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Plant Community Composition and Structure of Asabot Dry Afromontane Forest, West Harare Zone, Ethiopia

Tura TT*, Soromessa T, Leta S and Argaw M

Center for Environmental science, Addis Ababa University, Ethiopia

Abstract

Dry Afromontane forests are the most altered and threatened ecosystem. Indeed, having a diverse ecosystem and biodiversity designated as a priority site in conservation. The objective of this study was to demonstrate plant community structure, regeneration status, and conservation priority species. The study was conducted on Asabot mountain forest which is found in West Harare Zone, Oromia National Regional State, Ethiopia. The vegetation sampling was designed at clustered altitude through mixed spatial stratified-random sampling method to ensure a full coverage of environmental variation and habitat heterogeneity. The main parameters used in vegetation characterization was diameter at breast height (DBH), height, seedling, and sapling of wood species recorded at sampled quadrat. The study analyzed plant community indicator species, importance value index, and vegetation structure and regeneration status, and conservation priority of selected species. The plant community was described by 97 species of 90 genera and 52 families. The result showed that eight specific trends and three general trends of population structure based on DBH, seedling, sapling and mature trees or shrubs. The dominant classes of the Asabot dry Afromontane forest were small trees and shrubs which is an indication of secondary vegetation. The conservation priority classification and visual field observations of some woody species were required urgent management intervention. Furthermore, the detail botanical aspects of the forest, the reason for the absence of regeneration in some tree species and socio-economic aspect of the vicinity is strongly recommended farther research in order to inaugurate appropriate management intervention.

Keywords: Dry afromontane forest; Plant community; Indicator species; Structural analysis; Regeneration status

Introduction

The natural gifts of African countries with high endemism of animal and plant species passionate by Ethiopia diverse agroecology [1]. The agricultural extensive and excessive deforestation hampered natural regeneration and seedling establishment that affected the diversity and structure of plant communities in most tropical forests [2-4]. In a similarly way forests in Ethiopia in general and dry Afromontane, in particular, have been affected by climatic and anthropogenic factors [5-9]. The assessment of forest cover change history of Ethiopia indicated reduction from 40% to less than 2.8% in the 19th century with current improvement to 15% [10,11]. The shifted vegetation shared half by Afromontane forest or mostly by dry Afromontane forests [1]. The climatic characterization of Afromontane in Ethiopia distinguished by moisture than surrounding lowland [12,13]. The agroecology of dry Afromontane is described by an altitude range from 1500-3400 m above sea level; 700-1100 mm mean annual rainfall; and 14-25°C average annual temperature with coverage of distributed highland of central, northern, eastern and southern parts of Ethiopia [5,14,15]. This suitable for human inhabitation accompanied by sedentary agriculture, extensive cattle herding activities and socio-political instability. Dry Afromontane ecology exposed to heavy deforestation, forest fragmentation and loss of biodiversity, impoverishment ecosystems and climate change vulnerability [16]. Indeed, they are a very important in-situ biodiversity conservation spot [17]. In view, the study has been conducted valued on addressing plant community variation along an environmental gradient of Asabot mountain forest.

Though the current progress made on Asabot mountain forest demarcation as national wildlife protection sanctuary, the forest is currently continuously exploited by surrounding people for construction woodcutting, timber harvesting, charcoal production, firewood collection and other. Indeed, the plant community, floristic composition, and structure were not well studied yet. Therefore, the present study intended to analyze plant community, forest structure, and regeneration status of some woody species in order to forecast conservation priority and appropriate management.

Methods and Materials

Study site description

Asabot mountain forest is located in Miso district of West Harare Zone, Oromia Regional state, Ethiopia (Figure 1). Geographically, the study site is located at 40° 31’30 to 40° 42’0E and 9° 12’0 to 9° 21’0N. The altitude of Asabot Mountain ranges from 1087 to 2474 meters above sea level (Table 1).

Asabot mountain forest is part of evergreen dry Afromontane ecology; characterized by average minimum (451.2 ml) and maximum (1055.5 ml) annual precipitation, mean minimum (11.9°C) and maximum (31.9°C) temperature, respectively according to metrological data for the last ten years (Figure 2).

The topography of the study site was raged mountain characterized by flat (1577 hectare) to rolling (803 hectares) (Table 1 and Figure 3). Asabot mountain ascends from 1080-2447 meter above sea level with immediate facing (aspect) change. However, the vegetation samples collected from an altitude range of 1778 to 2404 meter above sea level in order to reduce edge effects and due to the scope of the study.

***Corresponding author:** Tura TT, Ph.D. fellow, Center for Environmental science, Addis Ababa University, Ethiopia, Tel: +251-111-239 472; E-mail: tulutollatura@gmail.com

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Sampling design

The vegetation sampling method was chosen the mixed spatial stratified-random procedure to ensure a full coverage of environmental variation and habitat heterogeneity within the altitudinal gradient following Kent and Coker [18] and Muller-DuBois and Eilenberg [19]. The direction of sampling quadrats was not followed strict procedure due to the complexity of the mountain. The quadrats covered clustered altitude of the study sites (lower, middle and upper) but aspect and slope not strictly followed. The 20 m × 20 m (400 m^2) size sampling quadrats of 150 m and 100 m distance between transect and quadrat, respectively used. Inside the 20 m × 20 m quadrat five, 5 m × 5 m subplots, one at each corner and one at the center of the main quadrat were set to sample shrubs. The seedling and sapling data were collected from five 2 m × 2 m subplots, one at each corner and one at the center of the main plot. The diameter of all woody plants was recorded using diameter tape while height was measured using Hagan hypsometer and Clinometer. The diameter of normal individual trees was measured at

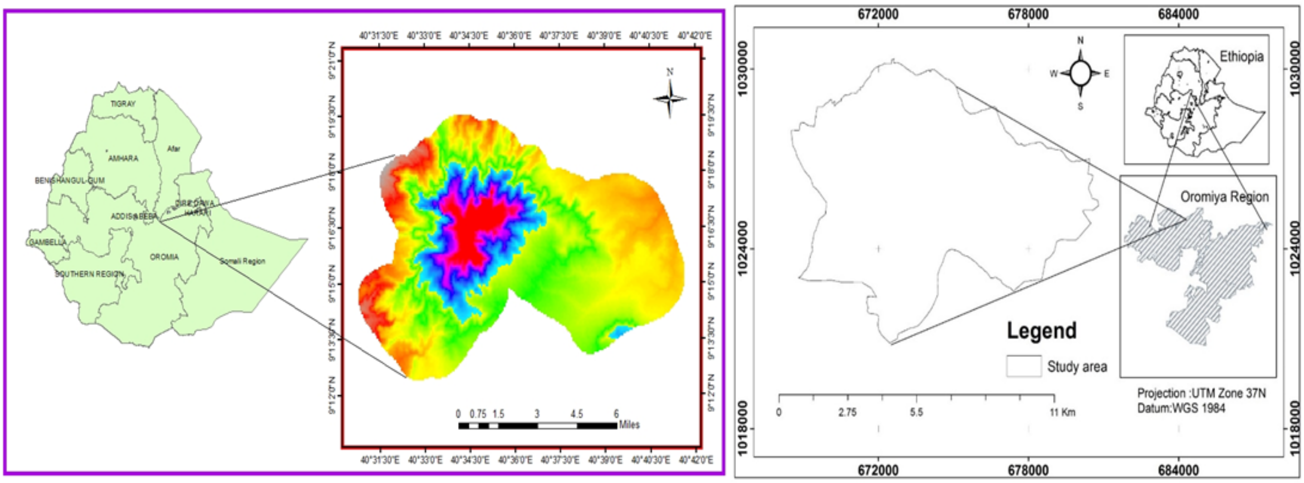

Figure 1: Map of Asabot dry Afromontane forest.

