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Diversity and Vegetation Structure of Shrubs and Trees in Magada Forest, Bule-Hora District, Borena Zone, Oromia Region, Southern Ethiopia

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Abstract: This study was conducted in Magada Forest, Bule-Hora District, Borena Zone, Oromia Region, Southern Ethiopia. The main objective of the study was to investigate diversity and vegetation structure of trees and shrubs in the forest. Systematic sampling method was used to collect vegetation data. Accordingly, 35 quadrats, each with 20 m x 20 m (400 m^2) were laid along line transects at the distance of 100m from each other. The plant species were collected, brought, identified and deposited at the National Herbarium (ETH), Addis Ababa University. Data were analyzed using different software such as Microsoft Excel, Shannon-Wiener diversity index, TWINSPAN and PAST. A total of 38 plant species belonging to 23 families and 27 genera were recorded and identified. Family Asteraceae had the highest number of individuals 227 followed by Celastraceae 221 and Apocynaceae 217. The forest was dominated by small sized trees and shrubs indicating that it is in the stage of secondary regeneration. The vegetation is disturbed because of many factors including grazing and browsing by livestock and other humans' activities. These further retards diversity and vegetation structure of the forest. Therefore, based on the results, to protect and conserve this forest appropriate management strategy and awareness creation for the local people on the wisely use is very important. The maintenance of biodiversity that promote sustainable use of the forest and its products are also recommended.

Keywords: DBH**,** Diversity, Magada Forest, Vegetation

1. Introduction

Ethiopia is a country with different landscapes and one of the tropical countries with diverse flora and fauna. The geographical location in the tropics, the variability in environmental factors and socio-cultural diversity result in a diverse flora and wide variety of traditional practices [1]. Ethiopia is a center of both faunal and floral diversity because of its favorable eco-geographic conditions. The forest ecosystems are complex and diverse containing various indigenous and endemic plant genetic resources of the country [2].

Forest ecosystems play multiple roles at global as well as local levels: as providers of environmental services to nature in general and humans in particular and as sources of economically valued products [3]. Forests form an integral part of life on earth, providing a range of benefits at local, national and global levels, covering approximately 40% of the world's total land mass [4]. Forest ecosystems are distinct, coherent communities comprised of a variety of life forms and a physical environment with which they interact [5]. Forests are ecologically important in influencing climate and maintaining global balances of carbon and atmospheric pollutants. They regulate climatic factors such as rainfall, humidity and temperature regime of a given area. They also protect the soil and landscape from wind and erosion. This clearly shows that forests have three broad functions: productive, regulative and protective [6].

The destruction of vegetation and environmental degradation has become issues of national and global concern in recent years. This is because of the fact that declining vegetation cover and depletion of natural resources are

closely associated with drought and food shortages that have become major threat affecting the life of millions of people. The depletion of the natural vegetation in many parts of the country has also led to the threat and decline in number and area of vegetation structure of many plant species [6], [7].

Ethiopia has the fifth largest flora in Africa. The flora is very heterogeneous and has a rich endemic element owing to the diversity in climate vegetation. Besides, Ethiopia has the largest population of livestock in Africa. Thus, grazing pressure has increased the rate at which tree and shrubs species are becoming scarcer [8]. The indigenous trees and shrubs species have largely been replaced by a few exotic species, notably Eucalypts, but they cannot provide such wide variety of products and services as do indigenous [9]. Information on vegetation may be required to help to solve an ecological problem: for biological conservation and management purpose; as an input to environmental impact assessments; to monitor management practices or to provide the bases for prediction of possible future changes [10]. The uncontrolled exploitation of forest areas by anthropogenic factors and depletion of vegetation by natural factors like forest fire has led to the threat as well as the decline in number of many plant species. Magada forest is one of the forests in the country, which have not been well studied before. The main objective of this study was to investigate the diversity and vegetation structure of trees and shrubs in the forest.

