Extended Abstract
Volume 9:7, 2021

Woody species diversity, Regeneration and population structure along altitude gradient in Alemsaga Forest, South Gondar, North Western Ethiopia

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Abstract

AForest ecosystems play a significant role in the biodiversity conservation, in regulating climate protection of hydrological services, and in regulating climate. Poor management of forest that leads the distraction of wood species diversity. The study was carried out to quantify the woody plant diversity and population structure in Alemsaga Forest, South Gondar zone. Collection of vegetation data was made using a systematic sampling method; laying six transect lines with 500 m apart and 54 quadrants 20 m X 20 m established 200 m distance to each other along the transect lines. Abundance, DBH and heights of all woody species were recorded within 400 m2 for trees, 25 m2 for sapling and 1 m2 for seedling. The Shannon-Wiener diversity index was computed to describe the woody species diversity. One way ANOVA was used to test the significance difference of diversity indices along altitude. A total of 66 woody plant species belong to 42 families were identified, which had 2.51±0.28 and 0.94±0.25 mean value of diversity indices and evenness respectively. Both diversity and evenness decreased with increased of altitude. The population structure and regeneration of forest was inverted J shape. This study provides important information about their regeneration status in order to develop management approaches, and protecting threatened and economically important species.

Key word--Forest, population structure, Regeneration status, Species diversity

I. INTRODUCTION

1.1. Background of the Study

Forest is defined as a land having more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ (FAO, 2010). Ethiopia is one of the countries in the world endowed with rich biodiversity due to the variations of climate, which results from its topography and latitudinal position, and which have diverse plant and animals that were found (Girma, 2002). Woody Species diversity generally tends to increasing with decrease of altitude (Brown, 2002).
The geological formations of Ethiopia bring about great geographical diversity which in turn resulted in the formation of different agro ecological conditions that derived to have enriched biodiversity (Taye et al., 1999). However, the rich biodiversity resources in Ethiopia, including forests, are being destroyed at an alarming rate manly affected by human activities. Due to such reasons forest area of Ethiopia has been reduced from 40% a century ago to an estimated of 11.40% today with significantly affected the ecological services (FAO, 2015). Therefore diversity is very important for carbon storage; enhance nutrient availability and socio economic important (Brown, 2002).
Few studies have been conducted to identify the forest resource of the Amhara region of northwest Ethiopia. The forest resources are estimated to cover about 8.2 % of the total area of the region (Mulatie et al. 2011). Such studies proved that the regional forest resource is declining as the population growth and overgrazing pressure increased from day to day.
Alemsaga forest is under pressure of human being and mostly depletion due to agricultural expansion, illegal cutting of tree for charcoal, fuel wood collection and timber. As a result the most important and valuable indigenous tree species are being severely affected in the study forest (Farta woreda Agriculture office, 2017). Therefore, woody species diversity, regeneration status in forest can be affected by altitude, anthropogenic factor (McEwan et al., 2011).
This study is initiated to provide primary information about woody species composition, species diversity, and population structure, regeneration status of Alemsaga forest. Therefore, Poor management system of woody plants that may lead to destruction of species existed in the forest. To act in response to this problem, the study was quantify woody species diversity, population structure, regeneration status, and determines the variation of diversity along altitudinal gradient.

II. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted on Alemesaga forest, Farta woreda, south Gondar zone, Amhara region of northwestern Ethiopia (Figure 1). It is located at 646 km north of Addis Ababa, 82 km east of Bahir Dar city and 20 km west of Debre Tabor town (Farta woreda agricultural office, 2017). The forest covers 780 ha including plantation forest (Enyew Esubalew et al, 2019). The forest has an elevation range between 2100- 2470m and located at 11°54'26"-11°56'12"N and 037°55'31"- 037°57'30"E (Enyew Esubalew et al, 2019). The average annual minimum and maximum are 8.7°C, 20.53°C respectively. The mean monthly temperatures 14.62°C. The agro ecological zone of this forest is moist wenadega. The rainfall pattern is unimodal, which obtain high rainfall from June to August and long term average of 1484 mm (Debre Tabor metrological station, 2018). The soils are reddish brown or brown of clay loam, slit clay and sandy loam texture, and freely draining with predominantly nithosols and leptosol (Enyew Esubalew et al, 2019).

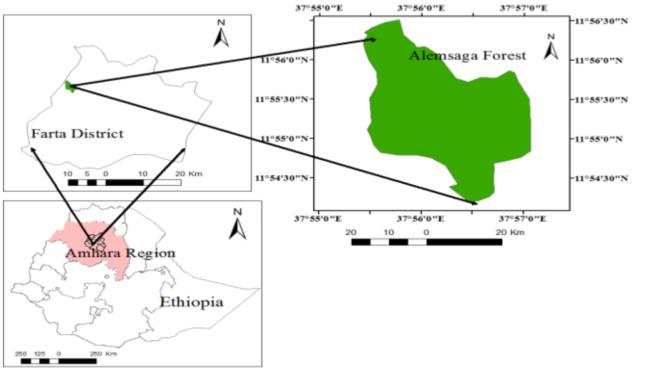

FIGURE 1: Map of Alemsaga Forest, South Gondar, North Western Ethiopia.