Altitude	Area in ha	Slope	Area in ha	Aspect	Area in ha
1087--1200	494	0--2	1577	North	4617
1201--1400	3688	3--8	6644	East	4697
1401--1600	7726	9--15	2781	South	3417
1601--1800	2360	16--32	4710	West	3776
1801--2000	1270	33--59	803	North	4617
2001--2200	676	-	-	-	-
2201--2474	297	-	-	-	-

Table 1: Description of Asabot mountain forest.

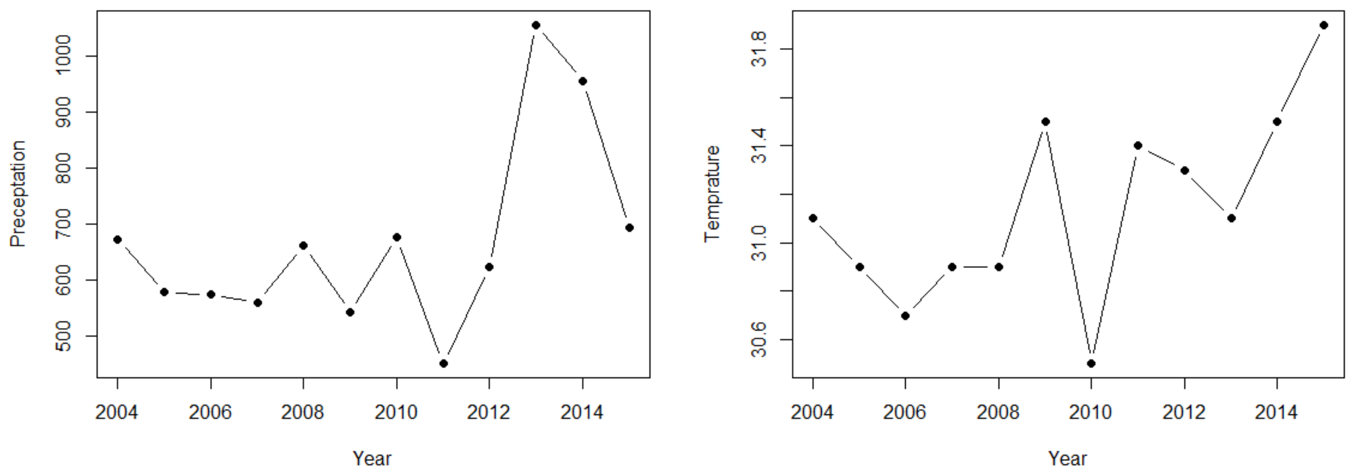

Figure 2: Mean annual precipitation and mean annual maximum temperature trends of the study site, 2004-2015.

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breast height if the tree branched at breast height; and the diameter was measured separately and averaged if the tree was multi-stemmed. The diameter was measured individual and recorded if the tree buttressed at breast height. The diameter was also measured above or below the breast height at normal shape; and if the tree was angled or slopes, the diameter was measured opposite direction of the inclination (Figure 4).

Where topographic features made it difficult to measure trees and shrubs, height was estimated visually. The environmental variables such as altitude, slope, aspects and geographical coordinates were measured for each plots using Garmin Geographical Position System and satellite image [18]. The specimens of all woody plant were pressed, dried and brought to the National Herbarium of Addis Ababa University for identification and storage. The wood plant nomenclature was followed Flora of Ethiopia and Eritrea book (FEE).

Plant community analysis

The dendrogram wood plant community cluster was analyzed based on cover abundance data of species composition in their hierarchical classification. The plant community types were named after two or three dominant species selected using the relative magnitude of their mean

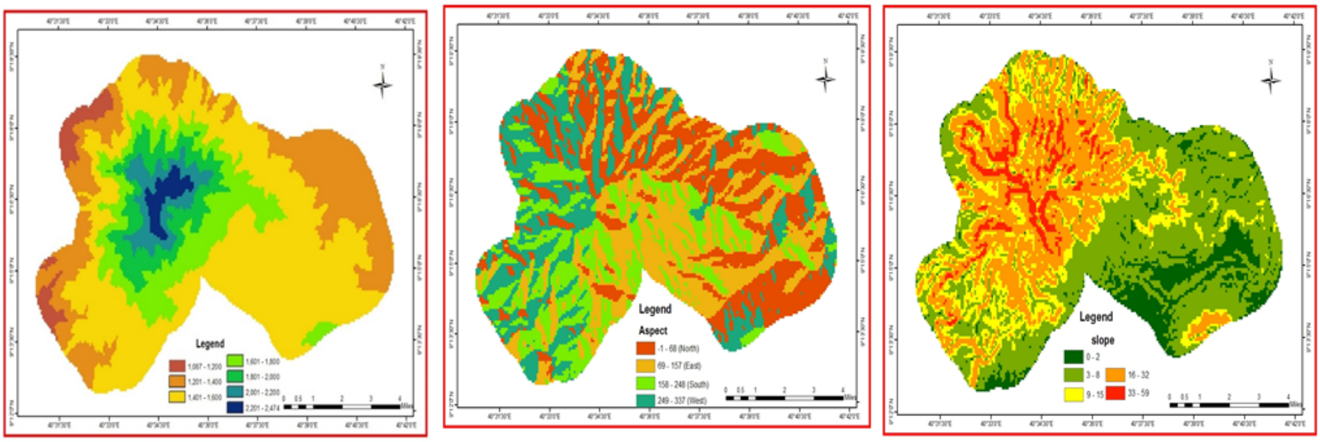

Figure 3: Altitude, slope and aspect description of asabot mountain forest.