2. Materials and Methods

2.1. Description of the Study Area

Magada forest is located in Bule-Hora District, Borena Zone, Oromia Region at the distance of 472 km far from Addis Ababa along the highway to Moyale. It is found at 7 km from Bule-Hora town to southeast. The forest is located between 05º038' North and 38º014' East. Magada forest is estimated to cover an area of around 19,980 hectare; of these, around 18,426.5 hectare is natural forest and around 1,567.5 hectare is man-made forest.The annual temperature of study area ranges from 20˚c to 25˚c with mean annual rain falls of 900mm to 1100mm. The altitudinal ranges is from 1850 to 2006 meters above sea level (m.a.s.l.).

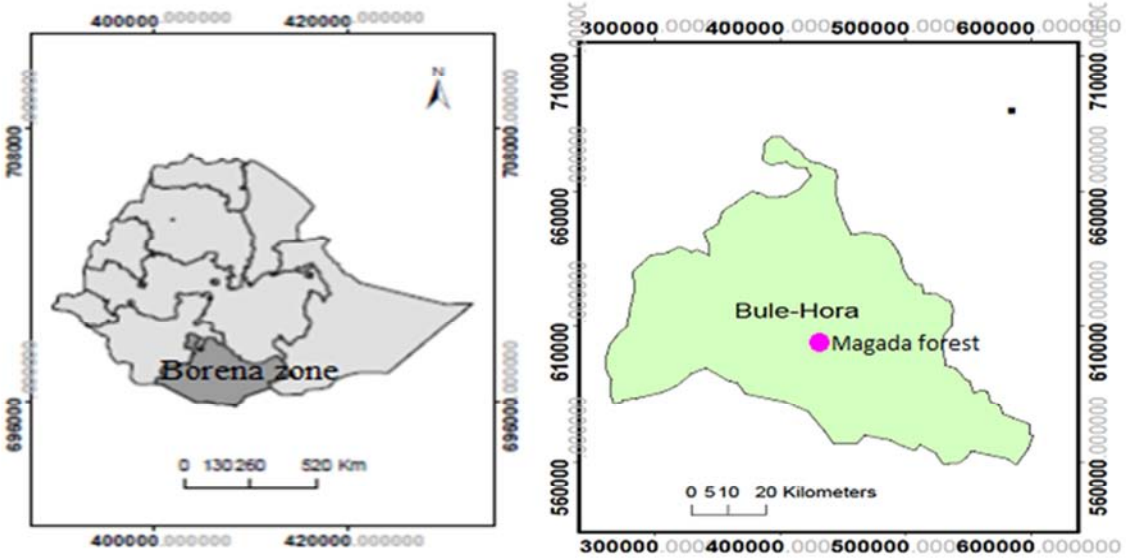

Fig. 1. *Map showing the study area.*

2.2. Methods

2.2.1. Sampling Techniques

This study of diversity and vegetation structure of trees and shrubs was carried out between November, 2010 to June, 2011.Thirty five quadrats 20m×20m (400m^2) in size were laid down purposefully along transects at 100 meters distance in four sites randomly selected in the forest. These four sites namely Bore, Burqa-Gole, Ifata-Farda and Udeyi in which all the four sites of study area were far apart and located at the different directions in the forest.

All trees and shrubs species in each quadrat were recorded and specimens were collected. Collected specimens were pressed, dried and taken to the National Herbarium (ETH) Addis Ababa University for identification. Identification was carried out by comparing with already identified specimens, consulting experts and referring the published volumes of Flora of Ethiopia and Eritrea. Identified plant specimens were deposited at the National Herbarium (ETH) Addis Ababa University. Family, genus and species common names as well habits were also recorded.

Height measurements and DBH (Diameter at Breast Height) were measured. All trees and shrubs individual with DBH values of 10cm and above, height of 2m and above were recorded. Individual tree and shrub species were counted to be used as a measure of total abundance. Floristic heterogeneity of study area was assessed by recording the frequency at which a particular species is recorded in each of the plot. The diameter of small crown and big crown diameters were also measured. Altitude and position of each of the plot was determined and recorded by using GPS.