2.2. Methods

2.2. 1. Sampling techniques and sampling size

A Stratified systematic sampling technique was employed in this study. The distance between transect line and plots was determined based on vegetation density, spatial heterogeneity of vegetation and size of the forest (Tefera et al., 2005).The transect lines with 500 m difference between each line, which were laid parallel to the slope and, the difference between consecutive plots was 200 m. The first transect line was laid dawn randomly at the edge of northern direction forest started from top mountain to bottom of mountain. Totally, six transects were laid to the different altitude by using the GPS reading system and 54 sample plots were sampled with 19 plots with a range of (2100-2220 m), 21 plots with a range (2221- 2330 m), and 14 plots with the range of (2331-2460 m). The GPS points also that helped to indicate each sample plots (Figure 2).

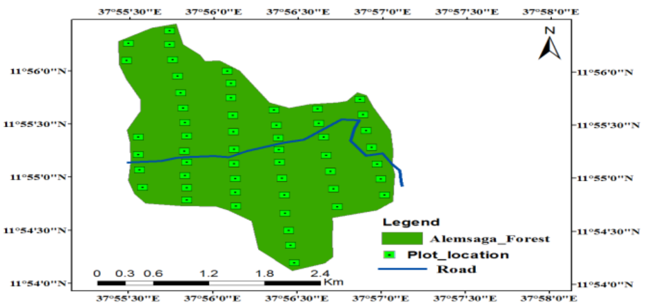

FIGURE 2: Plot Location in Alemsaga Forest, South Gondar, North Western Ethiopia

2.2.3. Vegetation data collection

2. The diameter was measured at breast height (DBH), 1.3 m height from the ground. DBH was measured by using caliper and tree height was measured by using clinometer. Plant identification was done in the field by the knowledge of the local people and using Flora of Ethiopia and Eritrea. All trees and shrubs of woody species were recorded in 20 m X 20 m plots (Figure 3), having ≥ 2 cm DBH and with height ≥ 3 m (Demel, and Granström 1997). In each plot, the number and height of seedlings and saplings were recorded to determine regeneration status of the forest. Sapling was recorded within 5m x 5m subplot at the center of the main plot (Figure 3), and the height of trees/shrubs of between 1m and 3 m were considered as sapling following (Feyera and Demel, 2001). The numbers of all seedlings that are less than 1m height were recorded in five 1m X 1m subplots, one at the center and one at each corner of the main plot to assess the diversity and structure of the tree (Singhal, 1996) (Figure 3). **3. Data analysis**

2.3.1. Measurement of species diversity

In this study, the Shannon-Wiener diversity index (H), species richness and Shannon evenness were computed to describe the species diversity of the woody plant (Shannon and Wiener, 1949).

$$H = -\sum pi \ln Pi \ldots\ldots \text{(1)}$$

Where; H: Shannon-Wiener Index

Pi: proportion of individual tree species

$$\text{Evenness} = \frac{H'}{H\ max} \ldots\ldots \text{(2)}$$

Where H'= Shannon diversity indices,

H max = is the maximum level of diversity possible within a given population, which equals lnS (ln number of species).

S= the number of species

2.3.2. Vegetation structure of woody species

The structural analysis of the vegetation was also described by using the following components:

$$\text{Relative density} = \frac{\text{Density of species A}}{\text{Total density of all species}} \times 100 \ldots\ldots \text{(3)}$$

$$\text{Relative frequency} = \frac{\text{Frequency of species A}}{\text{Frequency of all species}} \times 100 \ldots\ldots \text{(4)}$$

The basal area of the woody species was calculated by using DBH (Kent and Cooker, 1992).

$$\text{Basal Area} = \Pi\,(\text{DBH})^2/4 \ldots\ldots \text{(5)}$$

Where; d=diameter at breast height, π= 3.14

Dominance: It is the mean basal area per species time's

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number of the species.
Relative dominance (RDO): It is a basal area of a species x100………………….. ….(6)
Total basal area of all species
Important values index (IVI) = relative dominance (RDO) + relative density (RD) + relative Frequency (RF) (Kent and Coker, 1992). ……………………………… …………(7)
DBH and height class distribution were analyzed grouped into diameter classes and height classes, five DBH classes (i.e. 1= 2-10, 2= 10.1-20, 3= 20.1-30, 4=30.1-40, 5= >40 cm) and height class (i.e.1 = 2- 10, 2=11-20, 3= 21-30, 4= 31-40, 5= >40 m (Kitessa *et al*., 2007).