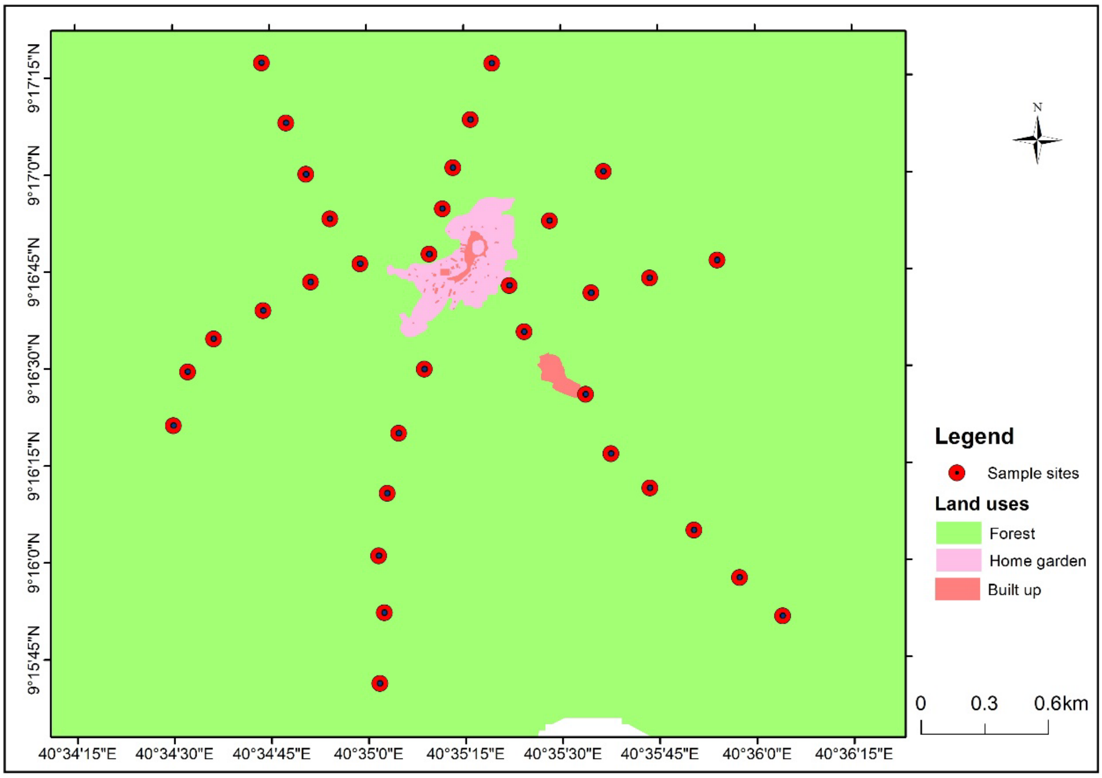

Figure 4: Sample plot distribution.

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cover abundance values. The synoptic table classification indicator species of plant community in each particular cluster were produced using R statistical tool. Synoptic table produced from the summation of Relative density (R_D)+Relative dominance (R_{DO})+Relative frequency (R_F) in percent.

Importance value analysis

The importance value indices (IVI) were computed for dominant woody species based on their relative density (R_D), relative dominance (R_{DO}) and relative frequency (R_F) as researcher Kenta and Coker described [18]. Importance value index (IVI)=Relative density (R_D)+Relative dominance (R_{DO})+Relative frequency (R_F), Where, Relative density (R_D)=(number of individual's species diameter at breast height (DBH) >2.5 cm)/(total number of individuals') × 100, where, Relative dominance (R_{DO})=(Dominance of a species DBH>2.5 cm)/(Dominance of all species) × 100, where, Relative frequency (R_F)=(Frequency of a species)/(Frequency of all species) × 100. However, the dominance is defined as the mean basal area per tree, multiplied by the number of trees of the species.

Structural data analysis

The DBH classes were analyzed based on the interval that class is, 1 stands for 1.0-2.50 cm, 2 stands for 2.51-10.0 cm, 3 stands for 10.01-15.0 cm, 4 stands for 15.01-20.0 cm, 5 stands for 20.01-25 cm, 6 stands for 25.01-30.0 cm, and 7 stands for >30.0 cm. In the similar way height classes were analysed based on the intervals that class is1 stands for 2-5 cm, class 2 stands for 5.01-8 cm, class 3 stands for 8.01-12 cm, class 4 stands for 12.01-15 cm, class 5 stands for 15.01-20 cm and class 6 for more than 20.00 cm. As literature states basal area importance in providing a better measurement of the relative importance of the species than stem count [20], we analyzed basal area (BA) using a standard equation based on diameter at breast height. B_A=d π^2/4, where, B_A is basal area, π=3.14; d is DBH (m). The density of trees or shrubs and basal area values were computed using a number of individuals per hectare and m^2 per hectare, respectively. Furthermore, the vertical structure of the woody species was analyzed using the IUFRO classification scheme [21]. This scheme categorizes a vertical structure of vegetation into upper, middle and lower story. The population structures of some selected species were also analyzed for the interpretation of the pattern of population dynamics in the forest.

Results and Discussions

Results

Species composition: According to our sample, Asabot mountain forest was characterized by 103 species of 91 genera and 54 families. The trees species account for 26; shrubs species account for 36; lianas species account for 6 and 35 species were a woody hemi-parasite. Poaceae, Oleaceae, and Anacardiaceous were the most dominant families, contributing 12, 5 and 5 species to the total, respectively. These families were followed by Euphorbiaceous, Fabaceae, and Malvaceae which contribute four species while the remaining 46 families contributed only three and fewer species.

Plant community: The plant community analysis was clustered under three classes based on relative abundance of the individual in their respective samples (Figure 5). The clustering Euclidean distance was named after two dominant species within the group following Whittaker method [22]. The abundance value of each species indicates the given community dominant species. The majority of sample plots have similar plant community abundance and classified under cluster one. Cluster 1 accounts for 54.14% sample plots; cluster 2 accounts for 31.43% sample plots; and cluster 3 accounts for 11.43% sample plots. The synoptic table indicated that the indicator species for plant community in cluster 1 were *Olea europaea, Dodonea angustifolia, Pterolobium stellatum* and *Euclea racemose;* cluster 2 plant community indicator species were *Jasminum abyssinicum, Cuppuresses lusitanica, Maesa lanceolata, Rumex nepalensis* and *Terminalia catappa,* and cluster 3 plant community indicator species were *Teclea simplicifolia, Podocarpus falcatus, Grewia sp., Myrsine africana* and *Acokanthera schimperi.* These species considered as Asabot dry Afromontane forest plant community indicator species and an illustration of species represents dry Afromontane forest ecology plant community if the macro and micro environmental variables variability not triggered. The plant community importance value index classes for each species showed an inverted J-shaped curve. That means most species in the first IVI class and few species in the last IVI class (Figure 6).

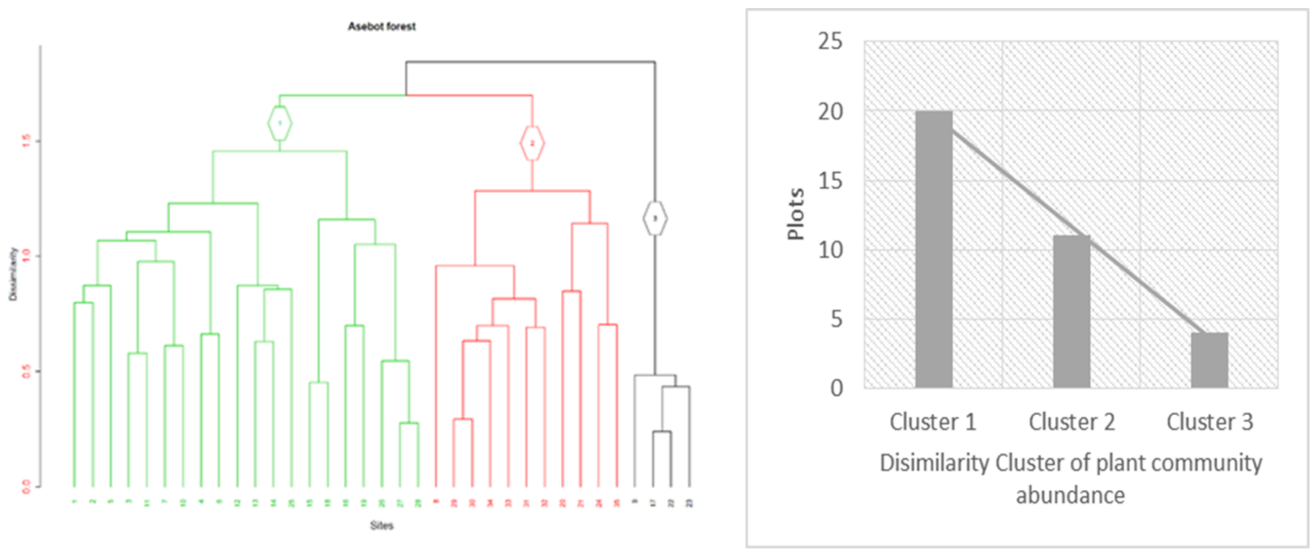

Figure 5: Dendrogram representation of plant community in asabot dry afromontane forest.

