Woody Species Diversity, Structure and Regeneration Status in Weiramba Forest of Amhara Region, Ethiopia: Implications of Managing Forests for Biodiversity Conservation

Zelalem Teshager[1]* Mekuria Argaw[2] Abeje Eshete[1]
1.Ethiopian Environment and Forest Research Institute, P.O. Box: 24536, Addis Ababa, Ethiopia
2.Center for Environmental Science, Addis Ababa University, P.O. Box: 1176, Addis Ababa, Ethiopia

Abstract
This study was conducted in Weiramba Forest, with the aim of determining the composition, structure, diversity and regeneration status of the woody species found in the area. A systematic sampling method was used to conduct the vegetation sampling. In order to collect vegetation data a total of 40 quadrats, each with the size of 10 m x 20 m at an interval of 100 m, were laid along the established transects at 200 m apart. For the assessment of seedling and sapling, two sub-quadrats each with the size of 2 m x 5 m were established at opposite sides of the main quadrat. In each main plot, data on species abundance, height, and Diameter at Breast Height (DBH) of woody plant species and altitude, slope and aspect were recorded. Woody Species Diversity analysis was carried out by using Shannon Weiner index. Results revealed that the total of 32 species representing 28 genera and 20 families were recorded in the forest. The Shannon Weiner diversity index and evenness were resulted to be 2.30 and 0.66, respectively. The population structure revealed in diameter and height class frequency distribution was to be Bell- shape with a very high decrease towards the lower and higher diameter and height classes. The total basal area of the forest was 32.10 m^2/ha. Results of population structure of woody plants and regeneration status analysis in the forest revealed that the Forest was dominated by small-sized trees and shrubs indicating that it is in the stage of secondary development and there is a need for conservation priority for species with poor regeneration status. From the point of view of managing forests for biodiversity conservation, the result suggested that the forest should be conserved and protected in a sustainable way for further biodiversity conservation.
Keywords: Weiramba Forest, Diversity, Structure, Woody species Composition, Regeneration

1. INTRODUCTION

Biodiversity of different ecosystems of the globe is not evenly distributed (Barthlott, 1998). Some regions of the world like that of tropics are relatively richer in biodiversity as compared to other places. Tropical dry forests form the largest component, more than 40 percent, of all tropical forests (Murphy and Lugo, 1986). In Africa, similarly dry forests account for 70-80% of the forested area. However, most of those countries of the tropics that are endowed with such huge biodiversity have poor economies, which is the major challenge to conserve their biodiversity.

Ethiopia is one of the top 25 richest countries in the world in terms of biodiversity (WCMC, 1994). Badege Bishaw (2001) also stated that Ethiopia is one of the few countries in Africa where virtually all major types of natural diversified vegetations are represented, ranging from thorny bushes, and tropical forests to mountain grasslands due to its wide variation in climate, topography, and soils. The flora of Ethiopia is very heterogeneous and has rich endemic taxa. The Ethiopian highlands contribute to more than 50 percent of the land area with Afromontane vegetation (Yalden, 1983; Bekele, 1994), of which dry forests form the largest part.

Forest serves as a source of food, household energy, construction and agricultural material, tourism and recreation values and medicines for both people and livestock (Bekele, 1994; Vivero *et al.,* 2005). Also, the forests worldwide are known to be critically important habitats in terms of the biological diversity they contain and in terms of the ecological functions they serve (SCBD, 2001). Although Forests have crucial ecosystem service in soil and biodiversity conservation and mitigation of climate change, they are being destroyed at an alarming rate largely due to human-related disturbances (Anonymous, 2009). Ethiopian People, particularly in the rural areas of the country, are highly dependent on forest resources to fulfill their basic needs such as fuelwood for cooking, heating, foliage for livestock, and timber for shelter and non-timber products for medicine. Environmental degradation and deforestation have been taking place for many years in the country. Especially during the last century, Ethiopia's forest has been declining both in size (due to deforestation) and quality (due to degradation) (EFAP, 1994). The clear-felling accelerates the loss of seedlings and saplings as well as disturbs the natural condition of the natural forests and hence the ecosystem (Haque *et al*. 1988).

Assessments on floristic composition, species diversity and structural analysis studies are essential for providing information on species richness of the forests, useful for forest management purpose and help in understanding forest ecology and ecosystem functions (Giriraj *et al.,* 2008; Pappoe *et al.,* 2010). Knowledge of floristic composition and structure of forest is also useful in identifying ecologically and economically important plants and their diversities, protecting threatened and economically important plant species (Addo-Fordjour *et al.,* 2009). Knowledge about the pattern of natural regeneration is important to answer the basic question of forest management (Hossain *et al*., 1999). Despite these, studies on the ecology and flora of the Weiramba Forest are lacking. The aim of this study was, therefore, to assess the woody species composition, structure, diversity, and regeneration status of Weiramba Forest.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was conducted in Gerado Kebele, Habru district which is Located in the Amhara National regional state North Wollo East Plain in Weiramba forest located at about 15 km from Mersa, 375 km from Bahirdar and 500 km from Addis Ababa. Habru district is located in a geographical zone of 39°30' to 39°45'N and 11°30' to 11°15'E within an altitude range of 1430-2800 m above sea level. Geographically, Weiramba forest is located between 1297343' - 1297867'E longitude and 562799'- 569978'N latitude. Its altitudinal range is between 2000-3000 meters above sea level.

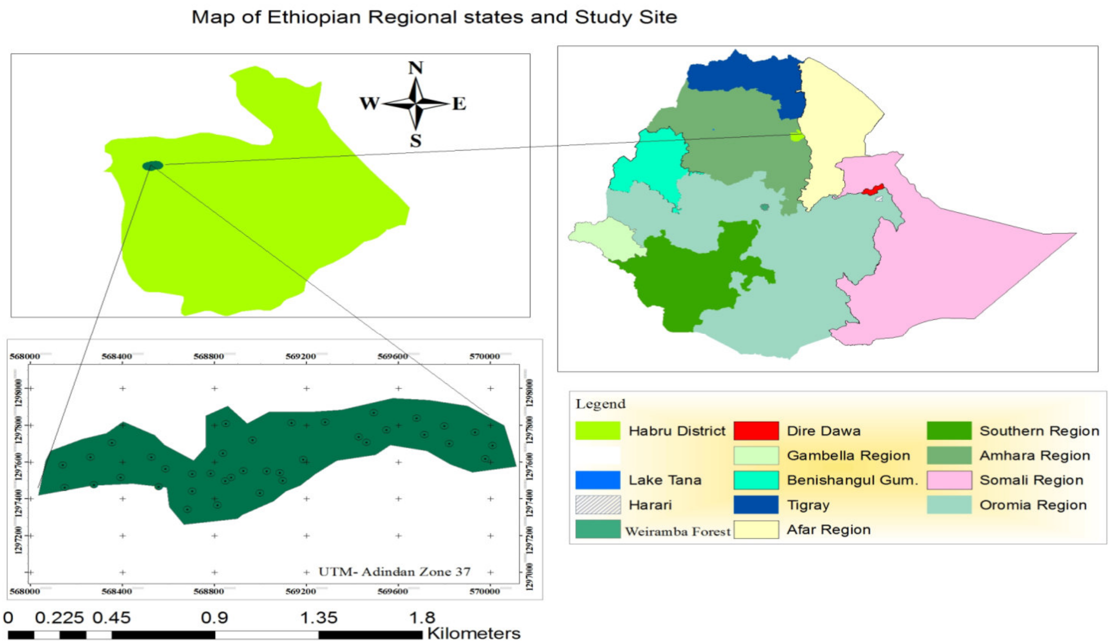

Figure 1. Map of the study area

The mean annual maximum and minimum temperature ranges 28.6 ^{0}c and 15 ^{0}c respectively and the mean annual rainfall ranges from 750 to 1000 mm.

Weiramba Forest is one of the remnants dry evergreen Afromontane forests in northern Ethiopia and the forest has an altitudinal gradient ranging from 1923 to 2225 m above sea level. According to the Habru District Agriculture and Rural Development Office (HDARDO), the forest covers a total area of 153 ha and it is a home for a variety of flora and fauna.

2.2 Reconnaissance Survey and Delineation of the study site

The reconnaissance survey was made across the forest in order to obtain an impression in site conditions and physiognomy of the vegetation, collect information on accessibility, identify sampling sites and calculate sample size. Then, the elevation range and transect direction of the forest were determined and transects were laid from the lowest altitudinal elevation to the highest (Alves *et al*., 2010). The boundaries of the study forest area were delineated by taking geographic coordinates with GPS at each turning point to facilitate accurate data.