2.3.3. Regeneration status of woody species
The regeneration status of woody species was determined based on the total count of seedlings and saplings of each species across all quadrants. The regeneration status of the forest was assessed using the following categories. Good, if the presence of mature <sapling < seedling, fair, if mature >seedling > sapling, poor, if species survive only sapling stage, and none, if the mature species only survive (Chauhan *et al*., 2008).

2.4. Statistical Analysis
The significance of species diversity was analyzed by using Statistical Package for Social Science (SPSS) software version 20. The relationship between each parameter was tested by descriptive statistics such as mean, standard deviation, minimum and maximum value. The significant difference of woody plant diversity along altitude at 5% of the level of significance tested by one way ANOVA, and Gabriel post-hoc test for multiple comparisons was used.

III. RESULTS AND DISCUSSIONS

3.1. Woody species composition
A total of 66 woody plant species, of which 46.98 tree species, 45.46% shrubs and 7.56%) climbers representing 42 families were identified and recorded. The forest has lower number of species as compared to other dry Afromontane forest like Gedo Forest with 130 species in West Shewa (Birhanu, 2010); Menagesha Saba State Forest with 82 species (Abate, 2007) and Abebaye and Tara Gedam Forest with 143 (Haileab *et al*. 2006), but a higher number of species than Denkoro Forest with 64 species located in Wello (Abate, 2003); Jibat Forest with 54 species (Tamrat, 1994); and Ambo State Forest with 58 species by (Solomon and Belayneh, 2017). The reasons for these differences may be due to forest size; anthropogenic influences and environmental factor have a strong impact on species composition and density (Espinosa and Cabrera, 2011).
Fabaceae was the dominant family which had seven (16.66%) species. Of all the families, similar studies by Solomon and Belayneh (2017) in the Ambo state forest, Erimas (2011) in Belete Forest, and (Haileab *et al*., 2006) in Tara Gedam Forest also showed the dominance of the Fabaceae family respectively. This dominance might be attributed to the adaptation potential of Fabaceae species to varying agro ecologies, and probably due to having efficient pollination and successful seed dispersal mechanisms (Ensermu and Teshome, 2008).

3.2. Species diversity and evenness
The overall average Shannon Weiner diversity indices (H) and the average evenness (E) value for the study forest were 2.51±0.28 and 0.94±0.25, respectively, which is less than in the Ambo forest (H =2.7) (Solomon and Belayneh, 2017), Tara Gedam forest (H =2.9) and greater than Abebaye (1.31) (Haileab *et al*., 2011). The Shannon Weiner diversity index is high when it is above 3.0, medium when it is between 2.0 and 3.0, low between 1.0 and 2.0, and very low when it is smaller than 1.0 (Cavalcanti and Larrazabal, 2004). The value species evenness was between 0 and 1, while the value is close to one the most abundant of all species equally distribute in a given area, but close to 0 completed disproportional or single species were dominated.
The study forest had medium Shannon diversity indices, because of the value were found between 2.0 and 3.0 and most of them were evenly distributed except a few of the dominant species in the higher elevation class. The medium Shannon diversity indices of the forest might be due to illegal harvesting for fuel wood, construction for house, timber and clearing of shrubs/trees for agriculture. The distribution of a few dominant species in the higher elevation class in the study forest was due to human interferences, livestock trampling and grazing, and slope and altitudinal differences. This agrees to work of (Abate, 2007).

3.3. Woody Species diversity and evenness variation along altitude gradient
The highest Shannon diversity indices were estimated in the lower altitude class. The diversity of woody plant species was highly significant along altitude gradient ($p<0.05$) (Table 1). The present study finding is in line with Brown (2002). The major decline in species richness and diversity in higher altitude is due to eco-physiological constraints, such as reduced growing season, decreases of temperature and ecosystem production (Gerytnes and Vetaas, 2002).Since, the decreases of temperature increase of altitude, reduced the activity of microorganisms, also availability of nutrient decrease, then reduced density as well as diversity at higher elevation. Mountains can be represented as rocky material that declines the colonization of woody species. In addition; disturbance may also have an influence on the woody species diversity at high elevations, because of the light loving herbs, grass and some shrubs easily grow and colonize the area, then reduced the woody species.
As elevation increases, the isolation of slopes also increases linearly. Therefore, stream available can be reduced, moisture availability also decreases, so a reduction the abundance of species that occupy in the higher elevation. Moreover, as the elevation increases, the range of the elevation band with certain set of ecological and climatic conditions decreases (Colwell and Lees, 2000). This may be one of the causes for the reduction of diversity at higher elevation in Alemsaga forest.