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The synoptic table classification of plant community was represented indicator species in each cluster. Plant community indicator species in Cluster 1 were *Olea europea*, *Dodonea angustifolia, Pterolobium stellatum* and *Euclea racemosa*, and cluster 2 plant community indicator species were *Jasminum abyssinicum*, *Cuppuresses lusitanica, Maesa Lanceolata, Rumex nepalensis* and *Terminalia catappa*; cluster 3 plant community indicator species were *Teclea simplicifolia, Podocarpus falcatus, Grewia sp., Myrsine africana* and *Acokanthera schimperi* (Table 2). Those species were also considered as Asabot dry Afromontane forest plant community indicator species.

Species	Cluster 1	Cluster 2	Cluster 3
Olea europaea	4.67	2.38	0.25
Dodonea angustifolia	3.56	3.46	0.00
Pterolobium stellatum	3.34	1.46	0.25
Euclea racemosa	2.72	1.69	1.25
Jasminum abyssinicum	0.23	**5.45**	1.50
Cuppuresses lusitanica	0.78	**4.85**	0.25
Maesa Lanceolata	0.17	**3.31**	0.00
Rumex nepalensis	0.06	**3.23**	0.00
Terminalia catappa	1.00	**2.85**	0.00
Teclea simplicifolia	0.06	1.54	**16.25**
Podocarpus falcatus	0.61	1.15	**1.50**
Grewia.sp	0.00	1.46	**1.50**
Myrsine africana	0.44	1.00	**1.50**
Acokanthera schimperi	1.11	0.69	**1.25**

(Refer Annex B for the entire species)

Table 2: Synoptic table cover-abundance values of species having higher value

Species	R_A	R_F	R_{DO}	IVI
Podocarpus falcatus	2.91	2.77	44.67	50.35
Cuppuresses lusitanica	1.05	2.65	25.38	33.35
Olea europaea	1.25	4.94	10.86	18.94
Jasminum abyssinicum	5.09	4.05	0.94	8.12
Teclea simplicifolia	2.97	4.97	0.07	8.01
Euclea racemosa	1.60	4.27	0.82	6.69
Anchyranthus aspera	3.17	1.08	1.76	6.01
Psydrax schimperiana	1.74	4.21	0.04	5.99
Olea welwitschii	1.32	1.92	2.54	5.79
Acokanthera schimperi	1.99	3.60	0.184	5.77
Dodonea angustifolia	1.64	2.78	1.28	5.56

(Refer Annex C for the entire species)

Table 3: Top ten species with high importance value index.

Importance value index (IVI): *Cuppuresses lusitanica, Olea europaea, and Podocarpus falcatus* species had the highest importance value index (Table 3). This might be due to the contribution of endowed monastery community by protecting those high economic and cultural value species from the local intruders in demand of timber and other construction material. These three species contributed about 30.05% of the total importance values whereas the remaining woody species had combined IVI of about 69.95% (Table 3). Species with lower IVI need high conservation efforts while those with higher IVI need monitoring and management.

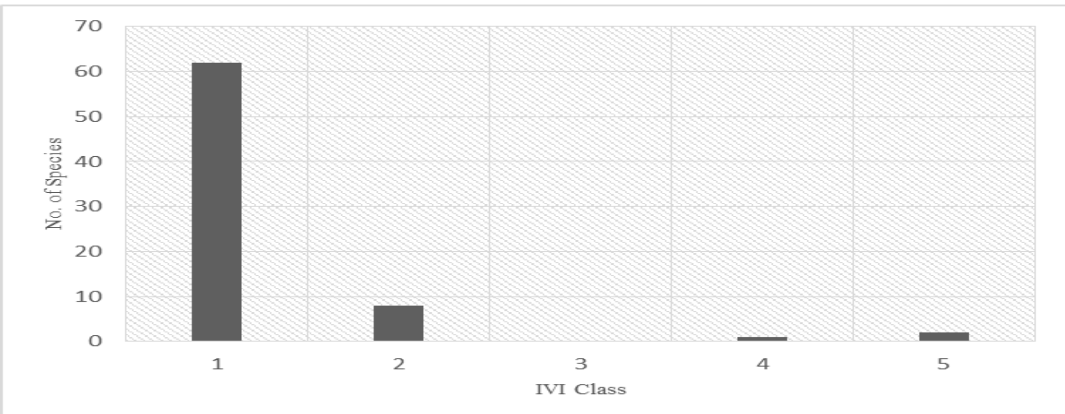
The study showed that most species have lower IVI classes whereas very few species have high IVI classes (Figure 6).

Tree and shrub density: The density of trees and shrubs with DBH greater than 1 cm was 875.97 individuals ha^{-1}. The density of trees and shrubs with DBH 10-20 cm was 137.5 individuals ha^{-1}. The density of trees and shrubs with DBH greater than 20 cm was 71.16 individuals·ha^{-1} (Table 4). The ratio described as c /d, is taken as the measure of size class distribution. Accordingly, the ratio of individuals with DBH 10.01-20 cm (c) to DBH >20 cm (d) was 1.93.

The comparison of tree and shrub densities in DBH class 10.01-20 cm (c), DBH class greater than 20 cm (d) and C/D ratio for Asabot mountain forest with eleven other forests in Ethiopia were given in Table 5. The ratio of DBH 10-20 cm to DBH>20 cm at Asabot mountain forest was lower than Chi limo, Dindin, and Masha Andaracha, Menasha Suba, and Mena Angst forests but higher than Alata-Bolale, Woof Washi, Kamtok, Kamtok, Guar Freda, Donor and Doodle Forests (Table 5).

DBH class distribution: The DBH class and wood species density showed the irregular relationship. As DBH increased from first class to second class, individual's species number increased very high from 17.31stems ha^{-1} to 650 stems ha^{-1}; then decreased and finally increased relatively. The curve was showed an irregular distribution of individuals across the DBH classes (Figure 7).

Tree species were classified according to different DBH classes, such as 1 stands for 1.0-2.50 cm, 2 stands for 2.51-10.0 cm, 3 stands for 10.01-15.0 cm, 4 stands for 15.01-20.0 cm, 5 stands for 20.01-25



(IVI classes 1 stands for 1-5, class 2 stands for 5.1-10.0, class 3 stands for 10.1-15.0, class 4 stands for 15.1-20.0, class 5 stands for >20.0)

Figure 6: Number of species in the importance value index class

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cm, 6 stands for 25.01-30.0 cm, and 7 stands for DBH>30.0 cm. The DBH class distribution showed that more than 76% of all individuals had DBH less than 10.01 cm (Table 6).

Basal area: The mean total basal area of Asabot mountain forest is 22.45 m^2 ha^{-1}. The highest percentage of basal area (74.98%) contributed by DBH class 7 (DBH>30.0 cm), however, the DBH class of the rest individual tree density was contributed only 25.02%. Conversely, individuals in the DBH classes less than 30 cm had a density of about 95% of the total but accounted only 25.02% of the total basal area of the forest (Table 7 and Figure 8).

