducted at Bishan Gari Forest in West Arsi Zone, Oromia Regional State, Ethiopia. The main aim was to determine florist composition, vegetation structure, and regeneration status, and identify major disturbance factors. Vegetation data were collected using systematic sampling and 40 plots of 10 × 50 m (500 m2) main quadrates for collecting tree and shrub species data, whereas 80 plots of 5 × 10 m (50 m2) were laid at every 100 m to collect seedling and sapling data. Google Earth Pro and QGIS version 2.18 were employed to define the boundary of vegetation, draw transect lines and plot sample plots along transect lines at a predetermined distance. All vegetation data analysis was carried out using the FGRCP Central Database, EXCEL, Stata version 13, and R software version 4.0.3 to determine the vegetation-environmental relationship. A total of 40 species belonging to 29 genera, 22 families, and 38 species were identified from the forest. The study vegetation comprised 62.5% trees, 27.5% shrubs, and 10% climbers/lianas. The overall diversity indices (D=0.65, H'=1.43 & J=0.7) for the entire forest portrayed lower diversity and higher evenness. Beyond to vertical structure category, *Podocarpus falcatus, Ficus ovata, Ficus vasta, Celtis Africana, Mimusops Kummel, Syzygium guineense, Croton macrostachyus,* and *Cordia Africana* were found in all vegetation strata. From the analysis of IVI 15 species required foremost priority for conservation, while aspect and slope gradient were identified, as the main determining factors of vegetation. Generally, it is mandatory to set priority for the conservation of threatened woody plant species to revive from current squashed risks and to reduce future dread of decline.

Keywords— Floristic Composition, Diversity, Forest Disturbance, Important Value Index, Species Density, Vertical structure.

I. INTRODUCTION

Ethiopia is a land of geographical contrasts with elevations that range from 125 m below sea level in the Danakil Depression to 4533 m above sea level in the Semien Mountains, a world heritage site. The diverse climate of various ecological regions of the country has driven the establishment of diverse vegetation, which ranges from Afro-alpine vegetation in the mountains to the arid and semi-arid vegetation type in the lowlands [1]. The flora is very heterogeneous and has a rich endemic element owing to the diversity of climate, vegetation, and terrain. Species diversity plays a great role in maintaining carbon flux, climate balance and the water cycle [2]. It is estimated to contain between 6,500 and 7000 species of higher plants, of which about 12% are endemic as [3] cited in [4]. Endemism is particularly high in the high mountains and the Ogaden area in southeastern Ethiopia. Forests and/or vegetation in these wide ranges of agroecological zones provide services such as socio-cultural, economic, ecological and environmental, and biodiversity conservations to humans.

However, Ethiopia's natural vegetation is under considerable pressure due to the rapidly increasing population, expanding agricultural activities, and increasing deforestation [5]. Ethiopia possesses diversified dry land vegetation which is collectively characterized as the Somalia-Masai vegetation formation [6]. 2.5 million hectares of land were covered with woodland and bushlands out of the total 75 million ha of dry land areas of the country. This figure indicates that the largest vegetation resources of Ethiopia are found in dry lands. However, this diverse valuable vegetation resource is under severe threat due to environmental degradation aggravated by poverty, which in turn accelerates the environmental degradation process [7].

II. RELATED WORK

Scholarly reports showed that more than 90% of the wood harvested from the forest in Africa is used for fuel [8]. According to EFAP reports, 16% of the land areas of Ethiopia were covered with forests in the early 1950s. But, this number declined to 3.1% in 1982, 2.7% in 1989, and less than 2.3% in 1990 due to an energy consumption increase (EFAP 1994). If this trend of forest devastation

continues unabated, there is a great danger of serious decline or loss of biodiversity resources. To revoke this problem country-wide, the economic policy of Ethiopia has been identified as one of the major problems to overcome by the conservation strategy of the country. Hence, it is important to set priorities for the threatened species in each vegetation type to study and document the remaining vegetation resources upon which sound management plans of conservation and sustainable utilization can be based. Therefore, the aim of this study was: i) to inventory and determine the regeneration status of indigenous woody plant species ii) to quantify the diversity and structure of the forest iii) to evaluate the floristic composition and set a priority list of the woody plant species for the vegetation of the area. Most importantly, this research gives a hint and general idea for conservationists, ecologists, researchers and the readership of Forest Science: how to determine species diversity dynamics based on the existing biophysical factors.

III. METHODOLOGY

Location

Heban Arsi is one of the West Arsi Zone districts that is located in the Oromia regional state of the west Arsi zone. The district Capital "Goljota" is located at a distance of 226 km from Addis Ababa in the southeast part of the country. The district embraces 9 rural districts and 3 urban districts which are characterized by diversified agroecological zones. The total area of the District is 35,613.6 hectares. Geographically, the district lies between 70 9'N7 0 42'N latitudes and 380 25' E - 380 54'E longitude. The altitude of the study area ranges between 1500- 3000masl [9].