2.3 Sampling Design

In this study area, there is high variability in topography and vegetation types. Hence, a rectangular nested quadrat design which is appropriate to incorporate the variable tree sizes (Brown, 1997; Hairiah *et al.,* 2001); was used. The systematic sampling method was used to take samples. Accordingly, a total of seven transects lines and 40 quadrats of 10 m x 20 m (200 m^2 each) in size were systematically established for vegetation sampling. The GPS points that were taken from the study site to indicate each sample quadrats were recorded. The alignment of transects was done using Compass and GPS. It was set up purposively across areas where there are rapid changes in vegetation and marked environmental gradients (Kent and Coker, 1992). Quadrats were laid systematically at every 100 m along transect lines, which were 200 m apart from each other. In order to eliminate any influence of the road effects on the woody species of the forest, all the quadrats were laid at least 100 m away from nearest roads. For the purpose of regeneration assessment, from the two sub-quadrats of 2 m x 5 m, seedling and sapling counting per species was made.

2.4 Data Collection

Primary data was obtained through field measurements in the study areas and the secondary data was collected from different resources like published and unpublished materials, books, journals, articles, reports, and electronic websites. To collect information of woody species composition, all live trees/shrubs with a diameter ≥ 2.5 cm were recorded in each quadrat using Caliper and Diameter Tape as indicated by (Pearson *et al.,* 2005). In addition, the total tree heights (to the top of the crown) were measured using Hypsometer (Brown *et al*., 2002; Pearson *et al*., 2007). Each tree was recorded individually, together with its species name and ID. Trees/Shrubs with multiple stems at 1.3 m height were treated as a single individual and the diameter was measured separately for the branches and averaged as one DBH and the tree/shrub boles buttressed, DBH measurement was undertaken from the point just above the buttresses. Trees with multiple stems or fork below 1.3 m height were also treated as a single individual (Kent and Coker, 1992). In all quadrats, additional trees and shrubs outside the quadrat boundaries but within 10-15 m were collected and noted as present. Besides to this, additional field layer species that were encountered outside the sub-quadrats were collected and noted as present. In this study, the seedling was considered as those woody individuals having less than 2.5 cm in DBH and less than 2 m in height, whereas Sapling was considered as those woody individuals having less than 2.5 cm in DBH and 2 m and above in height. Local names of trees were recorded and later scientific names were identified from all published volumes of Flora of Ethiopia and Eritrea and Useful trees and shrubs for Ethiopia (Azene Bekele, 2007). For species that proved difficult to identify in the field, herbarium specimens were collected, dried properly and transported to the National Herbarium at Addis Ababa University for identification.

2.5 Data Analysis

The Diameter at Breast Height (DBH), basal area, tree density, height, frequency and important value index were used for the description of vegetation structure. The following structural parameters were calculated for some species following Mueller- Dombois, and Ellenberg (1974) as follows:

Density of a species = the number of individuals of that species/area sampled

Percent frequency of a species = the number of quadrats in which that species occurs/total number of quadrats X 100

Relative frequency = Frequency of species/total frequency of all species X 100

Relative density = Density of species A/total density of all species X 100

Relative dominance = Dominance of species A/total dominance of all species X 100

Importance Value Index = Relative density + Relative frequency + Relative dominance.

Basal area (m^2) = $\pi (d/2)^2$ where d is diameter at breast height (cm), $\pi = 3.14$

Dominance = Total of basal area / area sampled

The distribution of the size classes was evaluated by computing the density of individuals with DBH >10 cm and > 20 cm as well as the ratio of the former to the latter (Grubb *et al.,* 1963). Species richness, diversity (Shannon Wiener diversity index) were calculated as per Magurran (1988). Regeneration status of the forest was examined by computing and comparing present tree populations (large trees) with the regenerating populations (seedlings and saplings) of tree species according to Dhaulkhandi *et al.* (2008) and Tiwari *et al*. (2010).

3. RESULTS

3.1 Woody Species Composition

A total of 32 woody species belonging to 28 genera and 20 families were recorded from Weiramba Forest. The collected species were composed of 46.67 % (14 in number) trees, 40 % (12 in numbers) trees/shrubs and 20% (6 in numbers) shrubs. Fabaceae is the most dominant family with 3 (11.11%) genera and 6 (19.35%) species followed by Cupressaceae, Myrtaceae, Rubiaceae, Sepindaceae which each has 2 (7.4%) genera and 2 (6.45%) species. Tiliaceae with 1 (3.7%) genera and 2 (6.45%) species ranked third. Balanitaceae, Sapotaceae, Apocynaceae, Casuarinaceae, Verbenaceae, Euphorbiaceae, Sapindaceae, Boraginaceae, Ebenaceae, Bignoniaceae, Celastraceae, Myrsinaceae, Oleaceae were represented each by 1 (3.7%) genera and 1 (3.23%) species.

3.2 Vegetation Structure

3.2.1 Density of Woody Species

A total of 3547 individuals, from 32 species, were recorded with the DBH ≥ 2.5 cm within 40 quadrats in Weiramba Forest between the altitudinal ranges of 1923 m and 2225 m.a.s.l. *Of these, Olea europaea* subsp.

Cuspidata was the dominant species in the study area covering 29.91% (1061 stems). *Acacia albida* is the second dominant species with 14.08% (499 stems) coverage of the study quadrats. *Pittosporum viridiflorum, Allophylus abyssinicus*, and *Dodonaea Anguistifolia* covered 13.72% (487 stems), 8.65% (307 stems) and 7.69% (273 stems), respectively. *Casuarina equisetifolia, Grewia ferruginea* was the least dominant species with equal coverage of 0.02% (1 stem) in the study forest. *Psydrx schimperiana, Ehretia cymosa, Balanites aegyptiaca, Leucaena leucocephala and Jacaranda mimosifolia,* were the next least dominant species covering 0.05% (2 stems), 0.08% (3 stems), 0.08% (3 stems), 0.11% (4 stems) and 0.11% (4 stems), respectively. The total density was 1343 stems per ha for DBH > 10 cm and 113 individuals per ha for DBH > 20 cm. The density ratio of individuals with DBH >10 cm to those greater than 20 cm is 11.94 for the study forest.

3.2.2 DBH class distribution

The DBH distribution of Weiramba forest was classified into five classes. The number of stems in DBH class 6-10 cm was 1086.25/ha (48.99%). The distribution of tree species in different DBH classes was 646.25/ha (29.2%) in 11-15 cm, 290.63/ha (13.1%) in ≤ 5 cm, 151.25/ha (6.8%) in 16-20 cm and it was found to be 42.5/ha (1.9%) of the total in DBH class >20 cm (Figure 2).

20.6% and 41.5% of the total density is found in the lower classes (first and second), whereas about 29.2% and 8.7% of the density was found to be in the middle classes (between second and fourth) and in the higher diameter classes (fourth and fifth), respectively. In general, most woody plants were located in the second and third classes. On the other hand, the rest of least number of plants were found in the first, fourth and fifth classes respectively. Accordingly, the cumulative density of trees in lower and higher DBH classes is lower when compared to the cumulative density of the intermediate ones.

The mean maximum DBH value in the study area was recorded for *Casuarina equisetifolia* with the average DBH value of 21.75 cm followed by *Cupressus lusitanica* and *Juniperus procera* with the average DBH value of 15.91 cm and 14.7 cm, respectively. The least mean DBH were recorded for *Clerodendrum myricoides* with the mean value of 5.15 cm followed by *Myrsine Africana abyssinica* with the value of 4.9 cm.

