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Floristic Composition and Structural Analysis of Susgen-Bosena Forest, Ambasel District, North Wollo, Amhara Region, Ethiopia

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ABSTRACT

Forest patches harbour a significant number of rare and endangered species. So far, no attempt has been made to assess the species composition of Susgen-Bosena forest patch. Such study would be vital to design appropriate forest management and stepping ground to restore a degraded landscape. Field data was collected on 30 sampling plots using systematic random sampling. Plant specimens were collected, identified, and placed in National Herbarium of Ethiopia, Addis Ababa University. The data were analysed using R Software. 180 plant species, which belong to 139 genera and 68 families, were recorded from 3 plant community types. The community types recognized were community type-I (*Ekebergia capensis* Spamn., *Bersama abyssinica* Spamn. and *Myrica salicifolia* A.Rich.*)*, community type-II *(Olea europaea* subsp *cuspidata* (Wall. Ex DC.) Cifferri., *Nuxia congesta* R.Br.ex Fresen. and *Pittosporum viridiflorum* Sims and, community type-III *(Olinia rochetiana* A. Juss. and *Juniperus procera* L.*)*. Altitude, slope, aspect, terrain ruggedness index, landform, and topographic wetness index were investigated for their influence on species distribution. Results found from the data indicated that altitude and slope affected significantly ($P<0.05$) species distribution in the study area. The ratio of the seedling to saplings was 1.2:1, and a sapling to mature individuals was 18.6:1. The result showed the presence of more seedlings than saplings, and mature trees, which indicated successful regeneration of forest species in the study forest. In conclusion, the present study provides additional evidence with respect to the contribution of forest patch in harboring plant species.

Keywords: Ambasel, diversity, environmental gradients, plant communities.

INTRODUCTION

Forest vegetation in Ethiopia have suffered decades of mismanagement due to significant human interference. The Forest vegetation has experienced a long history of deforestation starting about 2450 before present (Hurni, 1987), and 500 before Christ (Darbyshire et al., 2003) indicates a long history of anthropogenic impact. Correspondingly, the soil organic carbon isotope evidence was consistent with those historical documents, which suggest that long-lasting anthropogenic forest disturbances have occurred (Eshetu, 2002). The human factor is responsible for forest vegetation degradation in the country. Population growth, poverty, unstable land-tenure system, property right over forests, lack of forest and land-use policies, socio-political instability and the setting up of sawmills by the Italians occupation (1936–1941) were driving factors for deforestation (Zewude, 1998).

In a human-dominated ecosystem with a high portion of cultivated and grazing land, the small forest patches may have a significant contribution to overall species diversity and species composition (Berhane et al., 2013). Isolated patches are key habitats, harbour rare and threatened animal, and plant species. Patches of natural forests in the highlands of Ethiopia served as seed sources for restoration of degraded areas, as points of reference for restoration activities, and harbour biodiversity (Berhane et al., 2013). Forest development interventions may become very difficult if these remnants further deteriorate (Teketay, 2005).

Plant species distribution along environmental gradients is fundamental to managing ecosystems, particularly when habitats are fragmented due to intensive human land-use pressure. Environmental gradients are determinants for the spatial and temporal distribution of vegetation. Altitude exerts a strong influence on plants (Huggett, 1998). Several studies in Ethiopia have also showed a relationship between floristic diversity to elevation, slope, and aspects (Tekle et al., 1997; Senbeta & Teketay, 2001; Wassie et al., 2010; Aynekulu et al., 2012).

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Vegetation classification has been carried out over nearly the entire country, to serve as the basis for conservation-oriented inventories. Vegetation maps were produced using different principles. Friis et al. (2010) have published a detailed vegetation map for Ethiopia with a scale of 1:2,000,000. In this map, 12 vegetation types with 15 mapping units are recognized. Classification is at the highest level on pheno-physiognomy but then on concrete plant associations at more local levels in the hierarchy. For conservation purposes, a need has been identified for more local scale (Maarel, 2005).

Several studies have documenting the natural assemblage of forests of Ethiopia. For instance, some studies were reported the species composition and diversity of larger forest of south Wollo (Tekle et al., 1997; Ayalew et al., 2006). However, these studies did not report the species composition and diversity of Susgen-Bosena forest. A number of researchers have reported that forest patches harbour a significant number of rare and endangered species (Berhane et al., 2013). Forest patches in Wuchale district have not been systematically assessed, particularly the species diversity and structural analysis of Susgen-Bosena forest patches is lacking. Such information would be very vital to implement appropriate forest management scheme. Recent evidence suggests that the availability of a concrete reference data is very vital for better implementation of restoration activities (Elliott et al., 2013). Therefore, this study is intended to assess plant species composition, diversity, and vegetation structure analysis of Susgen-Bosena Forest patch, to provide information for possible conservation and management interventions.