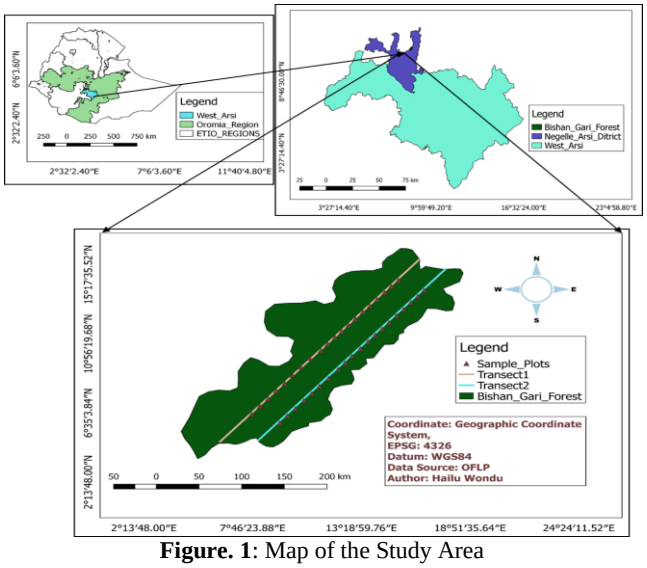

Figure. 1: Map of the Study Area

Vegetation

The physical conditions and variations in altitudes have resulted in a great diversity of climate, soil, and vegetation, which in turn caused the evolution of different plant species with a large diversity. Before 20 years ago, the District was substantially covered with natural forests. But today, that is only history much of the area, including farmlands and home gardens is covered by planted forests and woodlots. 19.19% of forest area covers the District out of the total land area, including natural forest, community forest, and private forest [9]. Large trees include Podocarpus falcatus, *Celtis africana, Olea capensis, Prunus africana, Ficus spp, Croton macrostachyus*, and *Mimosops kummel*. Furthermore, understory species include *Brucea antidysenterica, Cassipourea malosana, Lepidotrichilia volkensii, Maytenus spp., Vepris dainellii, Albizia schimperiana, Calpurnia aurea, Cordia africana, Olea europea subs*p. cuspidata are frequent at mountain edges [10].

Sampling procedures

Sampling System and Design

Before going to the study site, the Bishan gari forest had been digitized using GIS software and google earth to identify the boundary and determine the area coverage of the forest. Accordingly, two (2) transect lines and forty (40) sample plots were drawn systematically based on the area of the forest, variability of the species, and topographic features (altitudinal gradient) of the land.

Based on the above sampling system, specific directions of transects were decided to assess the vegetation and capture the diversity thoroughly, straight transects were used for collecting inventory data. Hence, at the beginning of the navigation, the bearings were determined using GPS. Then, to collect the data, the main quadrate of 50 × 10 m size; and a sub-quadrate of 10 × 5 m size were established within the main quadrate at the longest sides of both ends.

Transect and Quadrant layout

Two transect lines were drawn along the longest side of the vegetation on the gentle to flat landscape. Here, the rural roads either crossing or bordering the vegetation and Lake Langano were used as a baseline. Following this, the two transects were ribbed in the northeast direction. On both transect lines; at regular intervals with a 50m altitudinal drop, sample plots were designated. The regeneration status of woody plant species was assessed from sub-quadrates (sub-plots) that were established as aforementioned (10 m × 5 m) in the sampling design. In general, a total of two transects, 40 quadrates, and 400 sub-quadrates, were used to collect the tree species data from Bishan gari small-leaved deciduous evergreen vegetation.

Data collection

Physiography and soil data

Before the collection of vegetation data, geographical coordinates and altitude were recorded using GPS from each quadrate. Simultaneously, topographic characteristics such as slope gradient, soil depth, slope position, quadrant aspect, physiognomy, and disturbance scale were also recorded (as described in annexe 1) following the woody plant species diversity assessment field manual prepared by IBC. In addition, observational data on soil type, texture, and colour was also collected. These data were registered in the same format used for vegetation data collection.

Vegetation Data

To collect the vegetation data, two pre-structured woody plant species inventory and regeneration status assessment formats were used. However, in the beginning, the physiognomy and type of vegetation were described before going to collect the vegetation data. Thereafter, for each woody plant species that appeared in the sample plots and for trees and shrubs having a DBH ⩾ 2.5 cm, DSH/ DBH* was measured using the graduated caliper while the data of total height was taken on ocular estimation. For shrubs possessing several stems rising from below 2.5 cm DBH, each branch was measured for DSH/ DBH, and height as individual stems and numbers of stems were also counted exhaustedly.

Furthermore, combined with this, the growth habit and number of stems of each species existing in the plots were described and recorded. On the other hand, the data of the saplings and seedlings of woody plant species were collected from the sub-quadrates as described above. Simultaneously, plant specimens were collected and pressed into the field using the plant presser. These specimens were dried, identified, mounted, and kept at the Herbarium of EBI.