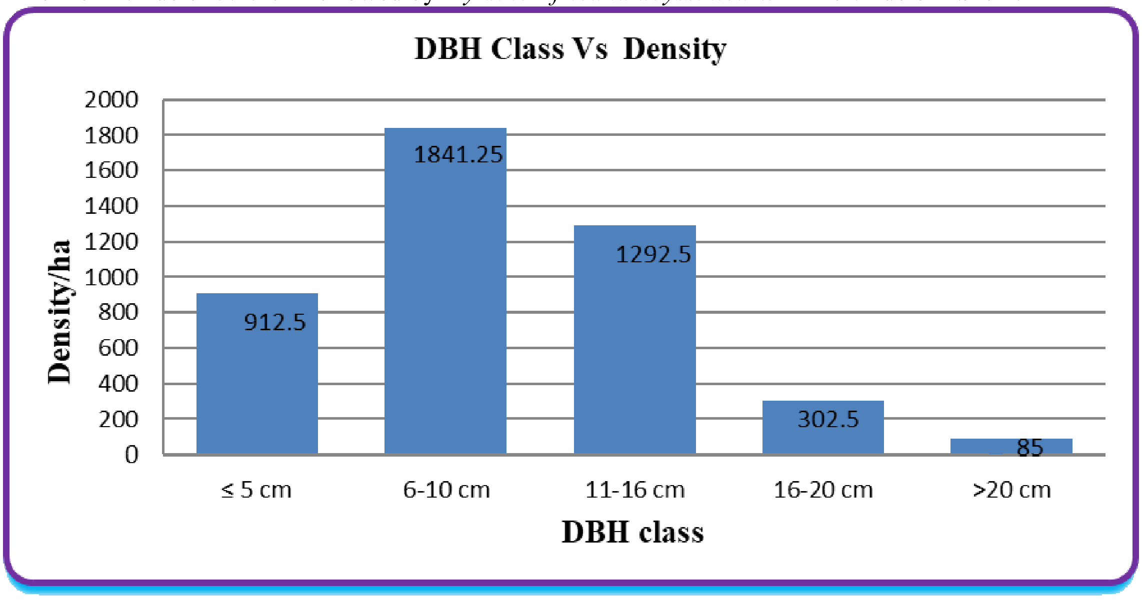

Figure 2: DBH class distribution of all trees recorded in the study area

3.2.3 Hight class distribution

Like that of DBH distribution of plants, the height distribution of plants also was classified into five classes (≤ 4 m), (5-8 m), (9-12 m), (13-16 m) and (>16 m). The density distribution of woody individuals in different height classes showed a Bell-shape pattern, which showed a type of frequency distribution in which a number of individuals in the middle classes were high, and decreased towards the lower and higher diameter/height classes. Generally, it showed a decrease in density with decreasing and increasing height classes (Figure. 3). This means, there is the higher number of individuals in the middle size and a gradual decrease towards the lower and upper size trees indicating continuous representation of individuals in all height classes. The highest number of individual trees was found to be 825.63 ha^{-1} (37.24%) representing the height class III. Trees in height class I and II have 140 and 747.5 individual trees per hectare and together make 40.04%. Trees in the height classes IV and V together are found to be 22.73 %. Height can be used as an indicator of the age of the forest. The old trees are found in the height class above 20 m and their percentage distribution are 6.91%.

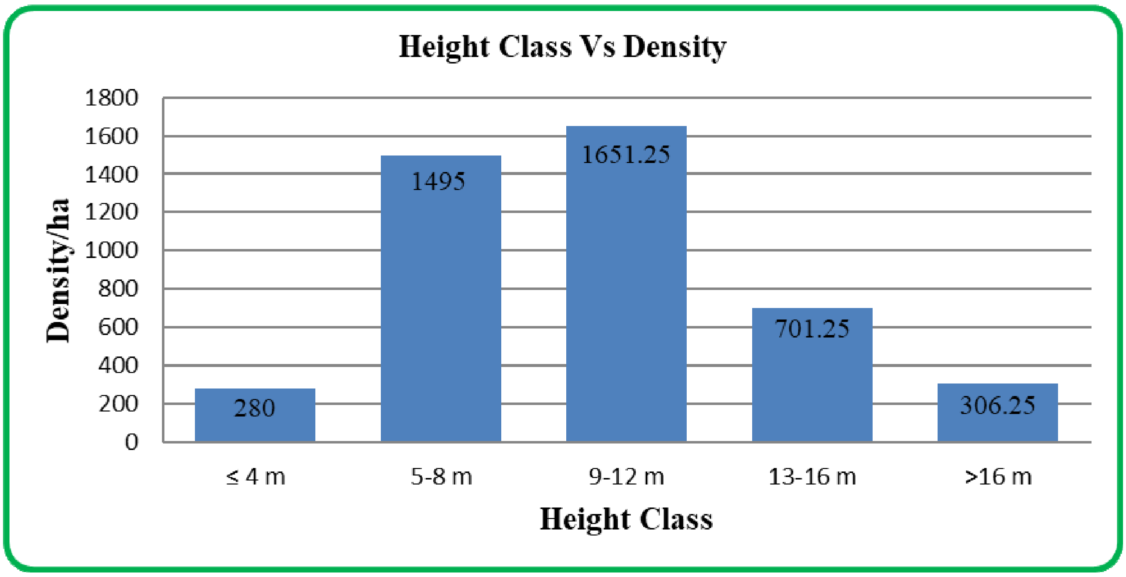

Figure 3: Height class distribution of all trees recorded in the study area

3.2.4 Frequency

Based on the percentage frequency values, the tree/shrub species were classified into five frequency classes: 1 = 0-20, 2 = 21-40, 3 = 41-60, 4 = 61-80 and 5 = 81 – 100. The frequency and % frequency values of species are given in Table 1. Accordingly, the frequency distribution of species showed that *Acacia albida* (100%) and *Olea europaea* subsp. *cuspidata* (95%) were the two most frequently observed tree species (in 40 and 38 quadrats out of 40, respectively). *Dodonaea anguistifolia, Allophylus abyssinicus*, and *Pittosporum viridiflorum* were 92.5%, 87.5%, and 82.5% distribution, respectively. The species with the least occurrence in the study site are *Aningeria adolfi-friedericii, Balanites aegyptiaca, Canthium oligocarpum, Casuarina equisetifolia and Clerodendron myricoides, Croton macrostachyus, Grewia bicolor, Jacaranda mimosifolia, Leucaena leucocephala, Premna schimperi, Psydrx schimperiana* and *Rosa abyssinica.*

Table 1: Tree species Name, mean DBH, frequency, relative frequency, density/ha and relative density of the species

Species Name	No. of individuals	Quadrats No. Spp. Occurs	Mean DBH (cm)	Frequency (%)	Relative Frequency	Density/ha	Relative Density
Acacia albida	499	40	12.1	100	12.08	623.75	14.07
Acacia decurrens	19	3	10	7.5	0.90	23.75	0.53
Acacia etbaica subsp. *Etbaica*	23	7	10.71	17.5	2.11	28.75	0.65
Acacia sieberiana	30	4	12.75	10	1.20	37.5	0.84
Allophylus abyssinicus	307	35	7.9	87.5	10.57	383.75	8.65
Aningeria adolfi-friedericii	13	1	8.41	2.5	0.30	16.25	0.36
Balanites aegyptiaca	3	1	10	2.5	0.30	3.75	0.08
Calpurnia aurea	16	6	5.75	15	1.81	20	0.45
Canthium oligocarpum	6	1	8.4	2.5	0.30	7.5	0.17
Carissa edulis	230	25	6.57	62.5	7.55	287.5	6.48
Casuarina equisetifolia	1	1	21.75	2.5	0.30	1.25	0.03
Clerodendron myricoides	5	1	5.15	2.5	0.30	6.25	0.14
Croton macrostachyus	5	1	6	2.5	0.30	6.25	0.14
Cupressus lusitanica	25	2	15.91	5	0.60	31.25	0.70
Dodonaea anguistifolia	273	37	6.78	92.5	11.17	341.25	7.69
Ehretia cymosa	3	2	12.25	5	0.60	3.75	0.08
Eucalyptus camaldulensis	94	15	7.35	37.5	4.53	117.5	2.65
Euclea divinorum	159	22	7.22	55	6.64	198.75	4.48
Grewia bicolor	1	1	6	2.5	0.30	52.5	0.02

Grewia ferruginea	42	10	7.44	25	3.02	1.25	1.18
Jacaranda mimosifolia	4	1	12	2.5	0.30	5	0.11
Juniperus procera	29	3	14.74	7.5	0.90	36.25	0.82
Leucaena leucocephala	4	1	5.88	2.5	0.30	5	0.11
Maytenus arbutifalia	126	20	7.22	50	6.04	157.5	3.55
Myrsine Africana	31	6	4.9	15	1.81	38.75	0.87
Olea europaea subsp. Cuspidata	1061	38	9.83	95	11.48	1326.25	29.91
Osyris quadripartite	33	9	6.75	22.5	2.71	41.25	0.93
Pittosporum viridiflorum	487	33	10.8	82.5	9.96	608.75	13.73
Premna schimperi	10	1	11.94	2.5	0.30	12.5	0.28
Prunus Africana	5	2	10	5	0.60	6.25	0.14
Psydrx schimperiana	2	1	14.62	2.5	0.30	2.5	0.05
Rosa abyssinica	1	1	3.75	2.5	0.30	1.25	0.02
Total	3547						

3.2.5 Basal Area (BA)

The total basal area calculated for the study area was about 32.10 m^2/ha for woody plants ≥ 2.5 cm in DBH and this constitutes 0.654 % of the total ground area. As indicated in table 2, *Olea europaea* subsp. *cuspidata* has the biggest share of the total BA (31.34%). The other four species (*Acacia albida, Pittosporum viridiflorum, Allophylus abyssinicus, Dodonaea anguistifolia)* together make 61.16% of the BA.

