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Status and Species Diversity of Alemsaga Forest, Northwestern Ethiopia

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Abstract
The study was conducted on Alemsaga Forest in South Gondar, northwestern Ethiopia with the objectives of determining the status & diversity of plant species. Systematically 58 (20 m × 20 m) plots were sampled along line transects radiating from the peak of the Forest in north-south directions. In each main pots, five subplots (2 m x 2 m) distributed one at each corner and one at the center were laid down to sample herbaceous species. All plots were laid at a distance of 100 m along the transect lines. In each main plot, data on species abundance, height and Diameter at Breast Height (DBH) of woody plant species and altitude, slope and aspect were recorded. Community classification was performed using R-Free Statistical Software. Shannon-Wiener diversity index were used to compute species diversity between the plant communities. Structure of the forest was analyzed using DBH, basal area and IVI. Results showed that a total of 124 vascular plant species representing 112 genera and 65 families were identified. Asteraceae followed by Fabceae, Malvaceae and Poaceae were the most species rich families. Based on the results of vegetation classification, three plant communities were identified and described. Species richness, diversity and evenness varied among the plant communities. Tukey's pairwise comparison of means among the plant communities showed significant variations in aspect and slope, implying that these terrain variables are among important factors determining patterns of plant community distribution. Results of structural analysis revealed that the Forest was dominated by small sized trees & shrubs indicating that it is in the stage of secondary development and there are species that require urgent conservation measure. Based on the results of this study, future research directions and appropriate conservation measures for sustainable use of the forest resources are suggested.
Keywords: Diversity, plant community, Alemsaga Forest, sustainable use of forest

INTRODUCTION

Unique geological formation of Ethiopia resulted great geographical diversity which in turn resulted in the formation of diverse ecological conditions that helped to have rich biodiversity (Taye Bekele *et al*., 1999). Previous studies (Taye Bekele *et al.,* 1999, Zerihun Woldu, 1999; Anonymous, 2009) justified that the richness in biodiversity is the reflection of diverse ecological settings, climate & topography in the country. Thus, the flora of Ethiopia is estimated to possesses about 6000 species of higher plants, of which about 10% are endemic (Ensermu Kelbessa *et al.,* 1992).

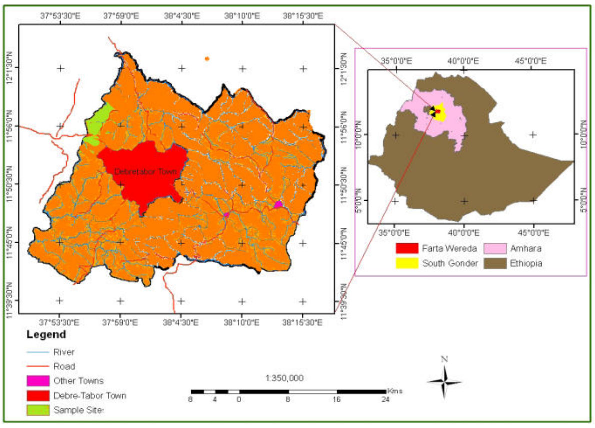
However, the rich biodiversity resources, including Forests, are being destroyed at an alarming rate largely due to human related disturbances (Anonymous, 2009). Population growth in highlands exerts great pressure on the natural Forests. As a result, northwestern highlands of Ethiopia have only fragments of natural Forests scattered & confined to inaccessible and sacred places (Alemayehu Wassie *et al*., 2005),which suggested that the highlands were once covered by high Forests (White, 1983). Large areas show severe land degradation and erosion (Darbyshire *et al*., 2003). Therefore, appropriate and immediate measures are required to maintain and restore the remaining natural Forests.

Studies on plant communities help to design appropriate conservation measures. Plant communities show spatial and temporal variations across landscapes. Environmental gradient analysis provides the underlying causes for the pattern and distribution of plant communities. Thus, the evaluation of variation of environmental variables is essential to understand the factors governing the distribution of species (Getachew Tesfaye *et al*., 2008). Besides, examination of patterns of population structures could provide valuable information about their regeneration and recruitment status that could be further employed for devising conservation strategies (Demel Teketay, 2005). Previous studies with due attention on plant community analysis (Tamrat Bekele, 1994; Tadesse Woldemariam, 2003; Teshome Soromessa *et al*., 2004; Teshome Soromessa and Ensermu Kelbessa, 2013a; Teshome Soromessa and Ensermu Kelbessa, 2013b; Teshome Soromessa and Ensermu Kelbessa, 2014; Desalegn Wana and Zerihun Woldu, 2005; Feyera Senbeta, 2006; Motuma Didita *et al*., 2010), demonstrated variations in the patterns of plant communities with variation in environmental variables. The results of these works provide relevant information, which is of paramount importance to undertake appropriate conservation and management measures. Despite these, studies on the ecology and flora of the Alemsaga vegetation are lacking. Therefore the objectives of the present study were to: (a) define plant community types, (b) compare species richness and diversity among different plant communities, (c) identify the factors that determine patterns of plant community formation, (d) describe the population structure of woody plant species and (e) suggest appropriate conservation measures.

MATERIALS AND METHODS

Study area

Farta is one of the districts in South Gonder, Northwestern Ethiopia. Debre-Tabor is the center of the district (Fig. 1) located at about 666 km north of Addis Ababa. The Altitudinal ranges of Farta vary from 1970 to 4135m.