TABLE 1
THE MEAN ± STANDARD DEVIATION (SD) SHANNON DIVERSITY INDICES ALONG ALTITUDE GRADIENT IN

ALEMSAGA FOREST, SOUTH GONDAR, NORTH WESTERN ETHIOPIA.

Altitude	Shannon diversity indices
Lower	2.75±0.25a
Middle	2.47±0.25b
Higher	2.24±0.14c
P value	0.00

The different letter in the same column indicates that the mean value was significant ($p < 0.05$).

3.4. Species evenness variation along altitude gradient

The highest species evenness was estimated in the lower altitude class. The species evenness also showed significant differences ($p < 0.05$) along an altitude gradient (Table 2). This being due to the presences adequate of channel availability, dispersal seeds through runoff and favorability environmental condition in lower altitude class and herbs and grass easily colonize in upper altitude. The area having low species evenness is the presences of a single species with high relative abundance and the variation of species evenness determined through the spatial difference in the abundance of the dominant species (Cerabolini *et al*. 2010).

In the higher elevation, there was a significant difference of species evenness as compared to lower and middle mean value of evenness, which indicates that single species, was dominant in the community. This might be species competition of nutrient, temperature, moisture and seed dispersal results unbalanced distribution of species. A low evenness value means that there is the dominance of single species in the community, while, higher evenness means that, there is equal distribution of the species in specific area, establishment that of individuals are well spread (Cavalcanti and Larrazabal, 2004).

Table 2

THE MEAN ± STANDARD DEVIATION (SD) SHANNON EVENNESS ALONG ALTITUDE GRADIENT IN ALEMSAGA FOREST, SOUTH GONDAR, NORTH WESTERN ETHIOPIA.

Altitude	Shannon Evenness
Lower	0.95±0.02a
Middle	0.94±0.03a
Higher	0.92±0.02b
P value	0.01

The different letter in the same column indicates that the mean value was significant ($p < 0.05$).

3.5. Vegetation Structure of Woody Species

3.5.1. DBH class distributions

The diameter distribution of study forest is an inverted J shape which indicates as the vegetation is in good regeneration and recruitment status (Figure 4). The present study finding is in line with Haile et al., (2008).

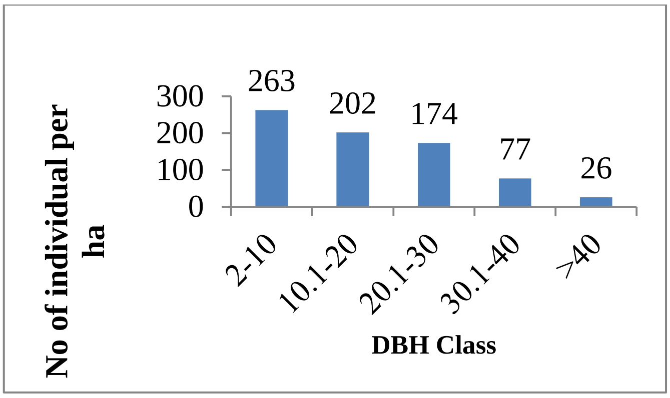
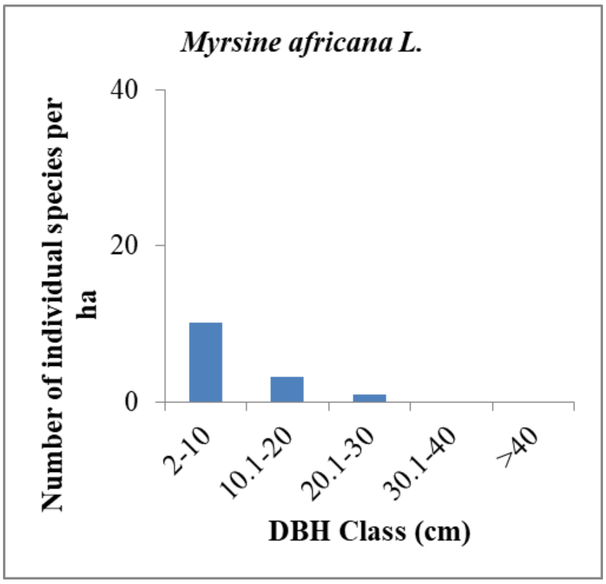
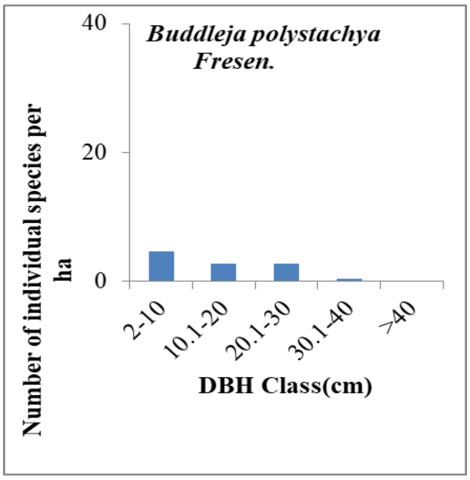
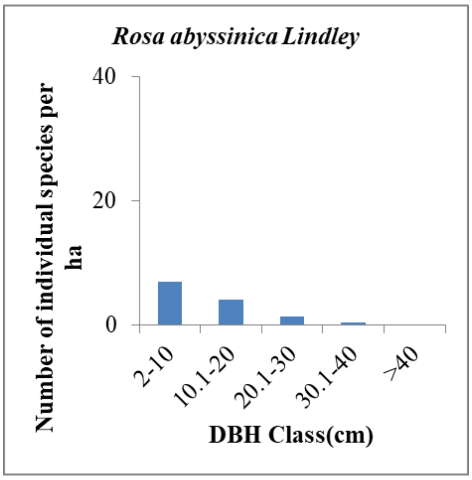