Table 2: Basal area, density and their percent contribution of five tree species in Weiramba Forest

Tree Species	**BA (m^2/ha)**	**% BA**	**Density**	**% Density**
Olea europaea subsp. *Cuspidata*	10.06	38.84	1061	40.39
Acacia albida	7.16	27.64	499	19.00
Pittosporum viridiflorum	5.57	21.51	487	18.54
Allophylus abyssinicus	1.88	7.26	307	11.69
Dodonaea anguistifolia	1.23	4.75	273	10.39
Total	25.9	100	2627	100

3.2.6 Importance Value Index (IVI)

The Importance Value Index (IVI) of 32 species was also calculated. Accordingly, species which had higher IVI values are *Olea europaea* subsp. *Cuspidata, Acacia albida,* and *Pittosporum viridiflorum*, whereas low IVI values are *Rosa abyssinica, Grewia bicolor, Leucaena leucocephala,* etc. (Table 3).

Table 3: The importance value index (IVI) in decreasing order and priority class for conservation of tree species in Weiramba Forest (RD = Relative density, RDO = Relative Dominance, RF = Relative frequency)

Item No.	Species name	Individuals No.	BA (m^2/ha)	RD	RDO	RF	IVI	%IVI	Priority
1	*Olea europaea* subsp. *Cuspidata*	1061	10.060	29.913	31.342	11.48	72.735	24.245	4
2	*Acacia albida*	499	7.169	14.068	22.335	12.08	48.484	16.161	4
3	*Pittosporum viridiflorum*	487	5.574	13.730	17.366	9.96	41.056	13.685	4
4	*Allophylus abyssinicus*	307	1.880	8.655	5.857	10.57	25.082	8.361	4
5	*Dodonaea anguistifolia*	273	1.231	7.697	3.835	11.17	22.702	7.567	3
6	*Carissa edulis*	230	0.974	6.484	3.035	7.55	17.069	5.690	3
7	*Euclea divinorum*	159	0.813	4.483	2.533	6.64	13.656	4.552	3
8	*Maytenus arbutifalia*	126	0.645	3.552	2.010	6.04	11.602	3.867	3
9	*Eucalyptus camaldulensis*	94	0.498	2.650	1.552	4.53	8.732	2.911	3
10	*Grewia ferruginea*	42	0.228	1.184	0.710	3.02	4.914	1.638	2
11	*Osyris quadripartite*	33	0.148	0.930	0.461	2.71	4.101	1.367	2
12	*Juniperus procera*	29	0.618	0.818	1.925	0.9	3.643	1.214	2
13	*Acacia etbaica* subsp. *Etbaica*	23	0.259	0.648	0.807	2.11	3.565	1.188	2
14	*Acacia sieberiana*	30	0.479	0.846	1.492	1.2	3.538	1.179	2
15	*Cupressus lusitanica*	25	0.621	0.705	1.935	0.6	3.240	1.080	2
16	*Myrsine Africana*	31	0.073	0.874	0.227	1.81	2.911	0.970	2
17	*Calpurnia aurea*	16	0.052	0.451	0.162	1.81	2.423	0.808	2
18	*Acacia decurrens*	19	0.186	0.536	0.579	0.9	2.015	0.672	2
19	*Premna schimperi*	10	0.140	0.282	0.436	0.3	1.018	0.339	2
20	*Aningeria adolfi-friedericii*	13	0.090	0.367	0.280	0.3	0.947	0.316	2
21	*Prunus Africana*	5	0.049	0.141	0.153	0.6	0.894	0.298	1
22	*Ehretia cymosa*	3	0.044	0.085	0.137	0.6	0.822	0.274	1
23	*Canthium oligocarpum*	6	0.042	0.169	0.131	0.3	0.600	0.200	1
24	*Jacaranda mimosifolia*	4	0.057	0.113	0.178	0.3	0.590	0.197	1
25	*Croton macrostachyus*	5	0.018	0.141	0.056	0.3	0.497	0.166	1
26	*Psydrx schimperiana*	2	0.042	0.056	0.131	0.3	0.487	0.162	1
27	*Clerodendron myricoides*	5	0.013	0.141	0.041	0.3	0.481	0.160	1
28	*Balanites aegyptiaca*	3	0.029	0.085	0.090	0.3	0.475	0.158	1
29	*Casuarina equisetifolia*	1	0.046	0.028	0.143	0.3	0.472	0.157	1
30	*Leucaena leucocephala*	4	0.014	0.113	0.044	0.3	0.456	0.152	1
31	*Grewia bicolor*	1	0.004	0.028	0.012	0.3	0.341	0.114	1
32	*Rosa abyssinica*	1	0.001	0.028	0.003	0.3	0.331	0.110	1
	Total	3547	32.097	100	100	100	300	100	

3.3 Species diversity, richness and equitability

The value of Shannon -Wiener Diversity Index (H') of the whole vegetation of this study area was 2.30 with the evenness or equitability value (J) of 0.66 (Table 4).

Table 4: The Shannon Wiener diversity index in the study area

Tree Species	**Ni**	**Pi**	**Lnpi**	**Pi*lnpi**
Acacia albida	499	0.1407	-1.9613	-0.2759
Acacia decurrens	19	0.0054	-5.2294	-0.0280
Acacia etbaica subsp. *etbaica*	23	0.0065	-5.0384	-0.0327
Acacia sieberiana	30	0.0085	-4.7727	-0.0404
Allophylus abyssinicus	307	0.0866	-2.4470	-0.2118
Aningeria adolfi-friedericii	13	0.0037	-5.6089	-0.0206
Balanites aegyptiaca	3	0.0008	-7.0752	-0.0060
Calpurnia aurea	16	0.0045	-5.4013	-0.0244
Canthium oligocarpum	6	0.0017	-6.3821	-0.0108
Carissa edulis	230	0.0648	-2.7358	-0.1774
Casuarina equisetifolia	1	0.0003	-8.1739	-0.0023
Clerodendron myricoides	5	0.0014	-6.5644	-0.0093
Croton macrostachyus	5	0.0014	-6.5644	-0.0093
Cupressus lusitanica	25	0.0070	-4.9550	-0.0349
Dodonaea anguistifolia	273	0.0770	-2.5644	-0.1974
Ehretia cymosa	3	0.0008	-7.0752	-0.0060
Eucalyptus camaldulensis	94	0.0265	-3.6306	-0.0962
Euclea divinorum	159	0.0448	-3.1050	-0.1392
Grewia bicolor	1	0.0003	-8.1739	-0.0023
Grewia ferruginea	42	0.0118	-4.4362	-0.0525
Jacaranda mimosifolia	4	0.0011	-6.7876	-0.0077
Juniperus procera	29	0.0082	-4.8066	-0.0393
Leucaena leucocephala	4	0.0011	-6.7876	-0.0077
Maytenus arbutifalia	126	0.0355	-3.3376	-0.1186
Myrsine Africana	31	0.0087	-4.7399	-0.0414
Olea europaea subsp. *cuspidata*	1061	0.2991	-1.2069	-0.3610
Osyris quadripartita	33	0.0093	-4.6773	-0.0435
Pittosporum viridiflorum	487	0.1373	-1.9856	-0.2726
Premna schimperi	10	0.0028	-5.8713	-0.0166
Prunus africana	5	0.0014	-6.5644	-0.0093
Psydrx schimperiana	2	0.0006	-7.4807	-0.0042
Rosa abyssinica	1	0.0003	-8.1739	-0.0023
Total	3547	1.0000	0.0000	0.0000
			H'	2.3012
			H'max	3.4657
			J	0.6640

Where Ni = No. of individuals of species i, Pi = fraction of the entire population made up of species i, ln = Natural logarithm, H' = the Shannon diversity index, H'max= lnS, S = number of species in the study site, J = Evenness or Equitability.

3.4 Regeneration Status of Weiramba Forest

From the 32 representative woody species, a total of 1635 (23%) seedlings/ha, 1116 (15%) saplings/ha and 4434 (62%) mature individuals/ha were recorded (Figure 4). Accordingly, seedlings and Sampling populations were less than matured individuals. The ratio of seedling and sapling to the parent plant was 1:0.37 and 1:0.25, respectively.