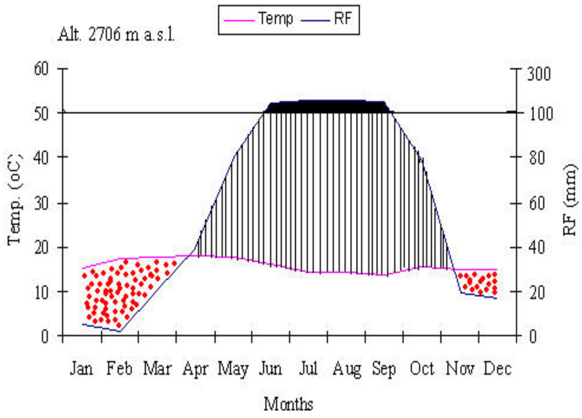


Fig. 1 Location Map of the study area Fig. 2 Climadiagram of Debre-Tabor Station

The average annual minimum, maximum and mean temperatures are 9.54^0C, 22.11^0C and 15.8^0C respectively (Fig. 2) The rainfall pattern is unimodal, stretching from May to September with the maximum rain from June to August having annual range between 1097 & 1954 mm & a long term average of 1448 mm (Fig. 2). The topography comprises uneven & ragged mountainous highlands, extensive plains & deep gorges.

Alemsaga Forest is established in the western edge of Farta district. The Forest is surrounded by five churches which create good opportunity for the protection of the Forest. The area is protected starting from 1978 with the objectives of providing seed source, conserving the remnant natural Forests and rehabilitating the degraded area. The Forest has elevation range between 2180- 2470 & located at $11^o54'$-$11^o56'$N & $037^o55'$-$037^o57'$E. During the civil war (1990-92) the area were converted in to pasture and farm lands. After political stability of the country the area was re-protected as Forest area. At present the Forest area is about 814 hectare including plantation around the edges of the Forest (communication with Farta district Agricultural Office)**.**

Vegetation sampling

Field data were collected from August 15 to September 15, 2013. Data were collected in sample plots placed in transect lines. Eight line transects were established following north-south orientation & with 100 m distance between them. At every 50 m drop in altitude, plots with sizes of 20 x 20 m were laid down along the line transects. A total of 58 plots were laid along transect lines. All mature woody plant species were recorded in 20 X 20 m plots while herbaceous species were recorded in five 2 X 2 m subplots distributed one at the center & one at each corner of the main plot. Diameter at breast height (DBH) was measured for any woody plant species with height ≥ 3 m and DBH ≥ 2 cm (Demel Teketay, and Granström 1997). DBH measurement was made using diameter tape. Altitude and geographical co-ordinates were measured for each plot using Garmin GPS. Slope and aspect were measured using Suunto Clinometer and Compass respectively. Plant species 10-15 m outside the study plots were also recorded to prepare a complete list of plants. Using local names species were recorded, herbarium specimens prepared & identified in the National Herbarium of Addis Ababa University using Flora of Ethiopia and Eritrea.

Data analysis

Hierarchical cluster analysis was performed using R-free statistical software to identify plant communities. Classification analysis was based on the abundance of 102 species recorded within 58 sample plots. The resemblance function used for plots grouping was a similarity ratio and the ward's method was used in order to minimize the total within group mean square or residuals of squares (van Tongeren, 1995). The community types identified from the cluster analysis where further refined in a synoptic table and species occurrences were summarized as a synoptic-cover abundance values. Synoptic values are the product of the species' frequency and average cover abundance value (van der Maarel *et al.,* 1987 cited in Tamrat Bekele, 1993). Dominant species of each community types were identified based on their synoptic value. Diversity of the communities was computed using Shannon-Weiner diversity index. To examine the significance of environmental variables in determining patterns of community formation Tukey's honestly significant difference (Tukey's HSD) test has been used. It was used in conjunction with an ANOVA to find means that are significantly different from each other (Zerihun Woldu, 2012). For the description of vegetation structure, DBH, basal area (BA) and importance value index (IVI) were used. Woody species basal area & density were computed on hectare basis. IVI = relative frequency (RF) + relative density (RD) + relative dominance (RDO) (relative basal area) (RF) where, RF = the number of plots where a species occurs/ the total occurrence of all species in all of the plots × 100; RD = the number of all individuals of a species/ the total number of all individuals x100; RDO = the basal area of a species/total basal area × 100 (DBH ≥ 2 cm).

$$D = \frac{\text{Number above ground stems of species couuntered}}{\text{Sampled area in hectare}}$$

Where: d = diameter at breast height in meter, π = 3.14

RESULTS

Floristic composition

A total 124 vascular plant species, belonging to 112 genera and 65 families were recorded from the vegetation (Appendix 1). The collected species were composed of 42% trees, 29% shrubs 29% herbs. The dominant families were Asteraceae represented by nine, Fabaceae by eight, Malvaceae by six & Poaceae by five species respectively. Endemic species (seven) accounted for 5.6% of the total species composition of the Forest (Table 1).

Table 1. Table list of endemic species

Species	Family	Habit
Acanthus sennii,	Acanthaceae	Shrub
Lippia adoensis	Verbenaceae	Shrub
Milletia ferruginea	Fabaceae	Tree
Rhus glutinosa	Anacardiaceae	Tree
Trifolium schimperi	Fabaceae	Herb
Verbascum stelarum	Scrophularaceae	Herb
Vipris dainielli	Rutaceae	Tree

Plant community types

Three plant community types were identified from the hierarchical cluster analysis (Fig. 3). Description of plant communities is given below.

***Maytenus arbutifola-Bersama abyssinica* Community (C1)**

This community type was distributed between the altitudinal ranges 2230-2430 m. The community was found in slightly steep slope (21.7%) facing largely towards north (45.5%). The community was represented by 17 plots and 85 species. Along with dominant species used to name the community *Maytenus arbutifola, Bersama abyssinica, Albizia schimperiana, Buddleja polystachya*, and *Grewia ferruginea* were dominant trees species. *Calpurnia aurea and Ocimum lamifolia were* among the dominant species in the shrub layer. The herb layer was dominated by *Bidens pilosa, Impatiens tinctoria & Leptochloa rupestris* (Table 2). The common climber was *Embelia schimperi. Albizia schimperiana* were emergent tree species. Most plots were relatively far from human encroachment contributing to high species diversity & richness.