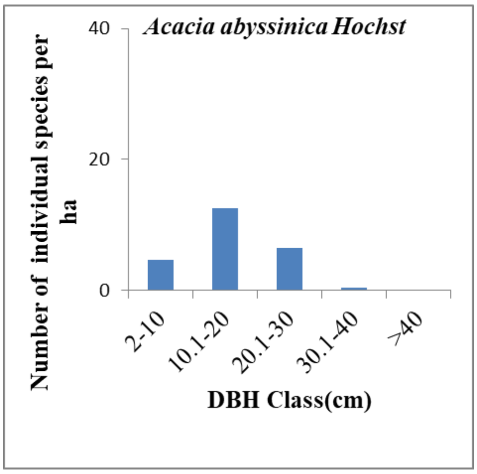
FIGURE 4: **The Diameter Class Distribution of Tree/Shrubs In Alemsaga Forest South Gondar, Northern Western Ethiopia.**

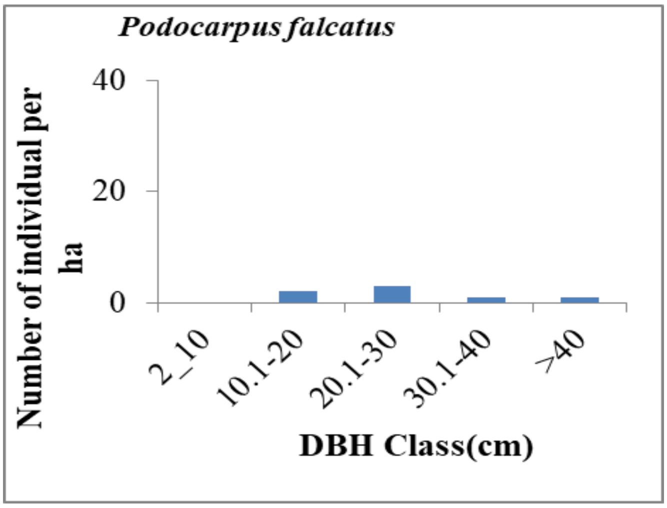
The DBH class distributions of the most important woody species having higher important value index values(IVI) the study forest *were Premna schimperi, Buddleja polystachya, Rosa abyssinica Lindley, and Myrsine africana were the most abundant* in the lowest diameter class which suggests that they had good regeneration potential, but some species such as *Acacia abyssinica, Acacia pilispina,Cordia african, Ficus vasta Forssk, Myrisine salicifolia* and Prunus africana were higher in the middle diameter classes (Figure 5). Bell shape distribution formed when a higher number of individual concentrated in the middle diameter class, this indicates the influences of grazing animal on seedling and large size or old trees were cut for fuel and charcoal production (Figure 5). Analysis of the population structure of woody plants has been used to provide an estimate about the status of regeneration of species (Swamy *et al.,* 2001; Tefera *et al.,* 2005). Therefore, seedling is very important for the establishment of new individuals to replace the old trees to provide sustainability of natural forest.