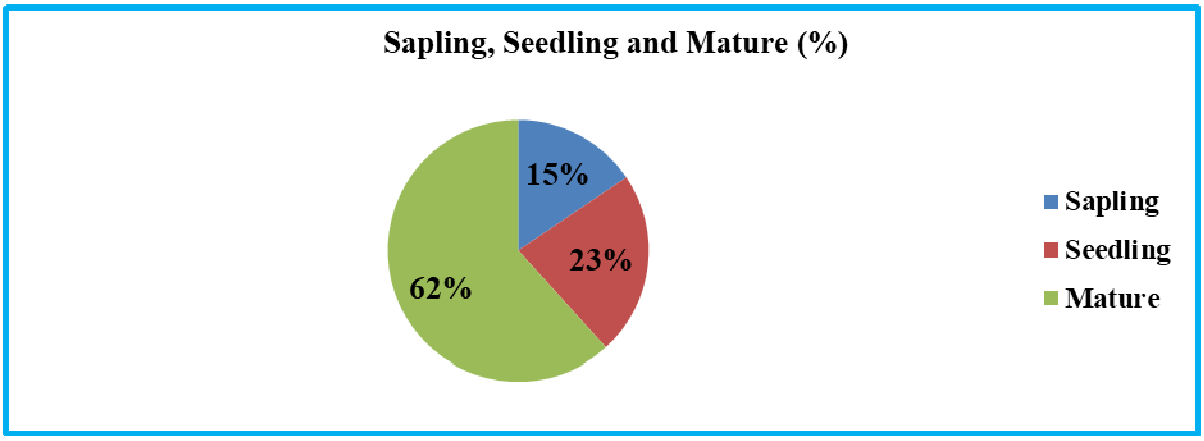

Figure 4: Density percentage of seedlings, saplings and mature of tree species in the study area

The different woody species encountered in the forest have different density of seedlings and saplings. Accordingly, *Dodonaea anguistifolia, Euclea divinorum,* and *Myrsine Africana* were with the highest density of sapling/ha. *Myrsine Africana, Euclea divinorum,* and *Dodonaea anguistifolia* were with the highest number of seedlings/ha in the study area (Figure 5).

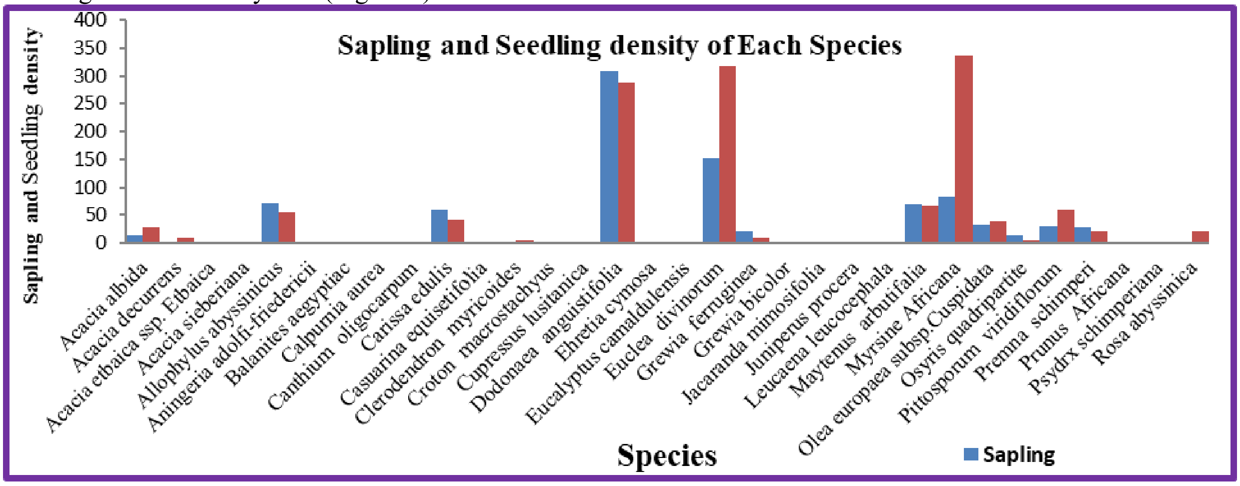

Figure 5: Sapling and Seedling numbers of each species

The selected woody species in the area were grouped into three on the basis of their seedling and sapling densities /ha in order to ensure conservation measures through prioritization to promote healthy regeneration and the sustainable use of these species. (I= species with no seedling and sapling, II= species with no sapling but < 5 seedlings/ha III= seedlings >5 but <10 individuals/ha and saplings > 1 but < 5 individuals) (Table11).

Table 5: Regeneration status of different Woody species and their groups for conservation priority in Weiramba Forest

Priority Class	**Family**
Priority class I	
Acacia etbaica subsp. *Etbaica*	Fabaceae
Grewia bicolor	Tiliaceae
Psydrx schimperiana	Rubiaceae
Balanites aegyptiaca	Balanitaceae
Ehretia cymosa	Boraginaceae
Jacaranda mimosifolia	Bignoniaceae
Leucaena leucocephala	Fabaceae
Croton macrostachyus	Euphorbiaceae
Prunus Africana	Rosaceae
Aningeria adolfi-friedericii	Sapotaceae
Calpurnia aurea	Fabaceae
Juniperus procera	Cupressaceae
Priority class II	
Calpurnia aurea	Fabaceae
Priority class III	
Grewia ferruginea	Tiliaceae

4. Discussion

4.1 Woody Species Composition

Weiramba Forest is characterized by species like *Juniperus procera, Olea europaea* subsp. *cuspidata*, *Rosa abyssinica*, etc. and it had different species composition, DBH, height, density, and frequency. In addition, the altitudinal range of this study forest (1923-2225 m) found within the altitudinal range for the dry evergreen Afromontane forest (1500-3400 m). Thus, due to these conditions, the Weiramba Forest undergoes to dry evergreen Afromontane forest.

Woody Species composition of the given vegetation can be described in terms of its richness in species, abundance, dominance, and frequency (Lamprecht, 1989). In this study, a total of 32 woody species, belonging 28 genera and 20 families, were encountered on 40 quadrats. Fabaceae is the most dominant family with 3 (11.11%) genera and 6 (19.35%) species followed by Cupressaceae, Myrtaceae, Rubiaceae, Sepindaceae which each has 2 (7.4%) genera and 2 (6.45%) species. The total woody plant species reported in the study forest (32 woody species) is lower than the range of other dry afrmontane forests of Ethiopia (87 species) (Haile Adamu, 2012), (70 species) (Semere Beyene, 2010), (44 species) (Kidanemariam Kassahun, 2014; Lemmessa Kumssa, 2010); however, the reported woody plant species richness in the present study is almost comparable to (34 species) (Adugna *et al*., 2013) and higher than (24 species) (Biniam Alemu, 2012). The reasons for low species number might be due to the dominance of few tree species (*Olea europaea* subsp. *cuspidata*, *Acacia albida*) over the others i.e. species lack equal chances for competition and human or animal disturbances.

According to Kent and Coker (1992), the Shannon Weiner index is the most frequently used for the combination of species richness and relative abundance. A value of the index of Shannon -Weiner usually lies between 1.5 and 3.5 although in an exceptional case, the value can exceed 4.5 (Pielou, 1969). Overall, the value of Shannon -Wiener Diversity Index (H') of the whole vegetation of Weiramba is 2.30 with the evenness or equitability value (J) of 0.66 (Table 4). From this result, one may infer that the study area is good in Woody Species diversity and richness with more or less even representation of individuals of all species encountered in the studied quadrats.

4.2 Vegetation Structure

Information on the species structure and composition of a forest is essential for its wise management in terms of economic value, regeneration potential (Wyatt-Smith, 1987) and ultimately may be leading to conservation of biological diversity (Verma *et al*., 1999). Species-abundance measures are ways of expressing not only the relative richness but also evenness and thereby assessing diversity (Barnes *et al*., 1998). In this study, the totals of 3547 individual were found in a sampled area. *Olea europaea* subsp. *cuspidata, Acacia albida*, *Pittosporum viridiflorum, Allophylus abyssinicus* and *Dodonaea anguistifolia* were contributed for the largest proportion of tree species density, whereas *Grewia ferruginea* and *Rosa abyssinica* were poorly reckoned in this regard.

Overall, only a few species were dominating the study forest in their abundance while many of the species were very rare or low in their abundance. Such a result reflects either adverse environmental situations (e.g. high temperature, low rainfall regime, human impacts in the form of intensive logging, livestock trampling and grazing, biotic and a abiotic impairments) or random distribution of available resource in the forest according to (Miranda *et al*., 2002 as cited in Feyera Senbeta *et al*., 2015). On the other hand, the reason of predominance of small individuals in study forest might be due to the dominance of *Olea europaea* subsp. *Cuspidate* and *Acacia albida* over the others i.e. species lack equal chances for competition.