***Acanthus sennii-Vernonia myriantha* Community (C2)**

This community was located in narrow altitudinal ranges between 2330-2380 m in a gentle slope (average 20%) facing largely towards north (50%). Six plots and fifty nine species were associated. The community was represented by least numbers of plots and species. *Croton macrostachus*, *Olinia rochetiana, Acalypha psilostachya* and *Hibiscus macranthus* were dominant in the tree-shrub layer. *Bidens carinata* was the dominant species in the ground flora. Moreover, dominant climbers were *Rosa abyssinica* and *Asparagus africanus. Croton macrostachus* were emergent tree species (Table 2).

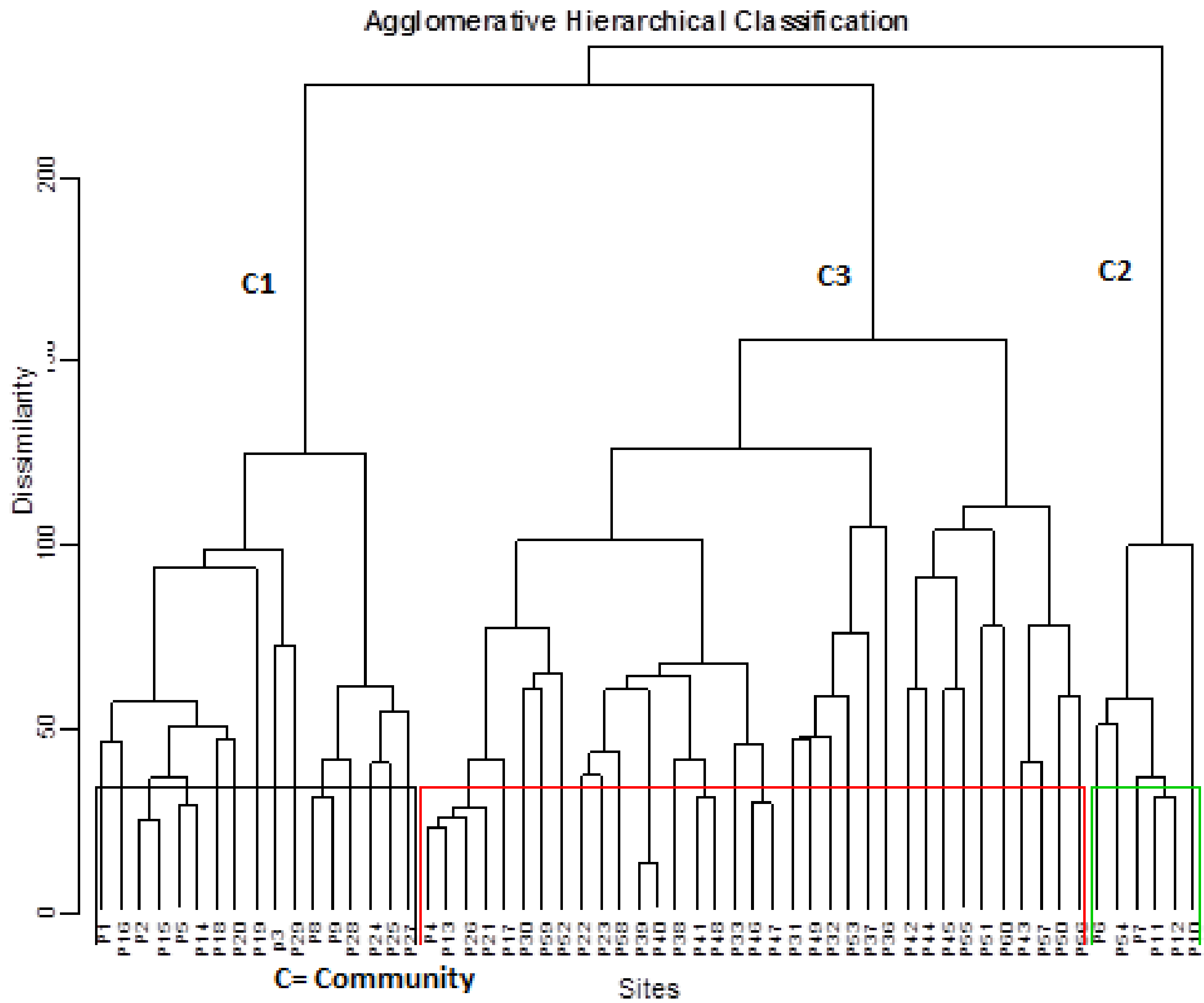


Fig. 3 Dendrogram output of the vegetation data

***Dodonaea angustifolia-Clutia abyssinica* community (C3)**

This community was found in a wide altitudinal range between 2180-2430 m distributed in large number of plots (36) & 84 species were associated in the group. Plots representing the community were dispersed in a steep slope (average 31.1%) largely facing towards south (43.3%) and southwest (40%). *Carissa spinarum*, *Rhus glutinosa, Lippia adoensis, Grewia ferruginea, Combretum molle* and *Vernonia bipontinii* were among the dominant species in the tree-shrub layer.

This community was not rich in herbaceous species composition & relatively common herbaceous species were *Guizotia scabra, Anethum graveolens* and *Cyanotis barbata. Jasminum grandiflorum* and *Clematis simensis* were common climbers of the community. The two ferns, *Adianthum Poiretii* & *Dryopteris schimperiana* were found in considerable number plots of the community.