2.2.2. Methods of Data Analysis

The collected data were recorded, summarized and analyzed by using Microsoft Excel, Shannon–Wiener diversity index and other software such as a FORTRAN Computer Program TWINSPAN. Ordination analysis was carried out using a multivariate computer program Paleontological STastics (PAST) to determine whether there are significant differences in pattern of distribution of trees and shrubs species in the four study sites. The percentage cover data on plant species composition were transformed to Ordinal Transform Values (OTV), and analyzed using a FORTRAN Computer Program TWINSPAN (Two-way Indicator Species Analysis) Version 1.0. TWINSPAN is a divisive polythetic method of vegetation classification. It classifies both samples and species. The default options were chosen while running TWINSPAN. Indicator species with an occurrence of more than 60% in the relevés of a particular association were used to name the plant communities. Combinations of the names of two indicator species were used, where the first was the indicator species used by TWINSPAN to separate a particular cluster from others at the same level while the second species was the one used to separate a group of clusters at the next higher level. The quantitative data were also analyzed using descriptive statistics like frequency, mean, percentages. Diversity indices like Shannon evenness (E) and Shannon Wiener diversity (H) were also used to determine the diversity of trees and shrubs species in the study area.

3. Results and Discussion

3.1. Floristic Composition

From the established sample plots, a total of 38 different species of trees and shrubs were recorded in the sites of study area. These species belong to 25 different families and 30 genera. Out of 38 species, 16 (42.11%) of them were found to be shrubs while 22 (57.89%) were trees (Table 1). This indicates that relatively more trees species are found at Magada forest compared to shrubs species.

Table 1. *The percentage of trees and shrubs species in the study area.*

Habit	Total %
Shrubs	42.11
Trees	57.89

The result showed that, family Fabaceae is the most dominant represented by 8 species (19.70%) and followed by Moraceae which represented by 4 species (8%) and Apocynaceae 2 species, Asteraceae 2 species, Oleaceae 2 species. The remaining 20 families are the least represented with only 1 species (Table 2). Compared with similar study findings on Gura-Lopho moist afromontane forest revealed different result in which Asteraceae as the most represented family 16 species that belong to 12 genera [1].

Table 2. *List of families recorded in the study area with the number of representative species in each family.*

No	Family name	No of species
1	Anacardiaceae	1
2	Apocynaceae	2
3	Aquifoliaceae	1
4	Asclipiadaceae	1
5	Asteraceae	2
6	Balantiaceae	1
7	Boranginaceae	1
8	Celastraceae	1
9	Cuppressaceae	1
10	Euphorbiaceae	1
11	Fabaceae	8
12	Lamiaceae	1
13	Melianthaceae	1
14	Myrtaceae	1
15	Moraceae	4
16	Oleaceae	2
17	Poaceaea	1
18	podocarpaceae	1
19	Rosaceae	1
20	Rubiaceae	1
21	Sapindaceae	1
22	Solanaceae	1
23	Sterculiaceae	1
24	Tiliaceae	1
25	Ulmaceae	1

3.2. Species Association Analysis in Magada Forest

The result of ordered two-way table from TWINSPAN illustrate that the species on the top are more abundant on the left side of the primary division than on the right side. The species on the bottom are more abundant on the right side of the primary division than on the left side. The species in the middle are somewhat constant, occurring widely on both sides. The analysis of the TWINSPAN indicated that the two species, *Bersama abyssinica* and *Solanium incanum*, are indicator species which are used to differentiate the group of samples to the left of the primary division ("Association 1"). On the other hand, *Olea europeana* was found to be indicator for the right side of the primary division "Association 2". Both *Bersama abyssinica* and *Solanium incanumin* "Association 1" are shrubs species where as *Olea europeana* in "Association 2" is a tree species. *Mytenus senegalensis* and *Carissa spinarum* are found constantly; while *Podocarpus falcatus* and *Croton macrostachyus* are tree species almost found frequently in most.