Analysis based on relative density distribution by DBH and height classes carried out for tree species of the forest site showed different patterns. Different patterns of species population structure can indicate variation in population dynamics (Adugna *et al*., 2013). The distribution of the forest species in the present study showed a high number of individuals in the second DBH classes, whereas small values in the rest classes.

The ratio of the density of individuals with DBH >10 cm to those greater than 20 cm showed the distribution of size classes (Grubb *et al.,* 1963). This ratio is high (11.94) for the Weiramba Forest, indicating high variation between the small-sized and large-sized stems. On the other hand, the a/b ratio in Weiramba Forest indicates the predominance of small-sized tree individuals which indicates the forest was under heavy degradation and in a stage of secondary development. The ratio of the density of trees with DBH greater than 10 cm to DBH greater than 20 cm reported in the study forest (11.94) is higher than other dry Afromontane forests of Ethiopia as shown in Table 6.

Table 6: Comparison of tree density of Weiramba and other dry evergreen montane forests in Ethiopia

Forest	DBH > 10 cm (a)	DBH > 20 cm (b)	a/b
Chilimo	638	250	2.6
Menagesha Suba	482	208	2.3
Wof-Washa	329	215	1.5
Denkoro	526	285	1.9
Dodola	521	351	1.5
Dindin	437	219	1.9
Angada	372.8	252	1.47
Menagesha Amba Mariam	155.5	197	0.8
Weieramba (present study)	1343	113	11.94

Sources: Tamirat Bekele (1994); Kitessa Hundera (2003), Abate Ayalew *et al*. (2006); Simon Shibru and Girma Balcha (2004), Abiyou Tilahun (2009) and Shambel Alemu (2011).

As indicated in Table 6, a/b ratio of Weiramba Forest is higher than all other forests. This indicates that there is the predominance of small-sized individuals for some species in Weiramba Forest than other forests, which is largely due to the high density (dominance) of *Olea europaea* subsp. *cuspidata, Acacia albida* and *Pittosporum viridiflorum* over the others i.e. species lack equal chances for competition (for sunlight, food, water) and human impacts in the form of intensive logging. On the other hand, there is the predominance of large-sized individuals in other forests than study Forest.

The distribution of all individuals in different DBH and height classes showed relatively a Bell-shape distribution, which revealed that a type of frequency distribution in which a number of individuals in the middle classes were high, and decreased towards the lower and higher diameter classes. On the contemporary, Bell-shape pattern is the reflection of a discontinuous or irregular recruitment. Human disturbance, livestock trampling or browsing, and some other biotic and abiotic impairment might be the problems which caused for the species being a retard from its normal recruitment status in the area. Species which are higher in DBH or height and important in providing timber, fencing or fuelwood services for local farmers can be cut by local farmers.

Competition between species can be the cause of hampered regeneration status of the species. According to Feyera Senbeta *et al*. (2015), Bell shape pattern indicates a poor reproduction and recruitment of species which may be associated with intense competition from the surrounding trees. Generally, the above reasons might be the causes that made the distribution pattern of the study forest being Bell-shape. Height can be used as an indicator of the age of the forest in which the older trees are found in higher height classes compared to the lower classes. These classes had low percentage distribution.

Frequency is the indication of homogeneity and heterogeneity of given vegetation in which the higher number of species in higher frequency classes and low number of species in lower frequency classes shows similar species composition while large number of species in lower frequency classes and small number of species in higher frequency classes indicates higher heterogeneity of a stand (Haileab Zegeye *et al*., 2005; Lamprecht, 1989). According to Lambrecht (1989), the species that appear in lower frequency classes have an irregular occurrence, whereas those appearing in higher frequency classes have regular horizontal classes. Similarly, the present study revealed that there is a high percentage of a number of species in lower frequency classes and the low percentage of the number of species in higher frequency classes. This indicates that the forest under the study has a high degree of Woody Species heterogeneity and low homogeneity. And in other words, it can be concluded as there were fairly presences of many species in most of the quadrats. These may be due to the fact that these species might have a wide range of seed dispersal mechanisms like by wind, livestock, wild animal, birds and the like.

The normal basal area value for virgin tropical forests in Africa is 23–37 m^2/ha (Dawkins, 1959 cited in Lamprecht, 1989). Thus, the basal area value of Weiramba Forest (32.10 m^2/ha) is within the normal range (Table 3). The basal area provides a better measure of the relative importance of the species than simple stem count (Cain and Castro, 1959; cited in Tamirat Bekele, 1994). Thus, species with the largest contribution to BA can be considered as the most important species in the forest. In this study, basal area analysis across individual species revealed as there was high domination by very few species. Accordingly, the most ecologically important tree species in Weiramba Forest were *Olea europaea* subsp. *cuspidata, Acacia albida, Pittosporum viridiflorum, Allophylus abyssinicus and Dodonaea anguistifolia* because of their higher relative density and frequency. *Olea europaea* subsp. *cuspidata* was the leading dominant in this regard.

Although species like *Grewia bicolor, Myrsine Africana* have high density, their basal area is not as high as *Cupressus lusitanica, Acacia sieberiana, and Premna schimperi* which have low density (Table 3). This might be due to the nature of the plants not to grow to higher Basal Area. This also indicates that species with the highest basal area do not necessarily have the highest density, indicating size difference between species (Tamrat Bekele, 1994; Simon Shibru and Girma Balcha, 2004; Dereje Denu, 2006; Birhanu Kebede, 2010). When we compare the BA of Weiramba Forest with other Ethiopian afromontane forests, it is lower than Yemrehane Kirstos (72 m^2/ha) (Amanuel Ayanaw, 2016), Masha Anderacha (49.80 m^2/ha) (Kumelachew Yeshitela and Taye Bekele, 2003), Komto (50.72 m^2/ha) (Fekadu Gurmessa, 2010), Chato (65.8 m^2/ha) (Feyera Abdena, 2010), Gura Ferda (69.90 m^2/ha) (Dereje Denu, 2006), Angada (79.8 m^2/ha) (Shambel Alemu, 2011) and more or less comparable with Gura Lopho (29.63 m^2/ha) (Lemessa Kumsa, 2010), Chilimo (30.19 m^2/ha) (Tamrat Bekele, 1994), Jima (33 m^2/ha) (Fufa Kenea, 2008), Gedo (35.5 m^2/ha) (Birhanu Kebede, 2010). But it is higher than that of Yangudi-Rassa (3.12 m^2/ha) (Semere Beyene, 2010), Beschillo and Abay (12.6 m^2/ha) (Getaneh Belachew, 2006), Boditi (23 m^2/ha) and Adelle (26 m^2/ha) (Haile Yinger *et al*., 2008) (Table 7).

Table 7: Comparison of Weiramba Forest with other thirteen Ethiopian dry Afromontane forests regarding with basal area

Forest	Basal Area (m^2/ha)	Source
Angada	79.8	Shambel Alemu (2011)
Yemrehane Kirstos	72	Amanuel Ayanaw (2016)
Gura Ferda	69.9	Dereje Denu (2006)
Chato	65.8	Feyera Abdena (2010)
Komto	50.72	Fekadu Gurmessa (2010)
Masha Anderacha	49.8	Kumelachew Yeshitela and Taye Bekele (2003)
Gedo	35.5	Birhanu Kebede (2010)
Jima	33	Fufa Kenea (2008)
Chilimo	30.19	Tamrat Bekele (1994)
Gura Lopho	29.63	Lemessa Kumsa (2010)
Adelle	26	Haile Yinger *et al*. (2008)
Boditi	23	Haile Yinger *et al*. (2008)
Beschillo and Abay	12.6	Getaneh Belachew (2006)
Yangudi-Rassa	3.12	Semere Beyene (2010)

High density and high frequency coupled with high BA indicates the overall dominant species of the forest (Lamprecht, 1989). Accordingly, *Olea europaea* subsp. *cuspidata, Acacia albida and Pittosporum viridiflorum* are the top three dominant species of the forest since all the three are found in the top five of the ranks of basal area, relative density, relative frequency and IVI per hectare of the ten top dominant species (Table 3).