Species with the largest contribution in the basal area can be considered the most important woody species in the forest. Accordingly, descending order of some top tree species with the highest basal area in Asabot mountain forest was *Podocarpus falcatus*, *Juniperus procera*, *Olea europaea*, *Olea welwitschii*, *Nicandra physaloides*, *Acacia abyssinica*, *Dodonea angustifolia*, and *Teclea nobilis*.

DBH (cm)	No. of individuals (ha^{-1})	Percentage (%)
1.0–2.5	17.31	2.0
2.51–10.0	650	74.2
10.1–20.0	137.5	15.7
>20.0	71.16	8.1
Total	875.97	100.0

Table 4: Density of trees and shrubs by diameter at breast height class.

Forests	Density		ratio	Source
	(c)	(d)	(c/d)	
Woof Washi	329.00	215.00	1.53	Bekele, 1993
Menasha Suba	484.00	208. 20	2.33	Bekele, 1993
Kamtok	330.00	215.00	1.53	Facade *et al.* 2012
Doodle	521.00	351.00	1.48	Hund era *et al.* 2007
Donor	526.00	285.00	1.85	Azalea *et al.* 2006
Guar Freda	500.00	263.00	1.90	Danu, 2006
Masha Andaracha	385.70	160.50	2.40	Yeshitela *et al.* 2003
Dindin	437.00	219.00	2.00	Shibru and Balcha, 2004
Mena Angst	292.00	139.00	2.10	Lulekal, 2008
Alata-Bolale	365.00	219.00	1.67	Woldeyohannes, 2008
Chilimo	638.00	250.00	2.55	Bekele, 1994
Asabot	137.50	71.16	1.93	Current study

Table 5: Comparisons of trees and shrubs density with DBH 10-20 cm (c) and tree density with DBH >20 cm (d) from Asabot mountain Forest with 11 other forests in Ethiopia.

The basal area of Asabot mountain forest was less than that of Wotagisho forest [23], Alata-Bolale Forest [24], Menasha Suba, Chilimo, and Denkoro Forests [25], Dindin Forests [26], Gendo Forest, Masha-Anderacha Forest [27], Jibat and Wof-Washa Forest [28].

Height class distributions: The density of individual trees and shrubs distribution along height classes of Asabot mountain forest were showed decreasing as height increases (Figure 9).

More than 88% of trees and shrubs were less than 8.01 m tall (Height classes 1 and 2). Only a small proportion, about 3.6%, reached a height of 20.01 m and above. The study showed that shorter plants were the dominant plant community (Table 7).

Vertical structure: The vertical structure story of Asabot mountain forest was classified using IUFRO classification scheme [21]. The maximum tree's height in Asabot mountain forest was 40 m which are comparable to another forest in Ethiopia. The main tree species that classified under upper story were *Juniperus procera, Nicandra physaloides, Podocarpus falcatus, Euclea racemosa and Cassipourea malosana.* When we compare each story based on the number of individual trees, the lower story was higher than the upper story (Table 8).

DBH Class		Density		Basal Area	
		Number of Stems	Percent (%)	Area (m^2)	Percent (%)
Class 1	1.0 0-2.5	17.31	2.00	0.01	0.02
Class 2	2.50-10	650.00	74.20	1.96	8.71
Class 3	10.01-15	90.38	10.30	1.11	4.95
Class 4	15.01-20	47.12	5.40	1.06	4.74
Class 5	20.01-25	15.39	1.80	0.63	2.79
Class 6	25.01-30	13.46	1.50	0.87	3.81
Class 7	>30	42.31	4.80	16.83	74.98
Total		**875.97**	**100.00**	**22.45**	**100.00**

Table 6: DBH class, Density and Basal Area of tree and shrub of asabot mountain evergreen natural forest.

Height Class		Density	Percent (%)
Class 1	**2-5**	512.5	58.50
Class 2	**5.01-8**	260.58	29.70
Class 3	**8.01-12**	53.85	6.10
Class 4	**12.01-15**	8.65	1.00
Class 5	**15.01-20**	8.65	1.00
Class 6	**more than 20.00**	31.73	3.60
Total		**875.97**	**100.0**

Table 7: Height class, density, and percent of trees and shrubs in the study site.

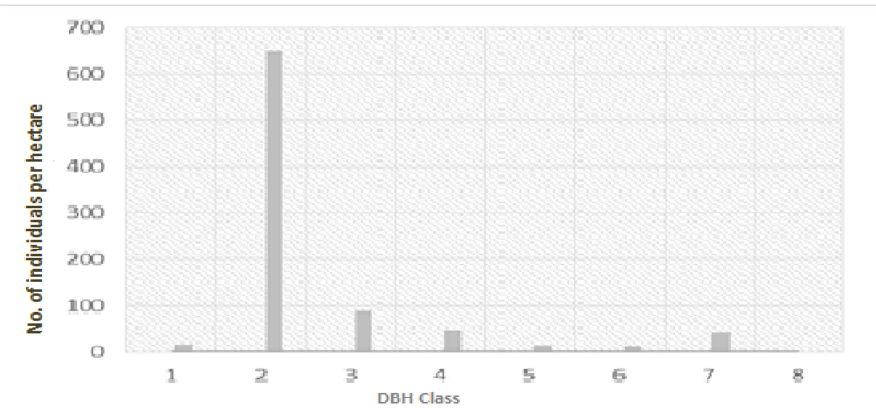

Figure 7: DBH class versus the number of individuals per hectare.

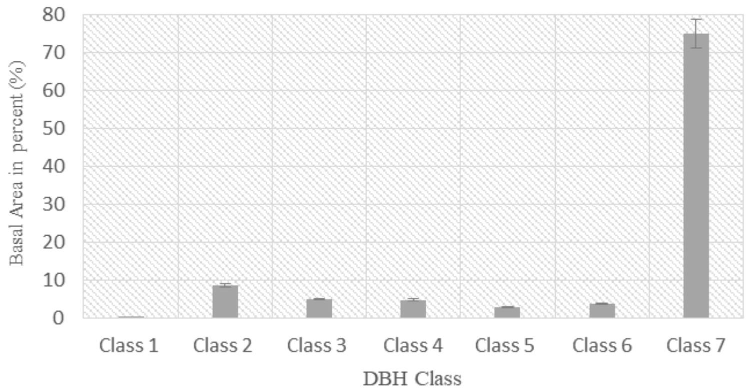

Figure 8: Basal Area distribution in percent across DBH class.

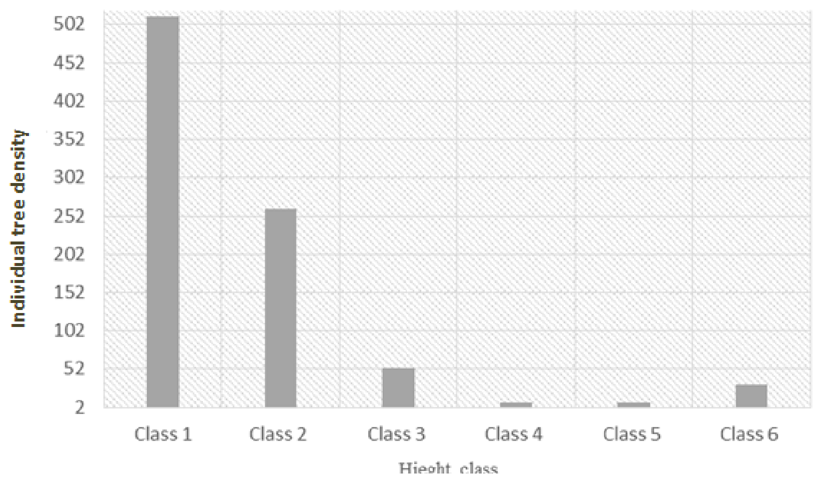

Figure 9: Tree and shrub individual density distribution along height class.