MATERIALS AND METHODS

Description of the study Area:

The study was conducted in Ambasel district which is located between 11^0 18' to 11^0 44' latitude and 39^0 16' to 39^0 40' longitude (Fig. 1). The district is bordered on the west by the Bashilo River that separates it from Tenta district, on the north by the North Wollo Zone, on the southeast by the Mille river, which separates it from Tehuledere, and on the south by Kutaber district.

The elevations in this district range from 898 to 4234 masl. The dominant major soil types are Lithic Leptosols, Eutric Leptosols, and Eutric Cambisols (Verelst & Wiberg, 2012).

Metrological data obtained from Hayk station showed that the study area is characterized by wet and dry seasons (Fig. 2). The distribution of rainfall mostly occurs from June to September is main rain season, and February to May is the short rain season, the mean annual temperature and mean annual rainfall 18.4 ^oC and 1148 mm, respectively.

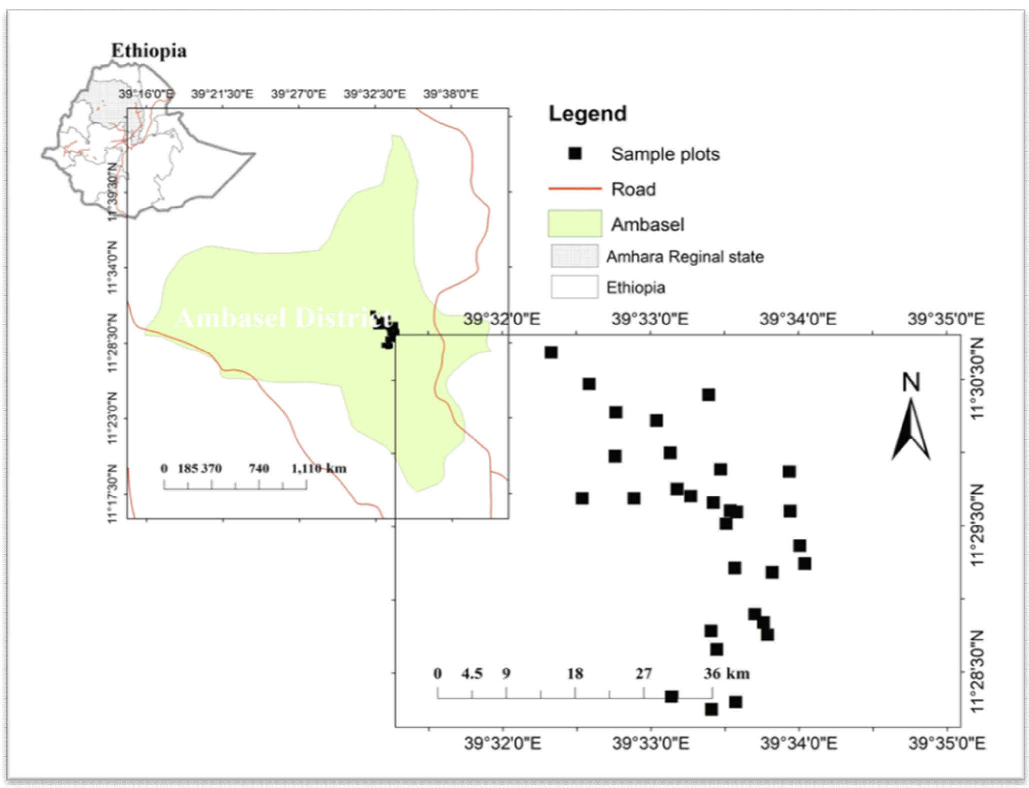

Fig. 1: map of the study area, Ambasel district, Ethiopia

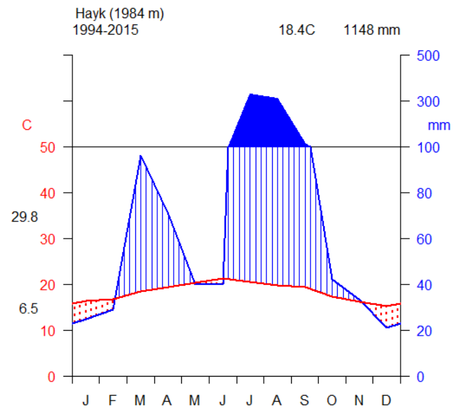

Fig. 2: Climate diagram of Hayk District (Data source: NMSA, 2016)

The natural vegetation of the study area is broadly classified as *Juniperus procera* forest or "dry single dominant Afromontane forest" with *Junip procera* and/or Olea as dominant species (Friis et al., 2010).