Data Analysis

The structure of the vegetation was determined using frequency distribution of height, Diameter class (DBH class), and Important Value Index (IVI) [11]. Tree or shrub density and basal area values were estimated on a per-hectare basis. IVI is the total of Relative Density (RD), Relative Frequency (RF) and Relative Dominance (RDO) [12] where;

$$RD = \frac{\text{the number of all individuals of a species}}{\text{the total number of all individuals}} \times 100 \ldots\ldots(1)$$

$$RF = \frac{\text{the number plots where a species occurs}}{\text{the total occurrence of all in all plots}} \times 100 \ldots\ldots\ldots 2)$$

$$RDO = \frac{\text{the basal area of species}}{\text{total basal area}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Finally, the Important Value Index is expressed as:

$$IVI = RD + RF + RDO \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

According to (Lou, 2006), Shannon -Wiener Diversity Index will use to analyze the species diversity, species richness, and evenness of the vegetation as:

Shannon Diversity Index (H):

$$(H') = \sum_{i=1}^{s} pilnpi = \sum_{i=1}^{s} \left[\left\{\frac{ni}{n}\right\} \ln\left\{\frac{ni}{n}\right\}\right] \ldots\ldots\ldots(1)$$

Simpson Index of species diversity (D):

$$(D) = \frac{1}{\sum_{i=1}^{s} Pi^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Equitability /Evenness (J):

$$(J): = \frac{H'}{Hmax} = -\sum_{i=1}^{N} \frac{pilnpi}{lnS} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where H' is the Shannon-Wiener Index; Hmax is the species richness; S is the number of species; Pi is the proportion of individuals of the ith species; ln: natural logarithm; D is Simpson Index and J is the Evenness of the ith species. The software employed for data analysis was: FGRCP central database, Microsoft Excel version 2016, Stata version 13, and R program version 4.03 mostly.

IV. RESULTS AND DISCUSSION

Environmental Data

Land Use/Land Cover

The study district was mostly covered with agricultural land (in the middle parts of the slope), woodland (small-leaved deciduous) (at the lower parts of the slope), and shrub and bushlands in the upper parts of the slope. Moreover, the spatial coverage of woodlots extends to most of the agricultural land and around home and settlement areas. The main types of crops cultivated are Maize, Wheat, Teff, Barely, and Sorghum.

Forest Disturbance

Both human and Livestock (Cattle, Goat, Sheep, and Donkey) interferences have caused disturbances influencing the vegetation. From the identified disturbance types in the area, grazing and Logging are the major existing factors for the degradation of the vegetation in the area. However, the degree of each factor's impact varies across disturbance types and among specified scales. Browsing and the level of impact range from very light/very rare to intensive causing 31.10% of the forest disturbance. Whereas, about 34.45% of disturbance effects were caused by grazing and logging with very light to an intensive degree of disturbance. (See *Table*.1).

Table 1: Proportion of degree of forest disturbance

Forest Disturbance Factors	Disturbance Scale				
	1 (Very light)	2 (Light)	3 (Moderate)	4 (Intensive)	Total (%)
Grazing	3	10	17	11	34.45
Browsing	3	12	13	9	31.10
Logging	2	24	12	3	34.45

As shown in Table 1, the livestock grazing tree logging/cutting by surrounding residents was moderately and very lightly degrading Bishan gari small-leaved deciduous forest more than browsing impact [13]. The people in the study area practice mixed agriculture, as a result of this they deliberately adhibit their livestock into the forest which leads to disturbance via grazing and browsing. This resulted in physical damage to trees, saplings, and seedlings while inhibiting the regeneration capacity of the vegetation by changing the structure of the soil.

Floristics Composition

A total of 40 woody plant species were collected from the Bishan gari forest. From this, 29 specimens were identified at the genera level, 22 families, and 38 at the species level. The identified specimens belonged to 21 families and 29 genera. The most frequent genera in the small-leaved deciduous vegetation were *Ficus* (Moraceae), *Olea* (Oleaceae), *Maytenus* (Celastraceae), and *Acacia* (Fabaceae) consecutively. In terms of family, Fabaceae is the most frequently diverse in the assessed forest vegetation, followed by Moraceae and Oleaceae, respectively. Among each consecutive genus, podocarpus falcatus (73.17), *Mimosops kummel* (53.66), Celtis Africana (51.22), *Maytenus arbutifolia* (43.90), *Calpurnia aurea* (43.90), Ficus ovata (41.46) and *Vernonia rueppelli* (41.46) were found the most widely diverse woody plant species in the area.

Without concerning the diversity of families, in the area, *Croton macrostachyus*, *Ficus vasta*, *Ptrerolobium stellatum*, *Cordia Africana*, *Syzgium guineense*, *Carissa spinarum*, *Ficus thonningii*, *Euclea racemosa*, *Bersama abyssinica*, *Albizia schimperiana*, *Ficus sur*, and *Ziziphus spina-Christi* were the commonly existed woody plant species. At the same time, the study portrayed that, Olea welwitschii, Maytenus sp, Acacia seyal, Galiniera *saxifraga*, *Haroressa*, *Albizia gummifera*, *Rhus glutinosa*, *Polyscias fulva*, *Olea europaea*, *Acacia albida*, *Clutia abyssinica*, *Justicia schimperiana*, *Phoenix reclinata*, *Ekebergia capensis*, *Allophylus abyssinica*, *Teclea nobilis* and *Caesalpina decapelata* were the rarely frequent and diverse in the dry evergreen montane forest of the study site.