The middle layer vertical structure of Asabot mountain forest was occupied by species including *Capparis tomentosa, Cuppresus lustanica, Podocarpus falcatus, Olea welwitschii, Bersama abyssinica, Ficus Sur,* and *Olea europaea.* However, the lower story was largely dominated by *Acacia abyssinica*, *Acokanthera schimperi, Capparis tomentosa, Clerodendrum myricoides, Dodonea angustifolia, Euclea racemosa, Pavetta abyssinica, Ozoroa insignis, Protea gaguedi, Psydrax schimperiana, Rhus retinorrhoea, Schefflera abyssinica* and *Terminalia sp.* The majority of species were concentrated in the lower story (76.27%) followed by the middle (15.25%) and very lowest at the upper story (8.48%) (Table 8). This showed a similar trend with Kamtok Afromontane moist forest [1] and Bonga Forest [29].

Plant diversity: Plant diversity indicates healthiness and survival capacity of ecology while unexpected environmental shocks happen. Species richness highest at cluster 1 (41.91%) and lowest at cluster 3 (18.38%). The Shannon diversity, Simpson diversity, Shannon Evenness and Simpson Evenness were highest at cluster 2 and lowest in cluster 3 (Table 9). Indeed, the study showed that high species richness not an indication of diversity and evenness.

The entire study site plant community structure was similar with cluster structure. The mean Shannon diversity index of plants in the study site was 1.61, Simpson diversity index was 4.83, Shannon Evenness index was 0.72 and Simpson Evenness index was 0.74 (Table 10).

Relative abundance, relative frequency, and relative dominance: *Achyranthus aspera, Allium sp., Teclea simplicifolia*, *Celtis toka, Jasminum abyssinicum, Myrsine africana, Pittosporum Veridiflorum, Grewia sp.* and *Podocarpus falcatus* were the most abundant species, account for 25.24% of total density. *Olea europaea, Teclea simplicifolia*, *Achyranthes aspera, Euclea racemosa, Psydrax schimperiana, Acokanthera schimperi* and *Pterolobium* were recorded highest frequency whereas *Podocarpus falcatus, Cuppuresses lusitanica* and *Olea europaea* were recorded highest relative dominance. *Olea europaea, Cuppuresses lusitanica* and *Dodonea angustifolia* were high relative frequency and high relative dominance species whereas *Podocarpus falcatus* and *Achyranthus aspera* were both high relative abundance and high relative dominance species. Indeed, *Teclea simplicifolia* was the only plant species with both high relative abundance and relative frequency in the study site (Table 11).

Population structure: The pattern of diameter class distribution indicates general trends of population dynamics and recruitment processes of each species. Indeed, the analysis of population structure for 27 species revealed eight specific and three general patterns (Figure 10). The total seedling, sapling, and mature woody tree densities of 27 selected species were about 1268, 231, and 911 individuals per hectare, respectively (Table 12). The structural analysis indicated the majority of plant community found in the DBH class 10 cm to 20 cm and the value less than most available studies in Ethiopia. But the ratio of medium (DBH class 10 to 20 cm) and large (DBH class >20 cm) was greater than Woof Washi [28], Kamtok [1], Doodle [30], Donor [25], Guar Freda [31], and Alata-Bolale [24] forests. The ration of medium and large classes was lower than Menasha Suba [28], Chilimo [13] and Masha Anderacha [27], Mena Angst [32] and Dindin [26]. The plant community structure of Asabot dry Afromontane forest mainly represents by the two DBH classes if the microscale environmental variables variability not triggered.

The DBH and height class distribution indicated an inverted J-shaped curve with most individuals in the lower size classes (Figures 7 and 8). However, the basal area class distribution of individuals showed J-shape. The DBH and height class distribution demonstrated a high rate of regeneration but the minimum number of tree density in the higher DBH and height class distribution might be due to the high rate of selective tinning. This agreed with studies conducted different parts of the country [1,33]. The total basal area of woody plant community in the sample plots of Asabot forest was 22.44 m^2 ha^{-1}. The highest basal area was contributed by *Podocarpus falcatus, Juniperus procera, Olea welwitschii* and *Olea europaea.* The predominance of these species in the forest was probably because of their spiritual significance and Asabot monastery community role in the management of forest from external intruders. But most of these species not dominate in another forest due to high market demand [1,33]. The study showed few plants contributed a large share of the total basal area confirming similar studies in Ethiopia [1,27,30,33].

The population of 27 selected tree species showed eight more specific and three general patterns based on DBH class of their abundance (Figure 9). Plant species represented their populations in particular pattern were *Olea europaea*, *Dodonea angustifolia, Protea gaguedi*, *Acacia abyssinica*, *Juniperus procera*, *Podocarpus falcatus*, *Olea welwitschii* and *Conyza hypoleuca.* Most of the pattern showed higher density in lower DBH classes which suggesting good reproduction and healthy regeneration potential. The other pattern showed the lowest density in the lower classes which is a sign of poor reproduction and recruitment. The other populations were represented by the irregular pattern. This result showed a similar trend with other studies in Ethiopia [1,24,34]. Most of the plant population in Asabot mountain forest was in a deficiency of intermediate DBH classes which might be due to selective removal of medium-sized wood plants. This might be due to Asabot mountain forest is the only natural forest in the vicinity currently under pressure of local intruders. In our observation, the main reasons for the absence of medium DBH classes were selective tinning for construction, timber and firewood.

Regeneration status of asabot mountain forest: The composition, distribution and density of seedlings and saplings are an indicator for the future habitat conditions, geographical distribution, composition, successful regeneration and survival and growth of forests within space and time [35-38]. The distribution of seedlings, saplings and mature

Story	Height (m) Class	Stems		Species		Ratio of individuals to species
		Density	Percentage (%)	No.	Percentage (%)	
Lower	2-13.33	826.93	94.4	45	76.27	18.38
Middle	13.33<H<26.66	33.04	3.77	9	15.25	3.67
Upper	>26.66	16	1.83	5	8.48	3.2

(The story of trees classified into upper, where the tree height is greater than 2/3 of the top height; middle, where the tree height is in between 1/3 and 2/3 of the top height; and the lower story, where the tree height is less than 1/3 of the top height)

Table 8: The vertical structure story of trees in the Asabot mountain forest.

Cluster	Richness	Shannon diversity	Simpson diversity	Shannon Evenness	Simpson Evenness
Cluster 1	57	3.37	20.37	0.83	0.36
Cluster 2	54	3.86	42.79	0.97	0.79
Cluster 3	25	2.30	4.32	0.71	0.17

Table 9: Species richness, Shannon diversity index (H), Simpson diversity index, Shannon Evenness index (j) and Simpson Evenness index of each cluster.

Berger Parker	Brillouin	Chao	D	Equitability	Evenness	Fisher alpha	Individuals	Margalef	Menhinick	H	Simpson	Taxa
0.38	1.67	10.44	0.26	0.82	0.72	3.51	33.13	1.91	1.37	1.61	4.83	7.48

Table 10: Shannon Diversity index (H), Berger Parker, Brillouin, Chao, Dominance (D), Equitability, Evenness, Fisher alpha, Individuals, Margalef, Menhinick, H, Simpson, and Taxa.