Importance Value Index (IVI) combines data from three parameters which include RF, RD, and RDO (Kent and Coker, 1992). Lamprecht (1989) also noted that the IVI is useful to compare the ecological significance of species. It was also stated that species with the greatest importance value are the leading dominant of specified vegetation (Simon Shibru and Girma Balcha, 2004). Thus, the ten-leading dominant and ecologically most significant trees in Weiramba Forest are *Olea europaea* subsp. *cuspidata, Acacia albida, Pittosporum viridiflorum, Allophylus abyssinicus, Dodonaea anguistifolia, Carissa edulis, Euclea divinorum, Maytenus arbutifalia, Eucalyptus camaldulensis* and *Grewia ferruginea* together contributed about 266 or 88.67 % from the total of 300.00 IVI value (Table 3). About 62.45% of the IVI was attributed by *Olea europaea* subsp. *cuspidata, Acacia albida, Pittosporum viridiflorum, Allophylus abyssinicus.* The reason why they have higher IVI value is that they have higher relative density, relative frequency and relative abundance relative to other species in the forest (Table 3). The leading dominant and ecologically most significant species might also be the most successful species in regeneration, pathogen resistance, preference by browsing animals (least preferred), an attraction of pollinators and attraction of seed predators that facilitate seed dispersal within the existing environmental conditions (Fufa Kenea, 2008). IVI analysis is used for setting conservation priority (Fekadu *et al*., 2011). Those species which receive lower IVI values need high conservation efforts while those with higher IVI values need monitoring management. Concerning the IVI species that should be given priority 1 (Table 3 and 5) should get the uppermost conservation priority since these are at risk of local extinction.

The type, composition, distribution, and density of seedlings and saplings indicate the future regeneration status of the forest. The various studies showed that open canopy might be in favor of seed germination and seedling establishment through increased solar radiation on the forest floor (Khan *et al*., 1987; Kadavul *et al*., 1999). The present study result of seedling and sapling to the parent plant ratio showed that the distribution of mature individuals is greater than seedlings and sapling indicate that the regeneration status of the forest is at the low state. Compared to matured individuals, there were less sapling populations implying the perishing off of most seedlings before reaching sapling stage due to factors such as closed canopy, human intervention, browsers, grazers, Climatic and nature of the seeds. One of the criteria to establish conservation priority classes among species in Weiramba Forest is the description of the regeneration status. Regeneration is a critical phase of forest management because it maintains the desired species composition and stocking after disturbances (Duchok *et al*., 2005). The Current study results showed that *Myrsine Africana, Euclea divinorum,* and *Dodonaea anguistifolia* species have high regeneration status.

Conversely, gaps between mature tree species composition and the seedlings and saplings were recognized since most mature tree species lack seedlings and saplings. This implies a need to develop and implement effective forest management Regimes in the area. On the other hand, the situation calls for conservation measures through prioritization. To ensure this, the woody species in the area were grouped into three on the basis of their seedling and sapling densities/ha. In the present study, the result showed, Conservation activity should first focus on the species under Priority Class I and treats them as the first priority species to be conserved since they lack both seedlings and saplings. Priority Class II, lack sapling, and small seedling number should come next and then III (Table 5).

5. Conclusion

This study in Wieramba Forest showed that the forest contains many diversified plant species comprising a total of 34 different species belonging to 28 genera and 20 families of which Fabaceae was the dominant family. Both the cumulative diameter and height class frequency distribution patterns of woody individuals resulted in a Bell-shape implies that density of woody species in the middle classes were high and decreased towards the lower and higher diameter and height classes indicating a discontinuous or irregular recruitment of individuals in the forest, which is the reflection of a more or less poor regeneration profile in the area. The total basal area for Weiramba Forest was 32.10 m^2/ha; however, the results of woody species revealed that only a few species were scored high basal area and density. About 62.45% of the IVI was attributed by *Olea europaea* subsp*. cuspidata, Acacia albida, Pittosporum viridiflorum, Allophylus abyssinicus.* But majority woody species are with low IVI Such as *Grewia bicolor, Leucaena leucocephala, etc.* indicating that they require proper conservation and management.
The analysis results of woody species regeneration revealed the insufficiency of seedling recruitment. The total absence of seedling and sapling was encountered for certain woody species (*Acacia etbaica* subsp*. etbaica, Grewia bicolor, Psydrx schimperiana, Balanites aegyptiac, etc.*) and sapling but no seedling for some others. Based on the regeneration status and population distribution patterns, three groups of species were identified as a priority for conservation of Weiramba Forest. The valuation of the status of vegetation in the study area showed that there was a significant proportion of woody species decline as a result of deforestation implying that they are under threat. Hence, it is essential to develop and implement effective conservation measures to save a forest and use the biodiversity resources in a sustainable way.

Acknowledgements

Ethiopian Environment and Forest Research Institute, Non-Timber Forest Products research case team, in particular, are highly acknowledged for the financial support. Mersa Bureau of Agriculture and Rural Development, and Sirinka Agricultural Research Center are acknowledged for the provision of secondary data.

References

Abate Ayalew, Tamrat Bakele and Sebsebe Demissew (2006). The undifferentiated Afromontane forest of Denkoro in the central highland of Ethiopia: A Woody Species and structural analysis. *SINET: Ethiop. J. Sci.* 29(1): 45-56.

Abiyou Tilahun (2009). Woody Species composition, structure and regeneration status of Menagesha Amba Mariam Forest central Highland of Shewa, M.Sc. Thesis, Addis Ababa University, Addis Ababa.

Addo-Fordjour, P., Obeng, S., Anning, A. and Addo, M. (2009). Floristic composition, structure and natural regeneration in a moist semi-deciduous forest following anthropogenic disturbances and plant invasion. Int. J. Biodiverse. Conserv, 1, 021- 037.

Adugna Feyissa, Teshome Soromessa and Mekuria Argaw (2013). Forest Carbon Stocks and Variations Along Altitudinal Gradients in Egdu Forest: Implications of Managing Forests for Climate Change Mitigation. *Science, Technology, and Arts Research Journal* 2(4): 40-46.

Alves, L.F., Vieira, S.A., Scaranello, M.A., Camargo, P.B., Santos, F.A.M., Joly, C.A., and Martinelli, L.A. (2010). Forest structure and live aboveground biomass variation along an elevational gradient of tropical Atlantic moist forest (Brazil). *Forest Ecology and Management* 260: 679-691.

Amanuel Ayana (2016). Woody Species diversity structure and regeneration status of Yemrehane Kirstos church forest of Lasta Woreda, North Wollo Zone, Amhara Region, Ethiopia. M.Sc. Thesis (Unpublished). Addis Ababa University. Addis Ababa.

Anonymous (2009). Convention on Biological Diversity (CBD) Ethiopians 4th Country Report, Addis Ababa.

Azene Bekele (2007). Useful Trees and Shrubs for Ethiopia, Identification, Propagation, and Management for 17 Agroclimatic zones. Technical manual, Pp. 550, (Tengnas, B., Ensermu Kelbessa, Sebsebe Demissew and Maundu, P. eds). World Agroforestry Center, English Press, Nairobi, Kenya.

Badege Bishaw (2001). Deforestation, land degradations in the Ethiopian Highlands: the strategy for physical recovery. *J. North East African Studies* 8:7-26.

Barthlott, W. (1998). The Uneven Distribution of Global Biodiversity: A challenge for industrial and developing countries. In: Ethlers T. and Krafft E. (eds.), German Global Change Research 1998. German National Committee on Global Change Research, Bonn, Germany.

Bekele, T. (1994). Phytosociology and ecology of humid Afromontane forest in the Central Plateaus of Ethiopia. J. Veg. Sci, 5, 87- 98.

Biniam Alemu (2012). Carbon Stock Potentials of Woodlands and Land Use and Land Cover Changes in North Western Lowlands of Ethiopia. M.Sc. Thesis, Hawassa University, Wondo Genet, Ethiopia.

Birhanu Kebede (2010). Woody Species Composition and Structural Analysis of Gedo Dry Evergreen Montane Forest, West Shewa Zone of Oromia National Regional State, Central Ethiopia. M.Sc. Thesis (Unpublished). Addis Ababa University. Addis Ababa.

Brown, S. (1997). Estimating Biomass and Biomass Change of Tropical Forests: A primer. UN FAO Forestry paper, Rome **134**: 20-55.

Brown, S. (2002). Measuring carbon in forests: current status and future challenges. *Environmental Pollution* 116: 363-372.

Dereje Denu (2006). Woody Species composition and Ecological study of Bibita (Gura-Ferda) Forest, Southwest Ethiopia. M.Sc. Thesis (Unpublished). Addis Ababa University. Addis Ababa.

Dhaulkhandi, M., Dobhal, A., Batt, S. and Kumar, M. (2008). Community structures are Regeneration potential of Natural Forest site in Gangotri, India. *Journal of Basic and Applied sciences* 4(1): 49-52.

Duchok, R., Kent, K., Khumbongmayum, AD., Paul, A. and Khan, ML. (2005). Population structure and regeneration status of medicinal tree *Illicium griffithii* in relation to disturbance gradients in the temperate broad-leaved forest of Arunachal Pradesh. *Current Science* 89(4): 673-676.