The existence of plant species in terms of growth habits was founded as Trees, 25 in number (62.5%), Shrubs, 11 in number (27.5%), and Lianas or climbers, 4 in the number of species, (10%) from the total growth habit (Figure.2). Despite this, the floristic composition does not include plant growth habits with herbaceous species; it needs further research to decide about the whole florist composition of the vegetation.

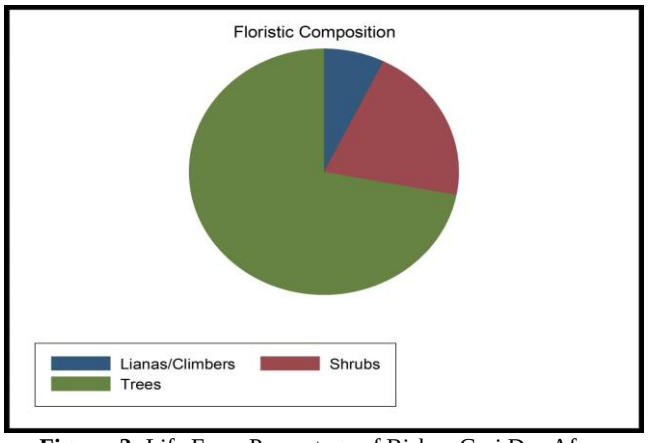

Figure. 2: Life Form Percentage of Bishan Gari Dry Afro-Monaine Forest

Species Richness, Evenness, and Diversity of Woody Species

Species diversity is a combination of the number of species and relative abundance within a given ecological site. The study of woody species showed variation in their species richness, evenness, and diversity (Table. 2). Site/plot 40 had the highest species richness, whereas sites 3, 16, and 37 comprised the second highest species richness. The highest species diversity was found in site 1 in all diversity indices (Shannon, Simpson's, and Fisher's Alpha diversity) by 2.12, 0.86, and 6.73 respectively. The least species richness and diversity were found on site 21 and site 38.

The overall Shannon-Wiener diversity and Simpson diversity indices were also estimated to measure the average degree of uncertainty in predicting to what species or an individual chosen from an exact collection of S species and N individuals belong. Thus, Shannon diversity (H) was computed to be 1.43 with a p-value of 0.35, where Simpson diversity index (H) = 1-p, which is an average of about 0.65. According to a scholarly report, the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5 [14]. Shannon diversity index is high when it is above 3.0, medium when it is between 2.0 and 3.0, low when between 1.0 and 2.0, and very low when it is smaller than 1.0 [15].

Therefore, this figure is the overall diversity indices of the Bishan Gari Forest and is relatively lower when compared to the diversity indices reported by [16]. Where the Shannon diversity index was= 2.60 for woodland vegetation on the islands of Lake Ziway. The average Pielou's evenness/equitability (J) for the overall species S = 40 was found to be 0.70. According to the basic interpretation of the Simpson diversity index (D), the larger value indicates lower diversity, and the smaller value shows a higher diversity of a species. Hence, the overall average Shannon-Wiener index (H'=1.43) and overall evenness (J = 0.70) for the entire forest indicated lower species diversity and higher evenness which this result was in line with [17], for evenness of 0.76 and contradict with Shannon Diversity Index (H' = 3.24) of woody species diversity of Woynwuha Natural Forest of North-western Ethiopia.

Findings confirm that no community existed in which all species were equally common [18]. Instead, only a few individuals represented the most. Thus, Fisher's alpha diversity measures the distribution patterns of a species at a community or site. As shown in (Table. 2) a few numbers of sites (sites 4, 9, 25, 26, and 30) had relatively similar species abundance, while most of the plots/sites consisted of different/unequal species distribution. Hence, the log series of abundance distribution was normal. Moreover, the overall average Simpson's diversity index was low (0.65), this might be due to poor species performance and/or some environmentally matched and dominated species such as Ficus ovata.

Table. 2: Diversity Indices of Bishan Gari Forest

Site numbers	Species Richness (S)	Shannon Diversity Index (H)	Simpson's Diversity Index (D)	Pielou's evenness (J)	Fisher's Alpha
S1	10	2.12	0.86	0.92	6.73
S2	7	1.71	0.78	0.88	4.45
S3	12	2.14	0.84	0.86	7.96
S4	10	1.93	0.82	0.84	3.58
S5	8	1.80	0.81	0.87	2.26
S6	7	1.80	0.82	0.93	2.93
S7	7	1.84	0.83	0.95	3.07
S8	9	1.94	0.83	0.88	3.67
S9	8	1.62	0.73	0.78	3.14
S10	11	2.21	0.87	0.92	4.06
S11	7	1.38	0.64	0.71	2.01
S12	8	1.50	0.71	0.72	2.74
S13	6	1.32	0.67	0.74	2.03
S14	6	1.01	0.50	0.56	1.54
S15	8	1.32	0.66	0.55	1.82
S16	12	1.47	0.63	0.59	3.81
S17	8	1.51	0.70	0.72	2.32
S18	9	1.25	0.60	0.57	2.03
S19	10	1.38	0.60	0.60	2.60
S20	7	1.33	0.64	0.68	2.52
S21	3	0.46	0.23	0.42	0.90
S22	5	0.90	0.44	0.56	1.71
S23	5	0.88	0.43	0.55	1.69
S24	5	0.92	0.45	0.57	1.64
S25	10	1.70	0.74	0.74	3.51
S26	10	1.57	0.70	0.68	3.51
S27	7	1.53	0.73	0.78	2.00
S28	6	1.01	0.48	0.56	1.96
S29	7	1.61	0.74	0.82	1.99
S30	10	1.61	0.70	0.70	3.37
S31	8	1.06	0.44	0.51	2.93
S32	10	1.26	0.61	0.55	2.68
S33	5	1.31	0.69	0.81	1.16
S34	7	1.19	0.61	0.61	1.73
S35	6	0.93	0.44	0.52	1.81
S36	6	1.08	0.54	0.60	1.70
S37	12	1.59	0.67	0.64	4.17
S38	3	0.71	0.40	0.64	0.70
S39	10	1.50	0.66	0.65	3.13
S40	13	1.88	0.76	0.73	4.15
Overall Average		**1.43**	**0.65**	**0.70**	**2.79**