Species	R_A	Species	R_F	Species	R_{DO}
Achyranthus aspera	5.81	*Teclea simplicifolia*	4.97	*Podocarpus falcatus*	44.67
Allium spalhaceum	3.18	*Olea europaea*	4.94	*Cuppuresses lusitanica*	25.38
Teclea simplicifolia	2.97	*Euclea racemosa*	4.27	*Olea europaea*	10.86
Celtis toka	2.64	*Psydrax schimperiana*	4.21	*Olea welwitschii*	2.54
Jasminum Abyssinicum	2.37	*Acokanthera schimperi*	3.6	*Achyranthus aspera*	1.76
Myrsine africana	2.12	*Pavetta abyssinica*	3.01	*Acacia abyssinica*	1.591
Pittosporum Veridiflorum	2.08	*Dodonea angustifolia*	2.78	*Protea gaguedi*	1.38
Grewia.sp	2.05	*Juniperus procera*	2.71	*Dodonea angustifolia*	1.28
Podocarpus falcatus	2.02	*Cuppuresses lusitanica*	2.65	*Nicandra physalodes*	1.2

Table 11: Selected high relatively abundant, relatively dominant and relatively frequent species.

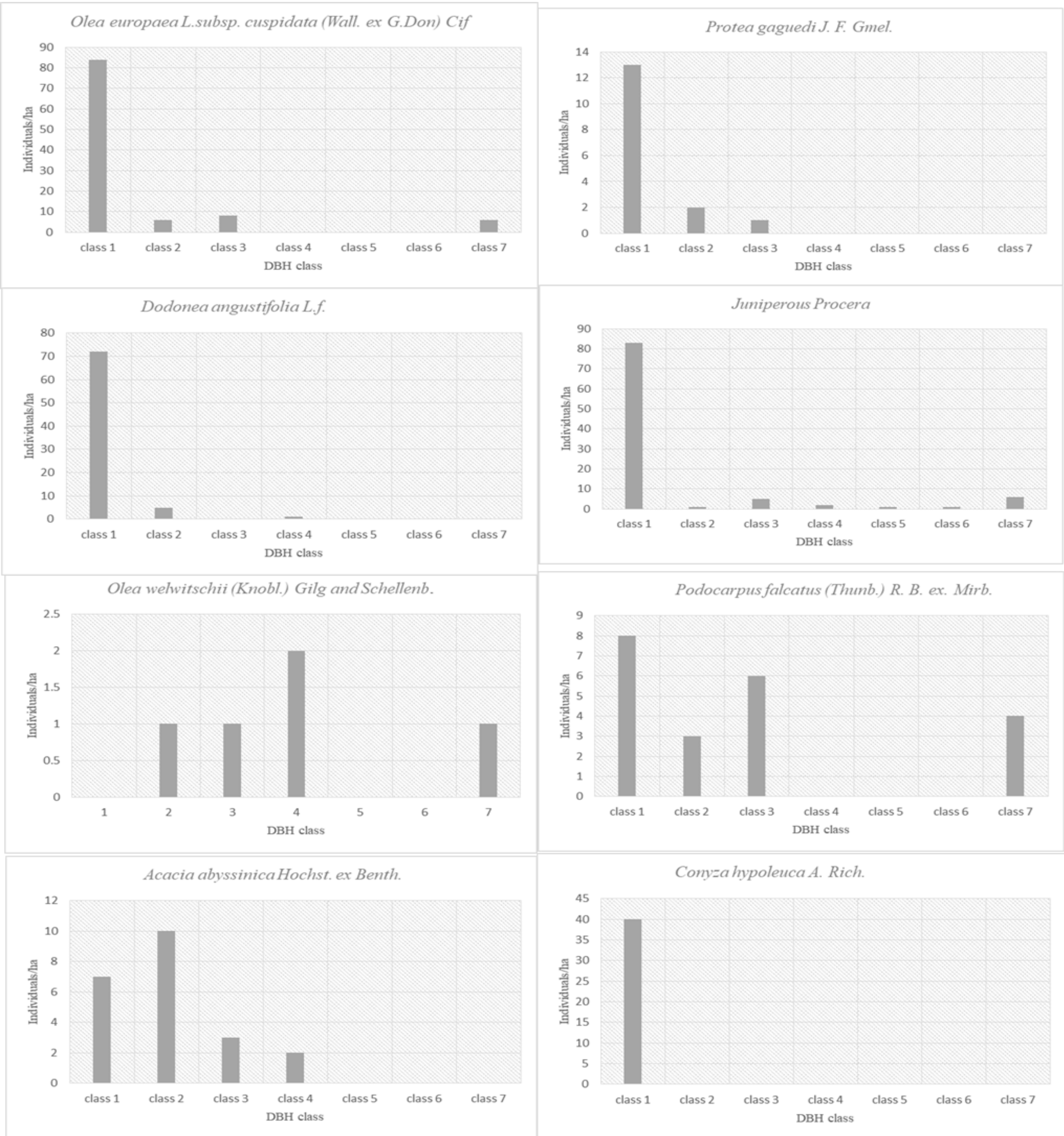

Figure 10: Population structure of selected tree species (Tree species were classified according to different DBH classes, such as, 1 stands for 2.6-12.0 cm DBH, 2 stands for 12.1-22.0 cm DBH, 3 stands for 22.1-32.0 cm DBH, 4 stands for 32.1-42.0 cm DBH, 5 stands for 42.1-52.0 cm DBH, 6 stands for 52.1-62.0 cm DBH, 7 stands for >62.0cm DBH).