Table 3. *TWINSPAN showing the plants species association of Magada forest.*

	2 23 13	22113 1111 13	1122 22323 2		
	112833402	70938055246894	172495753166		
9 Bers abys	22222-2--	----------	----------	0000	
24 Juni proc	--1------	----------	----------	0000	
37 Vern amyg	224222---	2-----4122--2-	-------2----	0000	
2 Acac buss	2------2-	--1-222----212	----------1-	0001	
30 Peri line	---------	3-2--------2--	----------	0001	
39 Zigi spin	--1-2----	----2---2---2-	----------	0001	
35 Sola inca	223322232	----------	----------	0010	ASS.1
33 Prun afri	--2-22211	--2-----211211	-1--------22	001100	
4 Acac tort	----2----	----------2	-1----------	001101	
10 Calp aure	2222-2222	--2222-2---222	----2--2--22	001101	
6 Albi gumm	-----2-21	--212-11222-1-	-11----2----	00111	
23 Ilex miti	21-----2-	2222-2-2------	-1-----2----	00111	
32 Prem schi	1----2-2-	----2221-221--	-1-------2-	00111	
18 Ficu ovat	2--------	----------	-1----------	01000	
25 Mill ferr	1----1-2-	---22-2211112-	-11-121-2111	01000	
38 Vern anth	---22---2	-2------222---	2--2--2-----	01000	
15 Crot macr	212222222	2-222222222222	22-22222----	01001	
26 Myte sene	-22222222	222----22222-2	12-2--2-----	001101	CONS.
31 Podo falc	222212-22	22--2222-11-21	22-----2----	001101	
12 Cari spin	222222222	22222-22222---	2-22---2--22	01001	
14 Cord afri	-22-22221	2222----------	2-2-22------	0101	
1 Acac brev	---------	-22--2--------	----------22	011	
13 Celt afri	-----122-	22122222----2-	---------222	011	
20 Ficu syco	---------	-1---11-------	----------21	011	
29 Peri Line	---------	---24232222---	--------223-	011	
17 Domb torr	----22---	22---------22-	2---2--2--2-	100	
22 Grew ferr	------2--	---2----22-2-2	2222-----212	1010	
3 Acac pent	---------	1--1--22--11-2	1111212111--	10110	
16 Domb angu	--2------	------22-2----	222222-2-2--	10111	
19 Ficu sur	---------	---1----2-1---	-11-1-2111--	10111	
28 Olea hoch	------2--	-21--2--------	2--122211121	10111	ASS.2
34 Rhus nata	---------	-------22--22-	222121222231	10111	
5 Acok schi	-----2-22	--1-----1-----	----111121--	110	
7 Andr chin	-----3222	----------	--222-------	110	
8 Bala aegy	---------	----------2-2	22--22222-22	1110	
21 Ficu vast	---------	----------	1--111--11--	1110	
27 Olea euro	---------	----------	2121211-11--	1110	
36 Sygi guin	---------	---2------2---	----2-222222	1110	
11 Cant lact	-----22-1	----------	2--221-222--	1111	
	000000000	00000000000000	111111111111		
	000000000	11111111111111	000000000011		
	000001111	00000011111111	0000000011		
	01111	00011100000111	00001111		
		00111			
	Cluster=1	Cluster=2	Cluster=3		

Key: ASS.1 = Association 1, ASS.2 = Association 2 and CONS. = Constant species

3.3. Species Abundance

Mean abundance values for each species recorded in the four study sites in Magada forest are presented in (Table 4). The result indicated Ifata-Farda site displayed the highest mean values 23.2, followed by Udeyi 20.53, Burqa-Gole20.51 and Bore 20.2. This indicates that Ifata-Farda site has the highest species abundance compared to the others sites. Regarding the overall number of trees and shrubs, Udeyi is the most abundant site with a total number of 849 individuals followed by Burqa-Gole, Ifata-Fard and Bore. In Bore site, the relatively lower number of individuals could be associated with human interference where grazing and browsing by livestock were frequently observed during our expedition. Whereas in Udeyi site with the highest abundance no such activities were observed and relatively it seems less human activities in this part of the forest.