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Table 2. Synoptic abundance value for species having value > 1 in at least one community type and values in bold refer to characteristic species

Species	C1	C2	C3
Maytenus arbutifola	**36.95**	20.67	12.70
Bersama abyssinica	**11.59**	**4.00**	**5.83**
Nuxia congesta	**7.64**	**4.83**	0.90
Ocimum lamifolium	**6.91**	**4.00**	**3.90**
Albizia schimperiana	**4.05**	**3.50**	**1.47**
Calpurnia aurea	**3.45**	0.83	**2.90**
Bidens pilosa	**3.09**	**1.17**	0.67
Grewia ferruginea	**2.32**	**1.33**	**8.87**
Leptochloa rupestris	**1.95**	**2.00**	**1.20**
Buddleja polystachya	**1.64**	0.00	**1.20**
Periscaria nepalense	**1.18**	0.00	0.67
Impatiens tinctoria	**1.09**	0.33	0.00
Embelia schimperi	**1.00**	0.00	0.00
Acanthus sennii	11.55	**97.00**	10.97
Vernonia myriantha	**5.82**	**11.17**	**1.43**
Bidens carinata	**4.45**	**5.50**	**4.00**
Rosa abyssinica	**2.00**	**2.83**	**2.10**
Croton macrostachus	**2.82**	**2.83**	**1.50**
Acalypha psilostachya	0.36	**2.50**	0.20
Asparagus africanus	0.55	**1.83**	0.60
Pterolobium stellatum	**1.36**	**1.83**	**1.57**
Hibiscus macranthus	0.00	**1.67**	0.00
Olinia rochetiana	0.95	**1.33**	0.00
Dodonaea angustifolia	1.82	**1.16**	**28.06**
Clutia abyssinica	9.14	10.17	**24.80**
Clausena anisata	12.59	10.67	**13.83**
Carissa spinarum	**5.23**	**7.17**	**13.67**
Premna schimperi	**3.36**	0.33	**10.93**
Rhus glutinosa	**1.23**	**4.67**	**10.13**
Lippia adoensis	**1.95**	**2.00**	**9.87**
Grewia ferruginea	**2.32**	**1.33**	**8.87**
Combretum molle	0.00	0.00	**7.83**
Vernonia bipontinii	0.23	0.00	**6.60**
Osyris quadripartita	**1.86**	**2.83**	**5.87**
Jasminum grandiflorum	0.41	0.00	**3.90**
Hypericum quartinianum	0.95	**1.33**	**3.87**
Rhus longipes	0.09	0.00	**2.97**
Myrsine africana	0.64	0.00	**2.53**
Acacia lahai	0.59	0.33	**2.30**
Pavetta abyssinica	0.59	0.50	**2.03**
Acacia abyssinica	**1.68**	**1.33**	**2.00**
Clerodendron myricoides	0.27	0.33	**1.57**
Schrebera alata	0.73	0.17	**1.50**
Clematis simensis	0.59	0.33	**1.27**
Guizotia scabra	0.82	0.67	**1.17**
Oleae europaea	0.00	0.00	**1.10**
Adianthum Poiretii	0.86	0.83	**1.07**
Anethum graveolens	0.00	0.00	**1.07**
Cyanotis barbata	0.00	0.00	**1.00**

Species diversity, richness and evenness of plant communities in Alemsaga Forest

Among the three communities, *Dodonaea angustifolia-Clutia abyssinica* community is found to be the most diverse with even distribution of individuals of species and the second in species richness whereas *Acanthus sennii-Vernonia myriantha* community is the least in species richness, diversity and evenness. *Maytenus arbutifola-Bersama abyssinica* community is intermediate between the other two communities (Table 3).

Table 3. Species richness (R) Shannon-Weiner diversity index (S) & evenness (E) of each plant community

Community	Richness	Diversity	Evenness
Maytenus arbutifola-Bersama abyssinica	85	3.23	0.73
Acanthus sennii-Vernonia myriantha	59	2.52	0.62
Dodonaea angustifolia-Clutia abyssinica	84	3.34	0.75

Community-environment relationships

Plant community distribution is mainly the manifestation of environmental gradients (Urban *et al.,* 2000 cited in Shiferaw Belachew, 2010). Altitude, slope and aspect were studied as environmental variables causing association of species in to plant community types. In order to determine significant differences in these variables among community types, Tukey's pairwise comparison was used. The ANOVA test indicated that the community types showed significant differences with respect to slope and aspect only (Table 4). Tukey's pairwise comparison was, therefore, used for these significant variables to determine which means amongst a set of means differ from the rest.

Table 4. ANOVA result for the environmental variables with plant community types

Factor	Degree of freedom	Sum Square	Mean Square	F value	Probability (>F)
Altitude	2	15691	7846	1.958	0.151
Slope	2	1320	659.8	5.324	0.008 **
Aspect	2	99.48	49.74	57.17	4e-14 **

The mean values for slope were variable among communities 1 and 3 and the mean values for aspect were variable among communities 1 and 3 and 2 and 3 (Table 5). Thus, the three plant communities identified varied in slope and aspect in which they occur.

Table 5. Pairwise comparison of community types based on slope and aspect using Tukey HSD

Community	Difference	Lower	Upper	Probability adjusted
Slope				
2-1	-0.848	-13.19	11.50	0.98
3-1	9.351	1.82	16.87	0.011*
3-2	10.200	-1.79	22.19	0.11
Aspect				
2-1	0.319	-0.71	1.35	0.73
3-1	2.683	2.052	3.31	0.0***
3-2	2.363	1.358	3.36	16e-6**

The significances of these variables were further verified using the graphical representation (Fig. 4) which indicated that comparisons between groups where the mean difference confidence interval does not span zero were statistically significant.

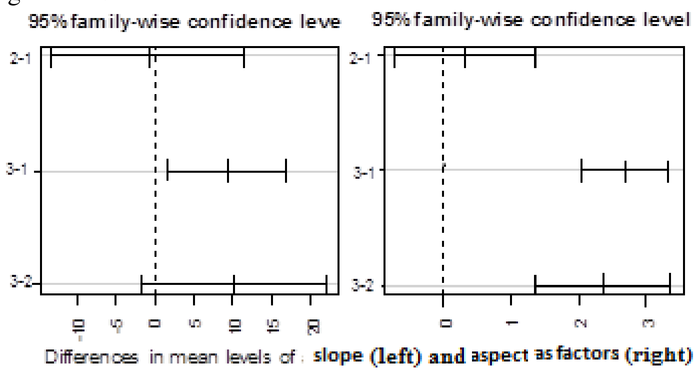

Fig. 4 Pairwise comparison of community types based on altitude, slope and aspect

Vegetation structure

DBH

In the present study, DBH class distribution of all individuals in different size classes showed an inverted J-shape distribution (Fig. 5A). This means that large numbers of individuals are distributed in the lower classes which later decreases in the successive upper classes. Large percentage (86.8%) of individuals was distributed in the 1st and 2nd classes whereas only 13.2% of individuals were distributed in the remaining upper classes. Diameter class distribution of selected tree species showed different patterns.