As shown in (Figure 3, sample-based species richness estimation was employed. The illustration in the figure indicated that species accumulate more slowly in the accumulation curve due to samples being added until an asymptote is reached or all species are already encountered. Similar reports state that the forest area is getting wider, and the probability of getting new species increases, contributing to a higher diversity value [19]. De-trended Correspondence Analysis (DCA) is of special interest as it provides ordinations in spaces that are defined in known units of standard deviation, being directly interpreted in terms of ecological turnover.

DCA improves multidimensional-rescaling ordinations by reducing the arch effect produced by other ordination techniques. The plotted DCA had a regular hexagonal diamond shape, in which most species and sample sites scored along the axis coherently (Figure 4). However, some species such as *Acacia seyal*, *Polyscias fulva*, and *Phoenix reclinata* have deviated from this ordination, which might be due to those species couldn't perform efficiently within the dynamic environmental gradients through time. This result is justified by a scientific statement which noted that the ecological space as defined by species arrangement suggests that axes have environmentally associated distributions along axes of ecological changes [20].

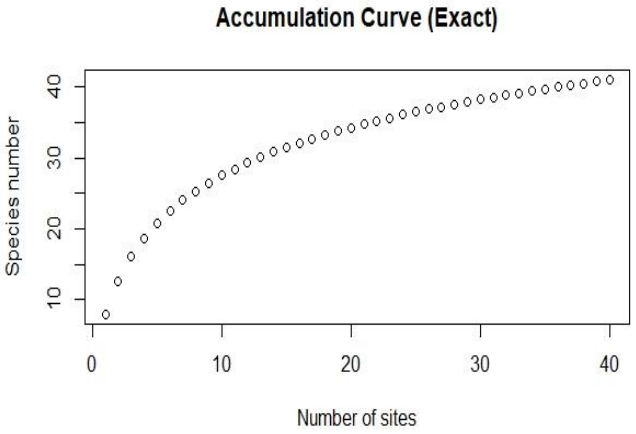

Figure. 3: Species Accumulation Curve of Bishan Gari Forest

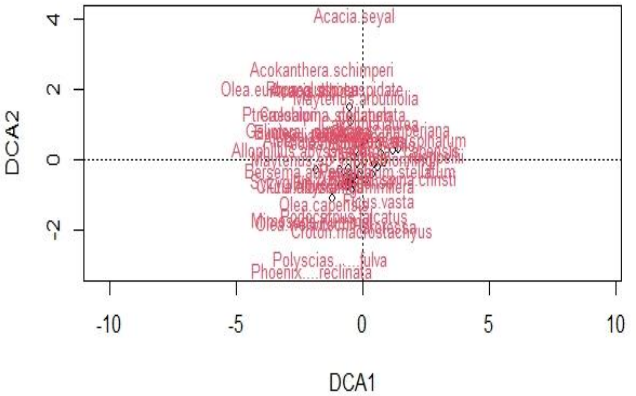

Figure. 4: De- trended Correspondence Analysis for Species in Bishan Gari Forest

Structure

Vertical Structure

In the tropics, the vertical structure of the vegetation was categorized according to [21], stratified vegetation category index, as follows:

1. Upper storey: the layer comprising the tree species which attain a height greater than two-thirds of the top height of a given forest.
2. Middle storey: When the stratum is formed by individual tree/shrub species with a height greater than one-third of the top height in a given forest.
3. Lower storey: When the stratum is formed by individual tree/shrub species with a height of less than one-third of the top height in a given forest.

Similar to this, the vertical structure of the Bishan gari forest generally can be categorized as illustrated in (Annex 1 & Figure 5). Accordingly, the tree species whose height exceeds 30m represented the upper storey consisting of about 15.1% of the floristic composition; those tree species whose height lies between 15.1-30 m were categorized as the middle stratum constituting about 41.51% of species composition and those tree species whose height ranges between 2-15m were classified to the lower layer, about 43.39% in proportion from the woody plant species counted in the study vegetation.

Beyond this category, the species like *Podocarpus falcatus Ficus ovata, Ficus vasta, Celtis Africana, Mimusops Kummel, Syzygium guineense, Croton macrostachyus* and *Cordia africana* were not specific to each vertical structure. Instead, they appeared in each stratum. According to researchers noted, such kinds of species are called species with a regular vertical distribution [22, 23]. In general, the analysis of the vertical structure of the Bishan gari evergreen montane forest reveals that the majority of the floristic composition was found in the lower strata of the vegetation.