Table 4. *The total abundance and average abundance of trees and shrubs species in the four different sites of study area at Magada forest.*

No	Site of study	Abundance	Mean value	Standard deviation
1	Ifata-Farda	789	23.2	18.1
2	Udey	849	20.53	15.23
3	Burqa- Gole	795	20.51	13.34
4	Bore	744	20.2	12.97

In addition, comparison of abundance was also carried out at family level (Figure 2). The result indicated that family Asteraceae is the most abundant family with 227 individuals, followed by Celastraceae, Apocynaceae and Euphorbiaceae. The 15 families were found to be represented by less than 100 individuals while the least abundant family is family Cuppressaceae with only three individuals.

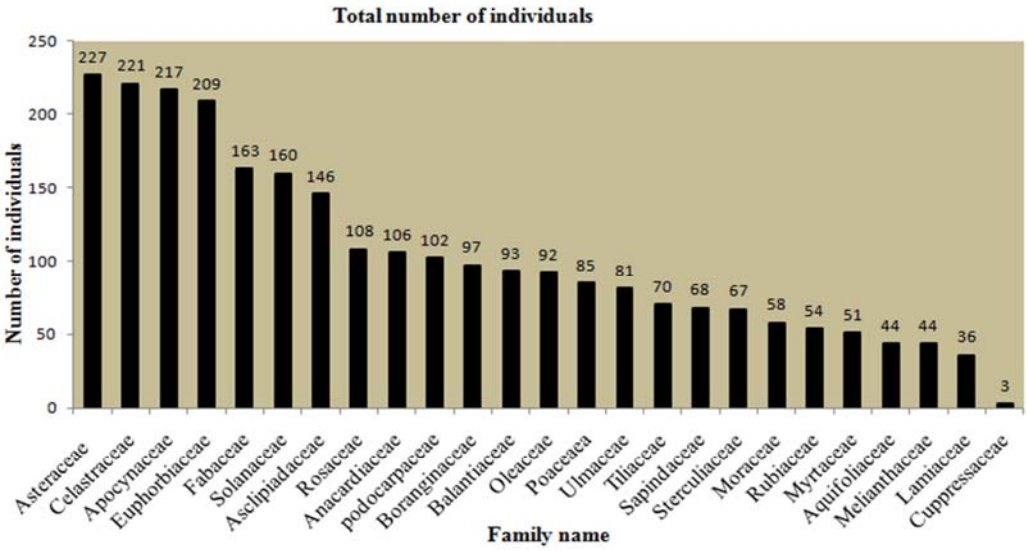

Fig. 2. *The plant families with total number of individuals found in the study area.*

3.4. Species Diversity Analysis

The result of Shannon-Wiener diversity index computed for the four different sites of study area is indicated that the Burqa-Gole site displayed relatively the highest diversity 4.643 of trees and shrubs followed by Bore site 4.493 (Table 5). Although Udeyi site has comparable species richness with Bore diversity index, however, lower diversity compared to both Burqa-Gole and Bore sites 3.957. On the other hand, Ifata-Farda site showed the lowest species richness 32 and diversity index 3.879. This lower value of diversity index could be due to the dominance of only certain trees and shrubs species such as *Croton macrostachyus*, *Mytenus senegalensis*, *Carissa spinarum* and *Podocarpus falcatus*.

Table 5. *Shannon-Wiener diversity index, species richness and evenness of plant communities of trees and shrubs at Magada forest.*

Site of study	Richness	Diversity index (H')	H'max	Relative diversity Index (J)
Ifat-Farda	32	3.879	0.903	0.121
Udeyi	35	3.957	0.954	0.113
Burqa-Gole	37	4.643	1	0.125
Bore	35	4.493	0.903	0.128

A similar study by different researchers such as [1], [6], [10] in different forest in Ethiopia revealed similar results. In general, compared to most of the studies conducted in the country lower species richness and diversity index were recorded for Magada forest. This could be associated to different anthropogenic activities such as selective cutting of economically important trees, grazing and browsing by livestock and other environmental factors. In our survey we were able to observe such activities (figure 3 and figure 4).