An inverted J-shaped distribution (Fig.5B), representing a pattern were the representative species showed high density in the lower DBH classes and their density decreases in the higher DBH classes. Other patterns were U- shaped (Fig. 5C); Zigzag or irregular (Fig. 5D); interrupted at one or more size classes (Fig.5D) and pattern with high percentage of distribution in the lower diameter classes and few or no individuals in the higher diameter classes (Fig.5F).

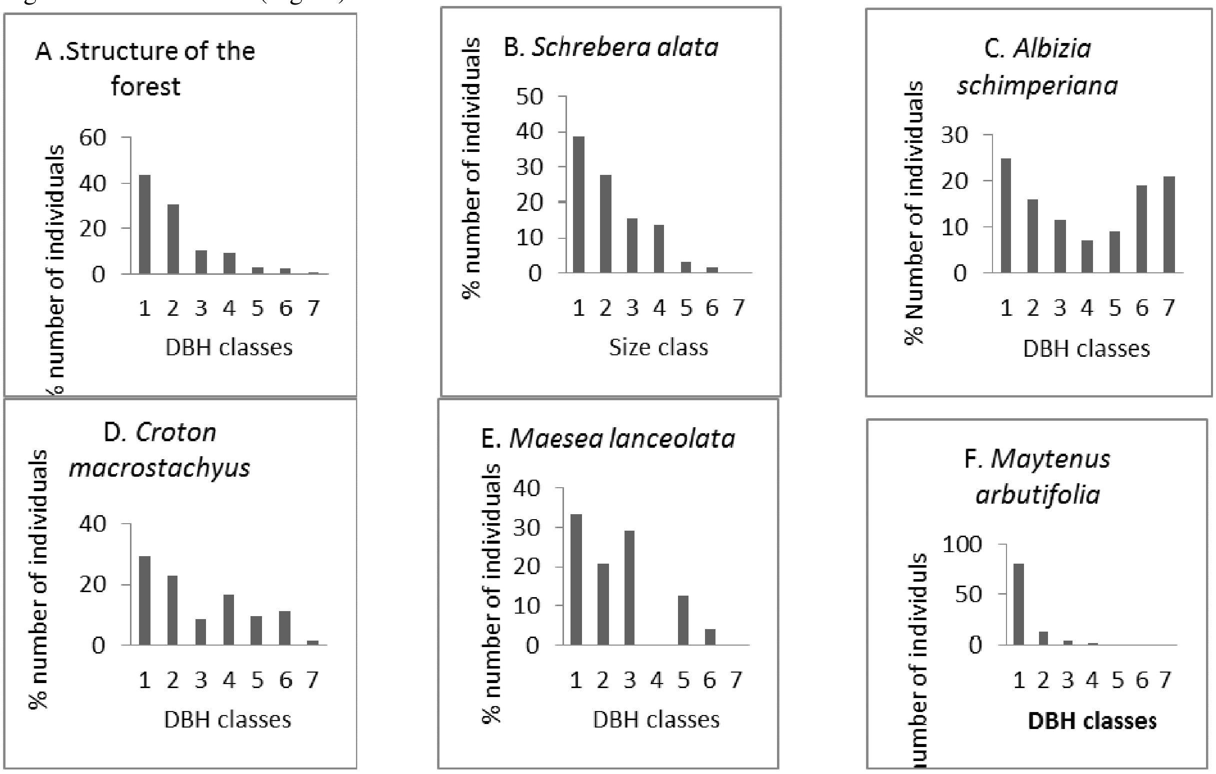

Fig. 5 (A-F): Size class distribution of the Forest (A) and Patterns of population structure of the representative woody species (B-F)

Basal area

As calculated from DBH data, the basal area of selected dominant woody species for Alemsaga forest was 75.37m^2 ha^{-1}. However, few species contributed to the higher basal area classes (Fig. 6) indicating that most species have small basal area. *Croton macrostachyus*, *Nuxia congesta*, *Albizia schimperiana* and *Combretum molle* were the only tree species contributed to the higher basal area classes.

The basal area of Alemsaga was compared with the basal areas of other 9 afromontane forests in Ethiopia (Table 6). Tara Gedam, Wof-Washa, Manna-Angetu & Sese Forests has greater basal areas than Alemsaga Forest.

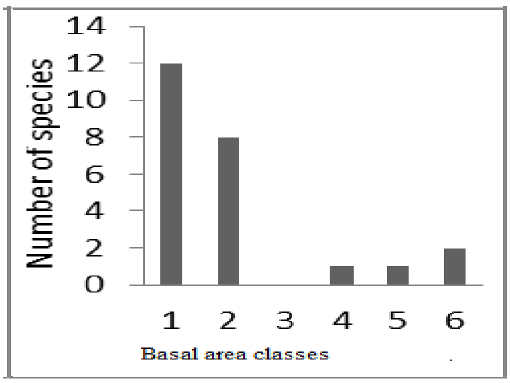

Fig. 6 Basal area percentage distribution of woody species

Table 6: Basal area (BA) Comparison of Alemsaga Forest with other afromontane forests (m^2ha^{-1})

Forest	BA	Source
Taragedam	115.4	Haelab Zegeye *et al*. (2011)
WofWasha	101	Tamrat Bekele (1994)
Manna	94.2	Ermaise Lulekal (2005)
Sese	88.6	Shiferaw Belachew (2010)
Alemsaga	75.3	Present study
Gura -Ferd	69.9	Dereje Denu (2007)
Jibat	49.8	Tamrat Bekele (1994)
Abebaye	49.5	Haelab Zegeye *et al*. (2011)
Menagesha	36.1	Tamrat Bekele (1994)
Jima	33	Futa Kenea (2008)

Importance value index (IVI)

Considerable number of species had higher IVI (Table 7). Based on their higher IVI value, five leading dominant & ecologically most significant woody species in Alemsaga were *Maytenus arbutifola, Bersama abyssinica, Carissa spinarum, Dodonaea angustifolia, Clausena anisata,* (Table 7). Other species with lower IVI were *Gnidia glauca, Ekebergia capensis, Ritchiea albersii*, etc.