EFAP (Ethiopian Forestry Action Program) (1994). Ethiopian Forestry Action Program, Vol. 2. The Challenge for Development. Ministry of Natural Resources Development and Environmental Protection, Addis Ababa.

Fekadu Gurmessa., Teshome Soromessa and Ensermu Kelbessa (2011). Floristic Composition and Community analysis of Komto Afromontane Moist Forest of East Wellega, West Ethiopia. *Science, Technology, and Arts Research Journal* 2(2): 58-69.

Feyera Abdena (2010). Woody Species composition and Structure of Chato natural forest in Horo Guduru Wollega Zone of Oromia Region West Ethiopia. M. Sc. Thesis (Unpublished). Addis Ababa University, Addis Ababa.

Feyera Senbeta, Getinet Masresha, Teshome Soromessa and Ensermu Kelbessa (2015). Status and Species Diversity of Alemsaga Forest, Northwestern Ethiopia. *Advances in Life Science and Technology* Vol.34.

Fufa Kenea (2008). Remnant vegetation and population structure of woody species of Jima Forest, Western Ethiopia. M. Sc. Thesis (Unpublished). Addis Ababa University, Addis Ababa.

Getaneh Belachew (2006). Woody Species composition and structure in Beschillo and Abay (Blue Nile) riverine vegetation. M. Sc. Thesis (Unpublished). Addis Ababa University, Addis Ababa.

Giriraj, A., Murthy, M., and Ramesh, B. (2008). Vegetation composition, structure, and patterns of diversity: a case study from the tropical wet evergreen forests of the Western Ghats, India. Edin. J. Bot., 65, 1– 22.

Grubb, P. J., LIoyd, J. R. Pennington, J.D. and Whitmore, J. C. (1963). A comparison of montane and lowland rainforest in Ecudor. I. The forest structure, physiognomy and Woody Species. *J. of Ecol*. 51: 567-601.

Grubb, P. J., LIoyd, J. R. Pennington, J.D. and Whitmore, J. C. (1963). A comparison of montane and lowland rainforest in Ecudor. I. The forest structure, physiognomy and Woody Species. *J. of Ecol*. 51: 567-601.

Haile Adamu (2012). Pattern Ecological Study of the Woodland Vegetation in Metema Area. Northern Ethiopia.

Haile Yinger, Ensermu Kelbessa, Tamrat Bekele and Ermias Lulekal (2008). Woody Species composition and structure of the dry Afromontane Forest at Bale Mountains National Park, Ethiopia. *SINET: Ethiop. J. Sci.*

31:103-120.

Haileab Zegeye, Demel Teketay, and Ensermu Kelbessa (2005). Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, south-central Ethiopia. *Flora* 201: 483-498

Hairiah, K., Sitompul, S.M., van Noordwijk, M., and Palm, C. (2001). Carbon Stocks of Tropical Land Use Systems as Part of the Global Carbon Balance: Effects of Forest Conversion and Options for 'Clean Development' Activities. ICRAF, Indonesia. 49 Pp.

Haque, S.M.S., and Alam, M.S. (1988). Some aspects of practicing the clear-felling followed by artificial regeneration system in the Cox's Bazar Forest Division. Chittagong University Studies (Part II): *Science* 12 (2): 87-95.

Hossain, M.K., Azad, A.K. and Alam, M.K. (1999). Assessment of natural regeneration status in a mixed tropical forest at Kaptai of Chittagong Hill Tracts (South) Forest Division. *The Chittagong University Journal of Science* 23(1): 73-79.

Kadavul, K. and Parthasarathy, N. (1999). Plant biodiversity and conservation of tropical semi-evergreen forests in the Shervanayan hills of Eastern Ghats, India. *Biodiversity and Conservation* 8: 421–439.

Kent, M. and Coker, P. (1992). Vegetation Description and Analysis. Belhaven Press, London 363 Pp.

Khan, M.L., Rai, J.P.N. and Tripathi, R.S. (1987). Population structure of some tree species in disturbed and protected sub-tropical forests of north-east India. *Acta Oecologica Oeol Applic*. 8(3): 247-255.

Kidanemariam Kassahun (2014). Forest Carbon Stock in Woody Plants of Ades Forest and its Variation Along Environmental Factors: Implication for Climate Change Mitigation, at Western Hararghe, Ethiopia. M.Sc. Thesis (Unpublished). Addis Ababa University, Addis Ababa.

Kitessa Hundera (2008). Woody Species Composition and Structure of the Dodola Forest. Bale Zone, Oromiya Regional State.

Kumelachew Yeshitela and Taye Bekele (2003). The woody species composition and structure of Masha Anderacha Forest, Southwestern Ethiopia. *Ethiop. J. Biol. Sci*. 2: 31-48.

Lamprecht, H. (1989). Silviculture in the Tropics. Tropical forest ecosystems and their tree species – Possibilities and methods for their long-term utilization.

Lemessa Kumsa (2010). Woody Species Composition and Structure of Gura-Lopho Moist Afromontane Forest, Horo-Guduru Wollega Zone, Oromia National Regional State, West Ethiopia. M.Sc. Thesis (Unpublished). Addis Ababa University. Addis Ababa.

Magurran, A. (1988). Ecological diversity and measurement. Crllm Hclm, London.

Muller-Dombois, D. and Ellenberg, H. (1974). Aims and Methods of Vegetation Ecology. John Wiley and Sons. Inc. New York. Pp 547.

Murphy, P. G., and Lugo, A. E. (1986). Ecology of the tropical dry forest. *Ann. Rev. Ecol. Syst.* 17: 67-88.

Pappoe, A. N., Armah, F.A., Quaye, E.C, Kwakye, P.K. and Buxton, G.N. (2010). Composition and stand structure of a tropical moist semi-deciduous forest in Ghana. Int. Res. J. Plant Sci., 1, 095-106.

Pearson, T. R., Brown, S. L., and Birdsey, R. A. (2007). Measurement guidelines for the sequestration of forest carbon. Northern Research Station, Department of Agriculture, Washington, D.C, Pp. 6-15.

Pearson, T., Walker, S. and Brown, S. (2005). Sourcebook for land-use, land-use change and forestry projects. Winrock International and the Bio-carbon fund of the World Bank. Arlington, USA, pp. 19-35

Pielou, E.C. (1969). An introduction to Mathematical Ecology. Wiley, New York.

SCBD: Secretariat of the Convention on Biological Diversity (2001). The Value of Forest Ecosystems. Montreal, SCBD, 67p. (CBD Technical Series no. 4).

Semere Beyene (2010). Woody Species composition and structure of Yangudi-Rassa National Park vegetation, Northeastern Ethiopia. M. Sc. Thesis (Unpublished). Addis Ababa University, Addis Ababa.

Shambel Alemu (2011). Woody species composition, diversity and structural analysis of Angada Forest in Merti Wereda, Arsi Zone of Oromia Region, Ethiopia. M. Sc. Thesis (Unpublished). Addis Ababa University, Addis Ababa.

Simon Shibru and Girma Balcha (2004). Composition, Structure and regeneration status of woody species in Dindin Natural Forest, Southeast Ethiopia: An implication for conservation. *Ethiop. J. of Biol. Sci.* 1(3):15-35.

Tiwari, G.P.K., Tadele, K., Aramde, F. and Tiwari, S.C. (2010). Community structure and regeneration potential of Shorea robusta forest in the subtropical submontane zone of Garhwal Himalaya, India. *Nature and Science* 8:70-74.

Verma, R.K., Shadangi, D.K. and Totey, N.G. (1999). Species diversity under plantation raised on a degraded land. *The Malaysian Forester* 62: 95–106.

Vivero, J.L., Kelbessa, E. and Demissew, S. (2005). The Red List of Endemic Trees and Shrubs of Ethiopia and Eritrea. Fauna and Flora International. Cambridge, U.K.

WCMC (1994). Priorities for Conserving Global Species Richness and Endemism. Caldecott, J. O., Jenkins, M.D., Johnson T. and Groombridge, B. (Eds.) World Conservation Press, Cambridge.

Wyatt-Smith J. (1987). Problems and prospects for natural management of tropical moist forests. In: F. Mergen and J.R. Vincent (eds.), Natural Management of Tropical Moist Forests. Silvicultural and Management Prospects of Sustained Utilization. New Haven: Connecticut, Yale University, USA, Pp.9-22.

Yalden, D. W. (1983). The extent of high ground in Ethiopia compared to the rest of Africa. *SINET, Ethiop. J. Sci.* 6: 35-39.