Fig. 3. *Cutting of trees for different purposes.*

Fig. 4. *Grazing and browsing by livestock.*

When we consider abundance at species level, *Mytenus senegalensis* was found to be the most abundant shrub species with 221 individuals recorded, followed by *Carissa spinarum, Calpunea aurea, Solanium incanum* with 217, 163 and 160 individuals, respectively. On the other hand, *Croton macrostachyus* was found to be the most abundant trees species with 209 individuals, followed by *Podocarpus falcatus*102, *Cordia africana,* 93 and *Prunus africana* 64 individuals for each respectively.

3.5. Patterns of Species

Principal Component Analysis (PCA) was carried out using abundance data for each species to see if there is any variation in species diversity and vegetation structure patterns among the four sites. The analysis revealed that there were indeed variations in species vegetation structure patterns among the four sites studied. Accordingly, Bore site labeled with red color + sign and Burqa-Gole site labeled by blue color squares sites displayed a clearly demarcated species distribution patterns (figure 5). Whereas, Ifata-Farda and Udeyi sites showed some degree of similarity in distribution pattern for 2 species. This indicates most of the species are not distributed evenly among the four study sites. Even some species were found to be specific for a particular site. This might be associated with environmental aspects.

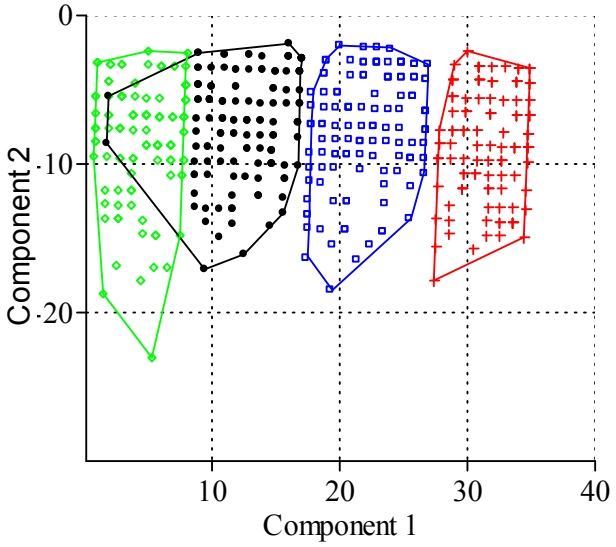

Fig. 5. *PCA plot showing the distribution pattern of each species in four of the study sites (Ifata-Farda= Green color, Udeyi = Black color, Burqa-Gole= Blue Color, and Bore=Red color).*

3.6. Vegetation Structure

3.6.1. Trees Density and Composition

The density of all trees in Magada forest based on DBH (Diameter at Breast Height) greater than 10 cm (a) was found to be 402 individuals per hectare while it was 236 individuals per hectare on DBH greater than 20 cm (b). Similar result on Denkoro forest also reported [7]. In Magada forest the number of individuals per hectare for both DBH classes (DBH>10 and DBH > 20) was high. This indicates the forest is under serious degradation due to human activities such as timber and non-timber production; grazing and browsing of by livestock. The ratio of DBH greater than 10 cm (a) to DBH greater than 20 cm (b) for Magada forest was found to be 1.7. So, this ratio is used as a good indicator as to the status of a particular forest. In this regard, compared many forests, the Magada forest showed a lower ratio (1.7) and is composed of mainly small sized trees and shrubs. Hence, it could be considered as a regenerating forest.

3.6.2. Diameter at Breast Height (DBH)

The Magada forest was further analyzed using DBH (Diameter at Breast Height) to get the vegetation structure of the forest. Based on the DBH values recorded six DBH classes were identified. Thus, DBH class I (10 cm to 20 cm), class II (20.1 cm to 50 cm), class III (50.1 cm to 80 cm), class IV (80.1 cm to 110 cm), class V (110.1 cm to 140 cm), and class VI (greater than 140 cm). The proportion of trees species in different DBH classes of Magada forest was found to be 41%, 40%, 14.67%, 2.54%, 1% and 0.46% for the DBH class I, II, III, IV, V and VI respectively.