Table 7. Relative dominance (RDo), relative density (RD), relative frequency (RF) & important value index (IVI) of woody species (with IVI > 1) of Alemsaga

Species name	RDO	RD	RF	IVI
Maytenus arbutifola	16.7	20	7.7	44.4
Bersama abyssinica	31.2	5.5	6.2	42.8
Carissa spinarum	15.5	8.4	7.9	31.8
Dodonaea angustifolia	2.2	17.	5.9	25.4
Clausena anisata	6.0	9.5	6.4	22
Premna schimperi	5.4	7.1	6.8	19.3
Grewia ferruginea	3.9	3.9	5.9	13.7
Nuxia congesta	4.3	2.6	6.1	12.9
Combretum molle	3.9	4.1	3.6	11.6
Croton macrostachus	3.1	1.7	6.4	11.2
Albizia schimperiana	2.9	2.0	4.8	9.71
Rhus glutinosa	0.5	3.2	4.4	8.02
Rhus longipes	1.1	2.3	4.2	7.57
Sterospermum kunthianum	1.63	3.8	1.1	6.5
Schrebera alata	0.1	1.0	4.2	5.39
Buddleja polystachya	0.9	0.9	2.9	4.81
Acacia lahai	1.4	1.2	1.9	4.64
Olinia rochetiana	2.3	0.3	1.6	4.32
Acacia sp	0.6	0.9	2.7	4.25
Pavetta abyssinica	0.1	1.1	2.7	3.89
Eucalyptus globulus	0.1	0.1	2.7	2.85
Cupressus lusitanica	1.6	0.2	0.6	2.39
Vipris dainielli	0.63	1.4	0.2	2.18
Myrica salicifolia	0.1	0.2	1.6	1.95
Oleae europaea	0.1	0.3	1.2	1.68
Acacia mearnsii	0.1	0.2	1.4	1.65
Gnidia glauca	0.1	0.2	1.1	1.31
Ekebergia capensis	0.2	0.1	0.9	1.22
Ritchiea albersii	0.1	0.1	0.9	1.03

DISCUSSION

Species composition

The results of this study revealed that Alemsaga natural Forest is one of the secondary dry afromontane forest in northwestern Ethiopia located in the northern massive. Though direct comparison of the species composition with the other forest is not feasible due to many reasons, overall comparisons of species richness of the forests can give a general over view. In this regard, the number of plant species in Almsaga Forest (124) was higher than some dry afromontane forests of Ethiopia, for instance Menagesha-Suba Forest with 82 species (Abate

Zewdie, 2007) & Jibat Forest with 54 species (Tamrat Bekele, 1994). Number of species in this Forest is also less than that of many dry afromontane Forests like Denkoro Forest with 174 species (Abate Ayalew, 2003) & Forest on the Peninsula of Zegie with131 species (Alemnew Alelign *et al*., 2007). The Forest consisted of some endemic species but the figure was lower compared to other dry montane forests of Ethiopia which ranges between 11-15% (Friis & Sebsebe Demissew, 2001). From the endemic plant species 42%, 29% and 29% were trees, herbs and shrubs respectively. The reason for the low number of endemic species might be small size of the Forest with less heterogeneity of the vegetation that reduces isolation of species.

Species diversity, richness and evenness

Species diversity, richness and evenness are widely used terms in community ecology and natural resource management. Species diversity is a function of the number of species present and the evenness with which the individuals are distributed among these species (Margalef, 1958; Pielou, 1966). Species diversity is a characteristic unique to the community level organization. Higher species diversity is generally thought to indicate a more complex and healthier community because of variety of species allowed for more species interaction, hence greater system of stability and indicate good environmental condition. A community is said to have high species diversity if many nearly equally abundant species present. In accordance with this, in the present study, *Dodonaea angustifolia-Clutia abyssinica* community is the most stable and healthier community owing to its highest species diversity and even distribution of individuals of species. This may be due to niche or habitat heterogeneity, reduced disturbance, topographic variables and position of sites in relation to the sun or various combinations of these variables. In this community, most representative plots were found far from anthropogenic disturbance. Moreover, sloppy natures of the sites that are not easily accessible to disturbance through selective cutting & grazing might also contribute to the highest diversity & stability. On the other hand, *Acanthus sennii-Vernonia myriantha* community was the poorest in its species diversity, richness and evenness which might be attributed to high level of disturbance where disturbance in the form road construction, selective cutting of trees & grazing were observed & plots were located near the edge of the Forest. Less number of plots which cover smaller areas in the Forest may also contributed to the least diversity of the Community. *Maytenus arbutifola-Bersama abyssinica* community exhibited intermediate characteristics.

Community-environmental variables relationships

Plant community distribution is mainly the manifestation of environmental gradients (Urban *et al.,* 2000 cited in Shiferaw Belachew, 2010). Mean values for slopes and aspects, in which the three plant communities occurred, were varied among plant communities. On the other hand, mean values for altitude did not vary among plant communities. This shows that slope and aspect are among the important environmental factors that determine species composition and distribution of plant communities across landscapes. The Forest species are distributed in landscape with two oppositely facing hills having wide flat area in between. Variation in exposure (aspect) of the two oppositely facing hills with respect to the position of the sun resulted in the variation of the patterns of community formation. In addition, considerable variation in slopes between the two hills might result variation in soil characteristics which in turn determine the pattern of the community formation. However, due to comparable elevation of the two hills altitude does not significantly determine patterns of community formation.