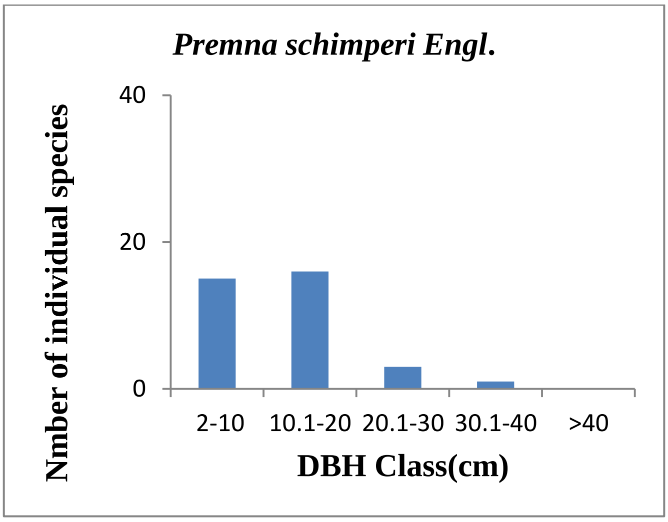


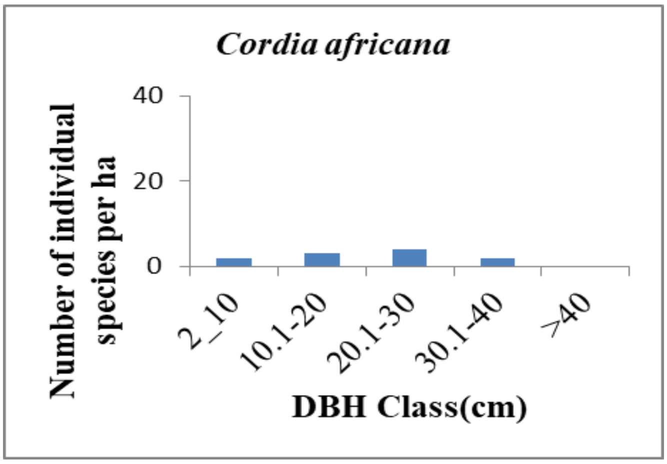

Buddleja polystachya Fresen.
40
20
0
Number of individual species per ha
2-10
10.1-20
20.1-30
30.1-40
>40
DBH Class(cm)


Rosa abyssinica Lindley
40
20
0
Number of individual species per ha
2-10
10.1-20
20.1-30
30.1-40
>40
DBH Class(cm)


Acacia abyssinica Hochst
40
20
0
Number of individual species per ha
2-10
10.1-20
20.1-30
30.1-40
>40
DBH Class(cm)


Podocarpus falcatus
40
20
0
Number of individual per ha
2_10
10.1-20
20.1-30
30.1-40
>40
DBH Class(cm)


Premna schimperi Engl.
40
20
0
Nmber of individual species
2-10
10.1-20
20.1-30
30.1-40
>40
DBH Class(cm)


Cordia africana
40
20
0
Number of individual species per ha
2_10
10.1-20
20.1-30
30.1-40
>40
DBH Class(cm)