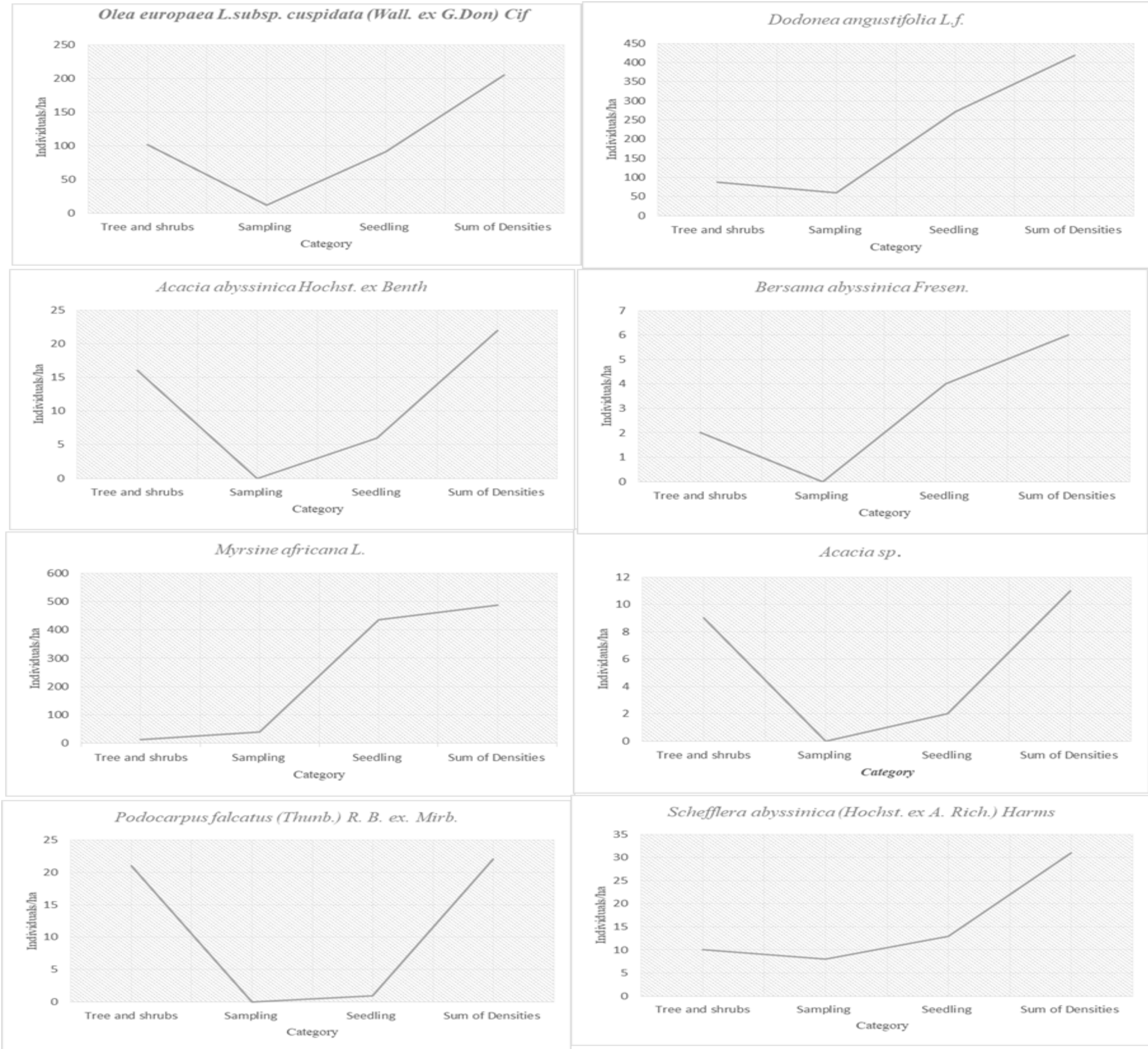

Figure 11: Trees/shrubs, saplings and seedlings distribution of some selected species of asabot forest.

trees/shrubs show eight distinct patterns and three general patterns (Figure 11).

Seven species (19.44%) were not represented by both seedlings and saplings, and only a few mature individuals were recorded for these species. On the other hand, five species (13.88%) of the total were not represented by saplings (Table 12). Accordingly, plant species were grouped into three conservation priority classes; Class 1 with no seedlings or saplings, Class 2 with seedlings but no saplings, and Class 3 with both seedlings and saplings greater than 1 individual's ha^{-1} (Table 13).

Plant species under conservation priority of class 1 and 2 might be due to human and cattle disturbance, grazing and browsing, seed predation, and the need of dormancy period for seeds of certain trees which causes insufficient seedlings and saplings. In addition, Facade and Coworker explained this phenomenon: litter accumulation, pathogens, moisture stress, and possession of alternative adaptations for propagation other than seed germination could also be the cause for lack of sufficient seedlings [1]. This study showed a similar result with Gurmessa, et al. [1], Danu [31] and Simon and Grima [26]. Indeed, our study showed plant species under conservation priority 1 and 2 might be under threat of local extinction and needs due attention.

Scientific name	Trees and shrubs	Saplings	Seedling	Sum of densities
Olea europaea	102	12	91	205
Acokanthera schimperi	25	6	16	47
Euclea racemosa	73	6	51	130
Psydrax schimperiana	8	17	43	68
Dodonea angustifolia	88	59	272	419
Carissa spinarum	24	30	88	142
Rhus retinorrhoea	49	7	73	129
Protea gaguedi	16	0	3	19
Acacia abyssinica	16	0	6	22
Maytenus spp.	13	4	24	41
Ozoroa insignis	2	0	90	92
Juniperus procera	70	22	30	122
Terminalia catappa	23	8	17	48
Bersama abyssinica	2	0	4	6
Capparis tomentosa	3	4	2	9
Myrsine africana	13	39	436	488
Clerodendrum myricoides	1	0	2	3
Acacia sp.	9	0	2	11
Sideroxylon oxyacanthum	1	0	3	4
Cassipourea malosana	2	1	3	6
Podocarpus falcatus	21	0	1	22
Croton macrostachyus	1	0	0	1
Calpurnia aurea	7	2	14	23
Schefflera abyssinica	10	8	13	31
Euphorbia tirucalli	4	3	2	9
Ficus Sur	3	0	0	3

Table 12: Selected tree species with their seedling, sapling and mature tree density per hectare.

Class 1	Class 2	Class 3
Croton macrostachyus	*Podocarpus falcatus*	*Calpurnia aurea*
Ficus Sur	*Sideroxylon oxyacanthum*	*Schefflera abyssinica*
-	*Clerodendrum myricoides*	*Cassipourea malosana*
-	*Acacia sp.*	*Capparis tomentosa*
-	*Bersama abyssinica Fresen.*	*Myrsine africana*
-	*Ozoroa insignis*	*Acokanthera schimperi*
-	*Protea gaguedi.*	*Juniperus procera*
-	*Acacia abyssinica*	*Terminalia catappa*
-	-	*Maytenus spp.*
-	-	*Rhus retinorrhoea*
-	-	*Olea europaea*
-	-	*Acokanthera schimperi*
-	-	*Euclea racemosa*
-	-	*Psydrax schimperiana*
-	-	*Dodonea angustifolia*
-	-	*Carissa spinarum*
-	-	*Rhus retinorrhoea*

Table 13: Species conservation priority classes.

Conclusion and Recommendation

The plant community in the study site within sampling quadrats was accounted for 103 species of 91 genera and 54 families. Dendrogram clustering of plant community based on their abundance was found more than 55% sample plots under similar class. The synoptic table which showed *Olea europaea, Jasminum abyssinicum* and *Teclea simplicifolia* was indicator species for their respective clusters and the study site. This illustrated Asabot dry Afromontane forest similar plant community abundance along the environmental gradient and structurally described by small trees and shrubs predominance was an indication of secondary regeneration forest type. The density of woody species inversely related with DBH and height classes implying good regeneration of the forest. The basal area of Asabot dry Afromontane forest covered by very few large plants while the majority contributed very small basal area. The population structure of Asabot mountain forest described by different patterns indicates high variation among species in population dynamics within the forest. The regeneration status analysis also showed that two species had no seedlings and saplings; seven species had no seedlings or saplings; and the rest species were represented by seedlings, saplings and trees or shrubs. The woody species of the Asabot dry Afromontane forest was classified into three priority classes for conservation based on their regeneration status giving due attention for first priority class as threatened species. Indeed, Asabot dry Afromontane forest is the only natural forest in the vicinity with high economic, social and political values for the local rural communities as a source of timber and non-timber forest products and ecosystem services for the lowland community. Indeed, the present multi-dimensional human influence on the natural forest needs urgent management strategy. Therefore, the first and the second priority class species should be given appropriate attention by all stakeholders. Furthermore, extensive research is needed to identify the reasons for the absence of regeneration in some species. In order to sustain forests, the vicinity participatory forest management programs should be introduced and implemented by sharing the responsibility of management and conservation with the local community through awareness creation and food security program. Finally, further investigation on the patterns of ecosystem functioning, socioeconomic and political environment in the vicinity should be studied for sustainable intervention.

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