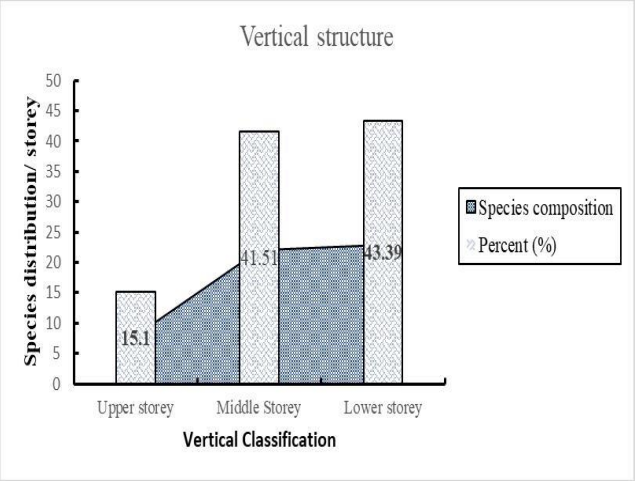

Figure 5: Vertical structure of Bishan gari forest

Species density

Species density in the deciduous forest ranges between 0.49–178.05 per ha. (Annex 1). The variation in the relative density of the species was also between 0.06–21.03%. Those species with the least density were *Acacia albida, Olea europaea, Polyscias fulva, Albizia gummifera, Harooressa, Galiniera saxifraga, Maytenus sp, Acacia seyal and Olea welwitschii,* whereas the highest species density (> 100 ha-1) was for *Vernonia rueppellii* (178.05) and *Calpurnia aurea* (134.63). The finding of this study depicted that there is a significant variation among the individual tree/shrub species in density ha-1. In the inventoried vegetation, the total species density per ha was 846.83. In this result majority of the species (47.5%) belonged to density class D (Table. 3). The species densities ha-1 with a diameter size greater than 10 cm DSH/DBH and greater than 20 cm DSH/DBH was 207.33 and 153.19 respectively and their ratio was 1.35. This entailed that the number of stems ha-1 was higher for species of smaller diameter size than for species of greater diameter size.

Tab. 3: Density class and the distribution of species

Species density class	Total density	Relative density	Number of species	Proportion (%)
A (>100)	312.68	36.95	2	5
B (50.1–100)	240.49	28.4	3	7.5
C (20.1–50)	180.47	21.30	6	15
D (1–20)	107.82	12.73	19	47.5
E (<1)	5.37	0.54	10	25
Total	**846.83**	**100**	**40**	**100**

Important Value Index (IVI)

As those with the greatest importance value are dominant in specified vegetation (Shibru and Balcha 2004) and might also be the most successful species in regeneration or an important parameter that reveals the ecological significance of species in a given ecosystem [24]. Accordingly, in the inventoried Bishan gari dry evergreen montane forest, the species IVI ranges between 0.41—43.07 (Table 4 & Annex 2). The lowest value was recorded for Olea welwitschii and Maytenus sp, while the highest value was registered for Ficus ovata. This result confirmed that in this dry evergreen montane forest, the species' relative frequency, density and dominance differed correspondingly. This is due indicated the importance of developing the conservation priority for existing species in the deciduous forest. Hence, to set the species priority in Bishan gari dry evergreen forest, the result of the IVI analysis was classified in (Table 4).

Table 4: IVI class and proportion of the woody plant species

Species IVI class	Number of species	Total IVI	Proportion (%)
A (<=1)	15	8.89	2.96
B (1.1—10)	14	53.79	17.93
C (10.1—20)	7	107.27	35.76
D (20.1—30)	2	49.77	16.60
E (30.1—40)	1	37.22	12.41
F (>40.1)	1	43.07	14.36
Total	**40**	**300.01**	**100**

In principle, when a certain species receive the lowest IVI, it entailed as it demands foremost priority for conservation, while those species with the highest IVI require only monitoring and management instead of setting priority for conservation. Having this in mind, fifteen species; *Maytenus sp, Olea welwitschii, Polyscias fulva, Galiniera saxifraga, Olea europaea, Harooreessa (Local name, Afaan Oromoo), Acacia albida, Albizia gummifera, Acacia seyal, Clutia abyssinica, Rhus glutinosa, Allophylus abyssinicus, Ekebergia capensis, Justicia schimperiana* and *Phoenix reclinata* demands high priority for conservation. The remaining 25 species need monitoring and management efforts. According to their IVI Class, the inventoried woody plant species (Table 5).