The abundance of trees shows a decreasing trend as the DBH class increases from I to VI. The proportion of trees with higher DBH is low, for example the first three lower classes comprise more than 95 % of the trees or shrubs recorded for the analysis. Thus, in Magada forest is composed of large proportion of small-sized trees or shrubs. This indicates that the forest have a good potential for regeneration. Similar reports were made on studies conducted in various forests in Ethiopia [5].

3.6.3. Tree Height

Height measurements were categorized into eight classes (figure 6).That is height class I, 2m to 5m, II, 5.1 m to 10m, III, 10.1 m to 15m,IV, 15.1 m to 20m, V,20.1 m to 25m, VI, 25.1m to 30m, VII, 30.1 m to 35m, and VIII, greater than 35m. Similar to DBH our result indicated that the proportion of trees in each successive class decreases as the height class increases. Thus, 61.25 % of the trees belong to the first two lower height classes (Less than 10 m) and only 1.13% of the trees attain the highest height class (greater than 35 m). These results suggest that the Magada forest is dominated by lower height class individuals. Plotting height class versus proportion of trees produce a reverse J shape curve. Such patterns of vegetation structure commonly referred to as reverse J-shape and it is an indicator of stable population structures. A comparable result at Denkoro forest also reported a similar result where high proportion greater than 65% of trees belong to the lowest height classes and less than 3% of the trees were found to attain high height classes [7]. This might imply that large trees are selectively removed for different purpose including timber and non- timber production, as fuel wood etc. Therefore, proper conservation measures and management intervention need to be in place very soon.

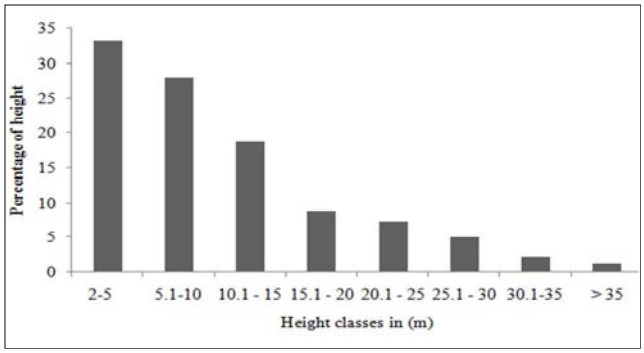

Fig. 6. *Percentage vegetation structure of trees in height classes in (m).*

3.7. Floristic Heterogeneity of Study Area

The frequency obtained could reflect both the pattern of vegetation structure as well as diversity and the number of times of a particular species is recorded in the sample area. In various studies, frequency was used as measure of homogeneity and heterogeneity of given vegetation species. The current result indicated that the most frequently observed tree species is *Croton macrostachyus* with a frequency of 80% (209 individuals) in 28 plots, followed by *Podocarpus falcatus* with a frequency of 65.71% (102 individuals) in 23 plots. Whereas *Juniperus procera* was found to be the least frequent tree species with a frequency of 2.86% (only 3 individuals) in a single plot. The most frequent shrub species is *Carissa spinarum* with a frequency of 71.43% (217 individuals) in 25 plots and followed by *Mytenus senegalensis* with a frequency of 60% (221individuals) in 21 plots, whereas *Zigiphus spina-christi* is the least frequent shrub species with a frequency of 11.43 %(42total number of individuals).

4. Conclusion

In this study about 38 different plant species belonging to 25 different families were recorded. Of these, larger numbers of them were found to be shrubs compared to trees species. *Croton macrostachyus, Podocarpus falcatus* and *Cordia africana* were the dominant tree species. Family Fabaceae is represented by highest species and followed by Moraceae. The result of TWINSPAN revealed two communities both species namely *Bersama abyssinica* and *Solanium incanum*, are indicator species for ("Association 1"), while *Olea europeana* was found to be indicator species for ("Association 2"). Burqa-Gole site displayed the highest species diversity 4.643 whereas Ifata-Farda site displayed the lowest species diversity 3.879 compared to other sites.The forest is composed of large proportion of small-sized plant species which means it has a good potential for regeneration. However, due to frequent disturbance mainly by anthropogenic and other factors, establishing appropriate conservation strategy and participatory management system are recommended.

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