Diameter at Breast Height

DBH class distribution of all individuals in different size classes showed an inverted J-shape distribution. This is a general pattern of normal population structure where the majority of the species had the highest number of individuals at lower DBH classes with gradual decrease towards higher DBH classes. This suggests good reproduction potential of the vegetation. However, large percentage (86.8%) of individuals were distributed in the 1st and 2nd classes, indicating the predominance of small and medium sized individuals in the Forest. This could be attributed to high rate of regeneration but poor recruitment in the forest, which might have been caused by selective cutting of large sized individuals.

Diameter class distribution of selected tree species demonstrated various patterns of population structure, implying different population dynamics among species. An inverted J-shaped distribution represented a pattern were the individuals of a species showed high density in the lower DBH classes and their density decreases in the higher DBH classes. Such pattern shows normal or healthy structural pattern with good reproduction and recruitment capacity of a given species (Feyera Senbeta *et al*., 2007). On the other hand, other distribution patterns such as U-shaped, Zigzag or irregular; interrupted at one or more size classes and pattern with very high percentage of distribution in the lower diameter classes are not healthy or abnormal because of selective removal of the species for construction and fuel wood. More or less, similar results were reported from remnant Afromontane forests on the central plateau of Shewa, Ethiopia (Tamrat Bekele, 1994) and Dello Menna, Southeast Ethiopia (Motuma Didita *et al*., 2010)

Basal area

Basal area of selected dominant woody species for Alemsaga Forest was found to be high as revealed from the comparisons of the basal area of Alemsaga Forest with other nine afromontane Forests. However, few species contribute to the higher basal area classes indicating that most species have small basal area. This indicated that the Forest is dominated by woody species with large number of small sized individuals.

Importance value index (IVI)

Curtis and McIntosh (1951) pointed out that IVI gives a more realistic figure of dominance from structural point of view. It is useful to compare the ecological significance of species (Lamprecht, 1989) in which high IVI value indicates that the species sociological structure in the community is high. Based on their higher IVI value, five leading dominant & ecologically most significant woody species in Alemsaga were *Maytenus arbutifola, Bersama abyssinica, Carissa spinarum, Dodonaea angustifolia* and *Clausena anisata.*

CONCLUSION AND RECOMMENDATIONS

High species richness and diversity in the Forest indicated that it would be a good source of forest products if it is sustainably used. Since the Forest harbors considerable number of endemic species, it needs conservation priority. Analysis of community and environmental variables relationship showed that aspect and slope are among the important factors determining the patterns of species distribution and plant community formation. Analysis of structural status of the Forest indicated that several species have abnormal population structure and predominance of small sized individuals in the lower diameter classes indicate good reproduction potential and rare occurrence of large individuals. Moreover, 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. IVI analysis showed that considerable proportions of species are not well represented in the Forest and are rare. To prevent local extinction these species, effort of nursery establishment and plantation of indigenous species should be practiced. Detailed ethnobotanical studies are required to explore the wealth of indigenous knowledge on the diverse use of plants and their implication to conservation. In addition, study on soil seed bank, soil-plant relation and carbon sequestrations are recommended.

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Appendix 1: Species list collected from Alemsaga Forest (H* = habit, H= herb, S= Shrub, C= climber)

Family	Scientific name	H*	Family	Scientific name	H
Fabaceae	*Acacia lahai* Benth.	T	Balsaminaceae	*Impatiens tinctoria* A.Rich.	H
Fabaceae	*Acacia* Species	T	Oleaceae	*Jasminum grandiflorum* L.	C
Euphorbiaceae	*Acalypha psilostachya* Hochst.	S	Acanthaceae	*Justicia schimperiana* L.	S
Acanthaceae	*Acanthus sennii* Chiov.	S	Crassulaceae	*Kalanchoe densiflora* Rofle.	H
Amaranthaceae	*Achyranthus aspera* L.	H	Verbenaceae	*Lantana viburnoides* (Forssk.) Vahl.	S
Adianthaceae	*Adianthum Poiretii* Wikstr.	H	Poaceae	*Leptochloa rupestris* Hubbard.	H
Fabaceae	*Albizia schimperiana* Oliv.	T	Verbenaceae	*Lippia adonsis* Hochst. ex Walp.	S
Sapindaceae	*Allophylus abyssinicus* (Hochst.) Radlk.	T	Celastraceae	*Maytenus arbutifola* (A.Rich.) R.Wilezek.	T
Amarantaceae	*Amaranthus hybirdus* L.	H	Myrsinaceae	*Measa lanceolata* Forssk.	S
Apiaceae	*Anethum graveolens* L.	H	Fabaceae	*Milletia ferruginea* (Hochst.) Baker.	T
Araceae	*Arisaema enneaphyllum* Hochst. ex A.Rich.	H	Cucurbitaceae	*Momordica foetida* Schumach.	C
Asparagaceae	*Asparagus africanus* Lam.	C	Myricaceae	*Myrica salicifolia* A.Rich.	T
Melianthaceae	*Bersama abyssinica* Fresen.	T	Myrsinaceae	*Myrsine africana* L.	S
Asteraceae	*Bidens carinata* Cufod.ex Mesfin	H	Loganiaceae	*Nuxia congesta* R.Br. ex Fresen.	T
Asteraceae	*Bidens pilosa* L.	H	Lamiaceae	*Ocimum lamifolium* Hochst. ex Benth.	S
Simaroubaceae	*Brucea antidysentrica* J.f. Mill.	S	Oleaceae	*Oleae europaea* L.	T
Loganiaceae	*Buddleja polystachya* Fresen.	T	Oliniaceae	*Olinia rochetiana* A.Juss.	T
Fabaceae	*Calpurnia aurea* (Ait.) Benth.	S	Cucurbitaceae	*Oreosyce africana* Hook.f.	H
Capparidaceae	*Capparis tomentosa* Lam.	C	Orobanchaceae	*Orobanche minor* Smith	C
Apocynaceae	*Carissa spinarum* L.	S	Santalaceae	*Osyris quadripartita* Decn.	S
Ulmaceae	*Celtis africana* Brum.f.	T	Lamiaceae	*Otostegia integrifolia* Benth.	S
Rutaceae	*Clausena anisata* (Willd.) Hook.	*T*	Oxalidaceae	*Oxalis anthelmtica* A.Rich.	H
Ranunculaceae	*Clematis simensis* Fresen.	*C*	Polygonaceae	*Oxygonium sinuatum* (Melsn) Dammer.	H
Liamiaceae	*Clerodendron myricoides* (Hochst) R.Br.ex Vatke.	S	Rubiaceae	*Pavetta abyssinica* Fresen.	T
Euphorbiaceae	*Clutia abyssinica* Jaub. & Spach.	S	Malvaceae	*Pavonia burchelii* (Dc) R.A. Dyer.	S
Combretaceae	*Combretum molle* G.Don.	T	Malvaceae	*Pavonia urens* Cav.	S
Commelinaceae	*Commelina africana* L.	H	Asclepiadaceae	*Periploca linearifolia* Quart.-Dill & A.Rich.	SC
Commelinaceae	*Commelina sabulata* Roth.	H	Arecaceae	*Phoenix reclinata* Jacq.	T
Boraginaceae	*Cordia africana* Lam.	T	Phyotlacaceae	*Phytolacca dodecandra* L'Herit.	C
Amaryllidiaceae	*Crinum abyssinicum* Hochst. ex A.Rich.	H	Apiaceae	*Pimipinella keniensis* Norman	H
Euphorbiaceae	*Croton macrostachus* Del.	T	Plantaginaceae	*Plantago lanceolata* L.	H
Poaceae	*Cyanadon dactylon* (L.) Pers.	H	Lamiaceae	*Plectrantus punctatus* (L.f.) L 'Her.	H
Commelinaceae	*Cyanotis barbata* D.Don.	H	Polygonaceae	*Polygonum nepalense* (Meisn.) Miyabe.	H
Amaranthaceae	*Cyathula unicinulata* (Schrad.) Schinz.	S	Liamiaeae	*Premna schimperi* Engl.	S
Boraginaceae	*Cynoglossum lanceolatum* Forssk.	H	Fabaceae	*Pterolobium stellatum* (Forsk.) Brenan	SC
Cyperaceae	*Cyperus dichroostachus* A.Rich.	H	Vitaceae	*Rhoicissus tridentata* (Lif.) Wild. & Drummond.	S
Cyperaceae	*Cyperus rotundus* L.	H	Anacardiaceae	*Rhus glutinosa* A.Rich.	T