Table 5: Woody plant species under the IVI classes

No	A (<1)	No	B (1.1–10)	No	C (10.1–20)
1	*Maytenue sp (Kombolcha)*	16	*Teclea nobilis*	30	*Syzygium guineense*
2	*Olea Welwitschii*	17	*Caesalpina decapetala*	31	*Carissa spinarum*
3	*Polyscias fulva*	18	**Xilloo**	32	*Maytenus arbutifolia*
4	*Galiniera saxifraga*	19	*Ziziphus spina christi*	33	*Celtis africana*
5	*Olea europaea*	20	*Bersama abyssinica*	34	*Ficus thonningii*
6	**Haroressa**	21	*Albizia schimpriana*	35	*Ficus vasta*
7	*Acacia albida*	22	*Ficus sur*	36	*Mimusops kummel*
8	*Albizia gummifera*	23	*Euclea racemosa*		**D (20.1–30)**
9	*Acacia seyal*	24	*Acokanthera schimperi*	37	*Calpurnia aurea*
10	*Clutia abyssinica*	25	*Cordia africana*	38	*Vernonea rueppellii*
11	*Rhus glutinosa*	26	*Ptrerolobium stellatum*		**E (30.1–0)**
12	*Allophylus abyssinicus*	27	*Olea capensis*	39	*Podocafpus falcatus*
13	*Ekebergia capensis*	28	*Petrolobium stellatum*		**F (>40.1)**
14	*Justicia schimperiana*	29	*Croton macrostachyus*	40	*Ficus ovata*
15	*Phoenix reclinata*				

Species population structure

The pattern of diameter class distribution is a denotation of the general trends in population dynamics and recruitment processes of a given species [25]. This is because the tessellation of diameter class distribution signifies the general trends of population dynamics and the reinforcement process of a particular species. This is portrayed by the computation of the diameter class of total species density distribution as an inverted J-shape curve (Figure A), which showed a pattern where a total species density distribution had the highest density in the lower diameter class and a gradual decrease towards the higher classes.

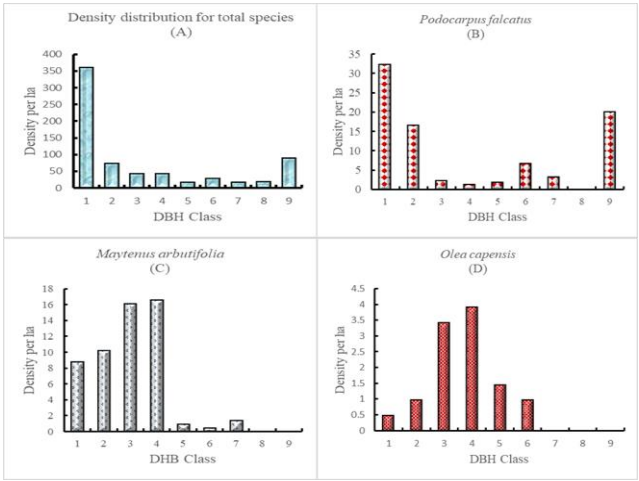

Figure. 6: Diameter class density distribution of selected tree species

DBHclass:1=2.6-7.5cm; 2=7.6-12.5cm; 3=12.6-17.5cm; 4=17.6-22.5cm; 5=22.6-27.5cm; 6=27.6-32.5cm; 7=32.6-37.5cm; 8=37.6-42.5cm; 9=>42.6cm

The population structure helps to study the regeneration pattern of a species [26]. The examination of selected individual species also disclosed two major patterns of population distribution. These are i) inverted J-shape curve for *Podocarpus falcatus* (Figure 6B), similar to the general trend of the diameter class total density distribution, this indicated the pattern which had the highest species density distribution in the lower diameter class and a gradual decrease towards the higher classes; ii) bell-shaped curve for *Maytenus arbutifolia* and *Olea capensis*, which was a type of density distribution in which it was high in the middle diameter classes and lower in the lower and higher diameter classes (Figure 6 C, D).

The population structure of the species was categorized for the sake of establishing the conservation priority for each species. To group these woody plant species, the criteria used were reproduction and recruitment status of the species in the vegetation. Reproduction refers generally to the regeneration status, while recruitment is meant to mean the existence of the species in different diameter classes or the next growth stage. Hence, based on these; the species were categorized as group 1 if both reproduction and recruitment were bad, group 2 if reproduction was good but recruitment was bad and group 3 if both reproduction and recruitment are good

Regeneration Status

Regeneration refers to the process of silvigenesis by which trees and forests survive over time [27]. The seedling status was recorded for 15 woody plant species, which belong to 13 genera and 11 families. This becomes about 37.5% when compared to the total matured woody plant species richness inventoried. Furthermore, the whole seedlings' density ha-1 was 2732. Concerning species, *Vernonea rueppellii, Calpurnia aurea, Acokanthera schimperi, Podocarpus falcatus* and *ptrerolobium stellatum* respectively contribute to the highest seedlings density in the dry evergreen montane forest, while *Maytenus sp, Ficus ovata, Carissa spinarum* and *Bersema abyssinica* were woody plant species consecutively constitute the lowest parts of seedling density ha-1 in the given forest.

The analysis result justifies that, only 37.5 species have seedlings as the regeneration, and about 62.5 have no seedlings from the total sampled population. This entailed that the regeneration status was very low and the possible reason could be the intensive trampling by livestock while browsing and grazing in the dry evergreen montane forest that compacted the soil and result in reducing the germination capacity of the seeds from the soil seed bank, similar reports by [27]. Based on this, they have resulted in physical damage to the seedlings by peeling during grazing and browsing. The result is also in line with the statement that the continuous disturbance occurring in the open area has prevented the development of vegetation [28].