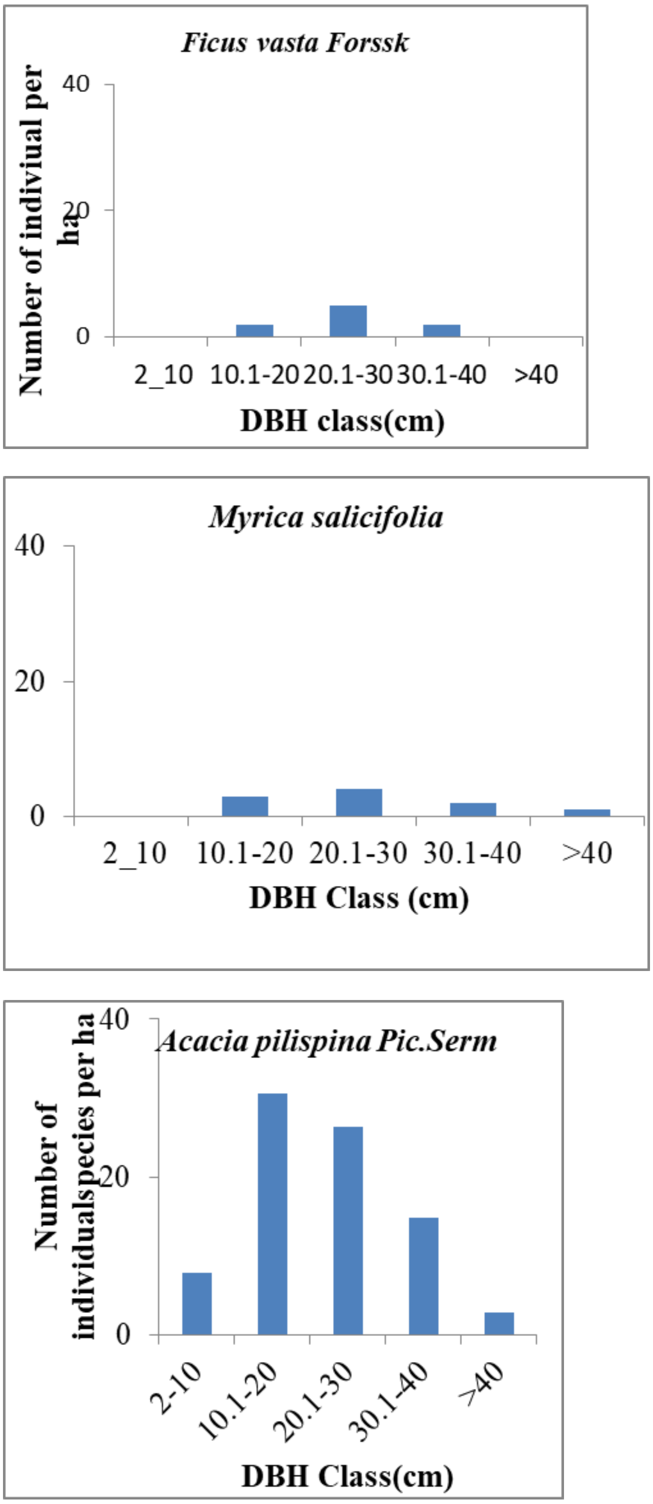


FIGURE 5: The DBH Class Distributions of Woody Species Having Higher Important Value Index in Alemsaga Forest, South Gondar, North Western Ethiopia.

3.5.2. Height distribution of woody species

The lower height class was higher frequent species, and then the structure of tree height was inverted J shape (Eigure 6). It might be due to the selective removal of mature trees. This result was similar with the finding of Abate (2007), and Birhanu (2010). Fekadu (2010) also stated that the density decreasing with increasing height could be attributed that high good reproduction. The dominance of small trees and shrubs in the forest indicates that the big tree species are selectively removed (Feyera and Demel, 2003).

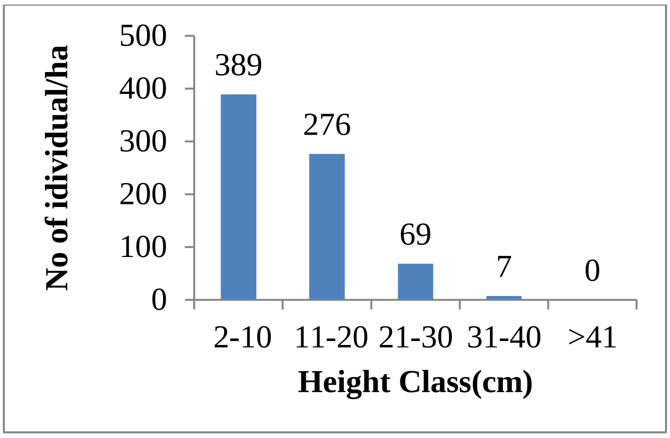


FIGURE 6: Height Distribution Class Of Tree/Shrubs In Alemsaga Forest, South Gondar, North Western Ethiopia.

3.5.3. Basal area of woody species

The total basal area of woody species in Alemsaga forest was 27.9 m^2/ha. The species with the highest basal area was *Juniperus procera* L (5.06 m^2/ha), followed by *Acacia pilispina* Pic.Serm (4.16 m^2/ha), *Croton macrostachyus* Del (3.42 m^2/ha) (Table 3). This result indicates that these three species were the most ecological significant of woody species in the study forest. Few species only had high basal area, but most species had a small basal area due to dominantly small size trees in the study forest. The reason of the small basal area was illegal and selective removal of large trees for fuel wood, timber and for construction in the local community. Basal area indicates that a key measurement of the status of the species than simple stem count (Fekadu, 2010). Hence, species which having great basal area can be reflected the most essential woody species in the study forest (Table 3).

TABLE 3

THE HIGHEST BASAL AREA OF WOODY PLANT SPECIES IN ALEMSAGA FOREST, SOUTH GONDAR, NORTH WESTERN ETHIOPIA

No	Scientific Name	Family	name Basal Area(m2/ha/)
1	Olea europaea	Oleaceae	0.99
2	Eucalyptus camaldulensis	Myrtaceae	1.69
3	Eucalyptus globulos	Myrtaceae	2.08
4	Albizia schimperiana	Fabaceae	2.30
5	Croton macrostachyus Del.	Euphorbiaceae	

	3.42		
6	Acacia pilispina Pic.Serm	Fabaceae	4.18
7	Juniperus procera L.	Cuppressaceae	5.06

3.5.4. Species Importance Value index (IVI)
Woody species which having highest IVI are those that exist in the greatest number or sizes of species that may have the greatest effect on the community. The IVI values can be used as an input for conservation strategies to protect woody species against anthropogenic factors (Shibru, 2002). The result indicates that the species having small IVI value would be focused for maintenance. It is an important index for brief explains vegetation characteristics, ranking species and conservation practices (Kent and Coker 1992). On the other hand, it indicates that the degree of abundance and dominance of a given species in the study forest (Table 4).

TABLE 4
RELATIVE FREQUENCY (RF), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDO) AND IMPORTANT VALUE INDEX (IVI) IN ALEMSAGA FOREST, SOUTH GONDAR, NORTH WESTERN ETHIOPIA.