Family	Scientific name	H*	Family	Scientific name	H
Cyperaceae	*Cyperus welwitschii* (Ridl.) Lye.	H	Anacardiaceae	*Rhus longipes* Engl.	T
Vitaceae	*Cyppostemma cyphopetalum* (Fres.) Wild. & Durmm.	C	Caparidaceae	*Ritchiea albersii* Gilg.	T
Sterculiaceae	*Dembeya torrida* (Hiern.) F. White.	T	Rosaceae	*Rosa abyssinica* Lindly.	S
Sapindaceae	*Dodonaea angustifolia* L.f.	S	Polygonaceae	*Rumex abyssinica* Jacq.	H
Flacourtiaceae	*Dovyalis abyssinica* Warb.	S	Polygonaceae	*Rumex nepalensis* Spreng.	H
Asclepiadaceae	*Dregea abyssinica* K.Schum.	C	Araliaceae	*Scheffelera abyssinica* Harms.	T
Asclepiadaceae	*Dregea rubicunda* Schum.	C	Oleaceae	*Schrebera alata* Welw.	T
Dryopteridaceae	*Dryopteriss schiperiana* C.Chr.	H	Poaceae	*Setaria pumila* (Poir.) Roem. & Schult.	H
Meliaceae	*Ekebergia capensis* Sparm.	T	Malvaceae	*Sida rhombifolia* L.	H
Myrsinaceae	*Embelia schimperi* Vatke.	T	Solanaceae	*Solanum incanum* L.	H
Poaceae	*Eragrostis tenuifolia* (A.Rich) Steud.	H	Poaceae	*Sporobolus africanus* (Poir.) Robyn. & Toum.	H
Ebenaceae	*Euclea divinorum* Heirn.	S	Apiaceae	*Steganotaenia araliacea* A.Rich.	H
Moraceae	*Ficus sur* Forssk.	T	Minispermaceae	*Stephania abyssinica* Walp.	H
Asteraceae	*Galinsoga quadriradiata* Ruiz. and Payon.	H	Bignoniaceae	*Sterospermum kunthianum* Cham.	T
Rubiaceae	*Gallium simense* Fresen.	H	Myrtaceae	*Syzygium guineense* Dc.	T
Geraniaceae	*Geranium ocellatum* Oliv.	H	Asteraceae	*Tagetes minuta* L.	H
Thymelaeaceae	*Gnidia glauca* (Fresen.) Gilg.	T	Fabaceae	*Trifolium schimperi* A.Rich.	H
Tiliaceae	*Grewia ferruginea* A.Rich.	T	Urticaceae	*Urera hyselodendron* Burm.f.	T
Asteraceae	*Guizotia scabra* (Vis.) Chiov.	H	Urticaceae	*Urtica urens* L.	H
Asteraceae	*Helichrysum splendidum* (Thunb.) Less.	S	Scrophularaceae	*Verbascum stelarum* Murbeck.	H
Malvaceae	*Hibiscus macranthus* Hochst.	S	Asteraceae	*Vernonia amygdalina* Del.	T
Malvaceae	*Hibiscus panduriformis* Burm.f.	S	Asteraceae	*Vernonia bipontinii* Vatke.	S
Malvaceae	*Hibiscus vitifolius* L.	S	Asteraceae	*Vernonia myriantha* Hook.f.	S
Hypericaceae	*Hypericum quqrtinianum* A.Rich.	S	Rutaceae	*Vipris dainielli)* Kwaro.	T
			Olacaceae	*Xymenia americana* L.	S
			Cucurbitaceae	*Zeneria scabra* Sond.	S