From other points of view, 21 woody plant species existing at the sapling stage were registered. This consists of 52.5%

of the total tree/shrub species inventoried. These were grouped into 20 genera and 16 families. Moreover, in terms of the individual stems ha-1 or density, 5,774.42 stems ha-1 were recorded as saplings. Regarding disturbance, in addition to browsing, grazing and cutting, there was high water logging in the forest due to the flow of headwaters without a channel on the ground of the Bishan gari forest. This might inhibit seed germination and elongation through soil pores, suffocation and seed deterioration of those species with no regeneration status. Therefore, it demands high priority to ensure the regeneration of these species and thereby conserve them in a sustainable way.

The general grouping of the woody plant species was embarked based on the criteria that if the species are absent in seedlings and saplings or the regeneration list at all they were categorized as group 1; as group 2 if the density is between 0.1-50 and group 3 if the density is > 50 according to listed in (Table 6).

Table 6: List of woody plant species grouped by regeneration status

Group 1	**Group 2**	**Group 3**
Acacia albida	*Maytenus arbutifolia*	*Vernonea rueppellii*
Acacia seyal	*Maytenus sp*	*Calpurnia aurea*
Albizia gummifera	*Croton macrostachyus*	*Justicia schimperiana*
Allophylus abyssinicus	*Eulea racemosa*	*Podocarpus falcatus*
Clutia abyssinica	*Rhus glutinosa*	*Acokanthera schimperi*
Albizia schimperiana	*Syzygium guineense*	*Ptrerrolobium stellatum*
Cordia Africana	*Caesalpina decapelata*	*Carissa spinarum*
Ekebergia capensis	*Celtis africana*	*Bersema abyssinica*
Ficus sur	*Ficus ovata*	*Petrolobium stellatum*
Ficus vasta	*Galiniera saxifraga*	
Harooreessa	*Teclea nobilis*	
Mmusops kummel	*Ficus thonningii*	
Olea capensis	*Justicia schimperiana*	
Olea europaea	*Bersema abyssinica*	
Olea welwitschii	*Carissa spinarum*	
Phoenix reclinata		
Ployscias fulva		
Xiilloo		
Zziphus spina-christi		

Measures Proposed for the Genetic Conservation of Woody Plant Species

Taking into account the population structure (PS), regeneration status (RS) and an important value index (IVI) of the woody plant species. Based on this, 12 woody species where can be conserved by both in In situ and Ex situ Seeding, planting and conservation of stands, whereas 28 species were recommended for the conservation of stands by In situ and seed storage in gene banks using Ex situ conservation method (See Annex 3).

Conclusion AND FUTURE SCOPE

The Bishan gari forest was classified under dry evergreen montane (small-leaved deciduous) vegetation. It consists of 40 woody plant species (trees, shrubs and lianas) which constitute 29 genera and 21 families and are dominated by large trees/shrubs. Compared to the spatial extent (311 ha) of the site, the vegetation was composed of high species richness and diversity. However, the overall average indices (Shannon Weiner and Simpson's) diversity index lies in the range of low diversity indices. Nevertheless, the vegetation was partially under problem due to human and animal disturbance.

At the site, grazing, browsing and tree logging were the major characteristics of factors that contribute to the disturbance of woody plant species diversity. These factors have caused a low rate of regeneration capacity by compacting the ground surface of the forest which inhabited seed elongation and germination as well as by feeding and stamping the juvenile species even that grow through these difficulties. Furthermore, water logging on a plain area of forest ground has also an impact on the regeneration of these species. The coexistence of all these factors has an impact on the ideal productivity of the vegetation without dropping/losing its floristic richness. According to a result of IVI analysis revealed; *Maytenus sp, Olea welwitschii, Polyscias fulva, Galiniera saxifraga, Olea europaea, Harooreessa (Local name, Afaan Oromoo), Acacia albida, Albizia gummifera, Acacia seyal, Clutia abyssinica, Rhus glutinosa, Allophylus abyssinicus, Ekebergia capensis, Justicia schimperiana* and *Phoenix reclinata* captured the underslung IVI value; which have forced them to categorize under IVI class 1. Therefore, it is mandatory to set priority for the conservation of these threatened woody plant species to revive from current squashed risks. In general, for sustainable conservation and utilization of forest genetics by present and future generations; the following recommendations were forecasted:

1. Conservation of those species with low IVI by setting priority is critically essential while providing proper management and monitoring for the remaining woody plant species.
2. It is necessary to encourage tree planting in homesteads, farmlands and churchyards via the supply of seedlings of indigenous and multipurpose tree species or the establishment of a nursery to reduce the pressure on the natural vegetation.
3. Ultimately, further studies on soil properties, ecological interaction among species, and the existence and impact of diseases on vegetation are crucial.

Abbreviations

DBH Diameter at Breast Height
DCA De-trended Correspondence Analysis
DSH Diameter at Stump Height
EBI Ethiopian Biodiversity Institute
EFAP Employee and Family Assistance Programs
FGRCP Forest Genetic Resource Conservation Program
GPS Global Positioning System
IVI Important Value Index
QGIS Quantum Geographic Information Science

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