NO	Scientific Name	RF (%)	RD (%)	RDO (%)	IVI(%)
1	Allophylus abyssinicus	4.02	3.50	2.57	10.08
2	Eucalyptus globulos	1.56	2.50	7.46	11.53
3	Osyris quadripartitaDec	6.03	5.06	0.91	12.00
4	Carissa edulis(Forssk.) vahl	6.70	9.93	1.68	18.31
5	Albizia schimperiana	4.91	5.56	8.35	18.82
6	Dodonaea angustifolia L.f.	8.48	11.06	1.72	21.26
7	Croton macrostachyus Del.	7.81	8.93	12.43	29.18
8	Juniperus procera L.	3.79	9.75	18.36	31.90
9	Acacia pilispina Pic.Serm	6.47	11.18	15.17	32.83

3.6. Regeneration of Woody Plant Species in Alemsaga Forest
The composition and density of seedlings and saplings indicate the regeneration status of study forest. The total density of mature tree/shrub, sapling and seedling of Alemsaga forest was 750 individuals per ha, 4480 individuals per ha and 7600 per ha respectively. The population structure characterized by the presence of sufficient population of seedlings, saplings and mature, indicates successful regeneration of forest species and the presence of saplings under the canopies of adult trees also indicates the future composition of a community. Regeneration status of trees can be predicted by the age structure of their populations. The regeneration of most tree or shrub species is fairly good because seedlings and saplings are much greater than the mature trees.
The highest seedling and sapling density species count per hectare were Carissa edulis, Dodonaea angustifolia, and Clutia abyssinica, good seedling density Croton macrostachyus, Juniperus procera. Acacia pilispina and species which have poor seedling density counts were Allophylus abyssinicus, Schefflera abyssinica, and Olea europaea (Figure 5). Some species had no seedling such as Podocarpus falcatus, Cordia africana, Ficus vasta Forssk, and Myrica salicifolia (Figure 5). This may be due to the selective cutting by humans, tramping and browsing effect of animals in the study area.
According to Taye et al. (2002), a tree species with no seedling and sapling in natural forest is under risky condition and it is suggested that these species are under threat of local extinction. Generally, good regeneration was observed for bush/Shrub species than trees, since trees were cutting more economical important and unpalatable through animal, so provide adequate seedling their reproduction. The study of the regeneration of forest trees has important implications for the management of natural forests.

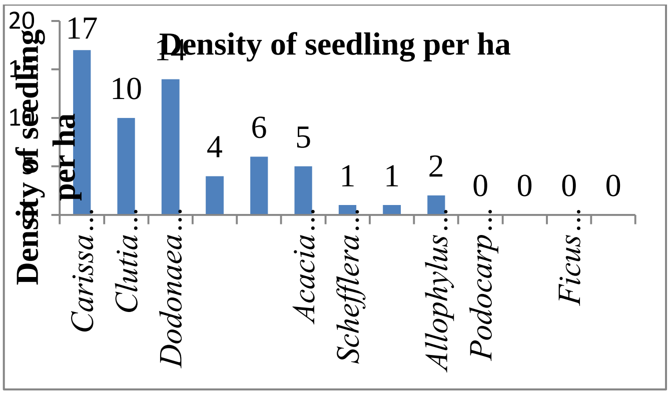


FIGURE 5: Seedling Density of Some Selected Species Shrub In Alemsaga Forest, South Gondar, North Western Ethiopia.

IV. CONCLUSIONS AND RECOMMANDETIONS

The study forest has medium Shannon diversity indices (2.51±0.28) and most of them were evenly distributed except few of the dominant species in the higher elevation class, which has less diversity as compared to most dry Afromontane forest due to week management. The analysis of population structure in the forest indicates that some tree species have no or few individuals at a lower size classes. These species need urgent conservation measures that would bring healthy regeneration. As the altitude increase the diversity and evenness of species decrease, which might be due to the dependence of the local societies for collecting fuel wood, charcoal production, bee forage and edible fruits, construction materials and grazing. Therefore, proper protection and management of woody species are very important for conservation of biodiversity. Research and development activities are necessary to enhance regeneration of the species, which having small IVI and low regeneration status. Generally, the present study can contribute towards the understanding of woody species diversity, population structure, and regeneration status, further study on soil seed bank, ethno-botanical, and land use and land cover changes is important.

ACKNOWLEDGEMENTS

Firstly, I would like to thank the Almighty GOD for giving me health and supplying strength to work. I would like to extend my deep thankfulness to the Ministry of Education Ethiopia for giving an opportunity for this study and supported finance. I am grateful to the staff members of the College of Dry land Agriculture and Natural resources finance and I would like to thank very much the Land Resources Management and Environmental Protection staff members for facilitating this research and their cooperation in all aspects of the research development.

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