Ambasel district has a total population of 121,899, an increase of 9.65% over the 1994 census, of whom 61,290 are men and 60,609 women; 116,017 or 95.2% are rural inhabitants (CSA, 1994). A total of 29,390 households were counted in this district resulting in an average of 4.4 persons to a household, and 28,407 housing units. In in rural areas of the district, a total housing unit of 24794, 22824 and 899 use firewood, dung and kerosene for cooking, respectively (CSA, 2007).

Data collection method:

Vegetation sampling:

In this study, systematic random sampling was employed. Thirty sampling plots (20m *20m) with an area of 1.2 ha of the total forestland (800 ha) were considered in the study. This resulted in a sampling intensity of one plot per approximately 26.6 hectares. Species area curve was also used to estimate the expected number of new species that may be encountered for given additional sampling efforts (Magurran, 1988).

Plants were categorized as mature plants (height > 3 m) saplings (height between 1.5 m and 3 m), and seedlings (height < 1.5 m) and counted following Adamu et al. (2012). Tree and shrub were enumerated on the sampled quadrats of 20 m × 20 m (400 m^2). For seedling and sapling inventory, 2m × 5m at the beginning and opposite sides of the main quadrat was used. Herbaceous species were collected from five 1 m × 1 m sub-quadrats, four sub quadrats at the corner and one at the centre, within each 400 m^2 quadrat.

The diameter and height of individuals of woody species were measured using meter tape and hypsometer, respectively. Trees with height greater than 1.5 m and with diameter at breast height (DBH) ≥ 2.5 centimetres was measured and recorded. Plants voucher specimens were collected, pressed, dried, identified, and authenticated by reconfirming at the National Herbarium, Addis Ababa University.

Environmental data:

In addition to vegetation data, in each sampling plots global positioning point was taken. These points used to compute the value of the environmental parameters such as slope, altitude, aspect, landform, topographic wetness index, terrain ruggedness index, windward, and leeward of the sample quadrates from Digital Elevation Model (DEM). DEM having 30 m resolution was used as input data to get the values of environmental parameter. A terrain analysis tool in the System for Automated Geoscientific Analyses (SAGA) (Conrad et al., 2015) was used to compute the values of each environmental parameter. SAGA has generated ESRI ASCII grids maps. ArcGIS point extraction tools used to extract values of environmental parameter from the grid maps using GPS points.

Data analysis:

Vegetation classification:

Plant communities were identified through multivariate hierarchical clustering using R-software (version 3. 2). To determine the optimal numbers of groups in the cluster analysis, different classification methods were used and their results were evaluated (Wildi, 2010). In this study, plant community was classified using agglomerative hierarchical classification.

Ordination:

Investigating the environmental gradients influencing on species distribution was tested using direct gradient analysis and indirect gradient analysis. These investigations determine the relationship between floristic and environmental variables. The appropriate ordination method was selected based on the nature of the input data and following the rule to decide whether to use unimodal or linear method based on the length of the first Detrended correspondence analysis axis (Legendre & Legendre, 1998). In this study, canonical correspondence analysis was used to test vegetation community - environmental relationships.

Diversity analysis:

Species richness, Shannon index, and Simpson index were used. Non-parametric species richness estimators applicable to sampling plot-based datasets were used to estimate the true number of species found in the study area based on the number of species observed in the sampling plots.

The shannon diversity index was calculated as follows; $H'=\sum_{i=1}^{s} pi \ln pi$; Where; H' = is shannon diversity index, pi= is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln = natural log, Σ = sum of the calculations, and s = the number of species.

Evenness index is calculated as following (J): $J= \frac{\sum_{i=1}^{s} pi \ln pi}{\ln S} = \frac{H'}{\ln S}$; Where; J = is the evenness diversity index. Evenness values lie between 0 and 1, with 1 being complete evenness (Magurran, 2004).

Structural data analysis:

The data obtained from the diameter at breast height of the woody plant was used for horizontal structure analysis. Density, frequency, basal area and their relative values and importance value index of tree species were calculated following (Mueller-Dombosis & Ellenberg, 1974; Kent & Coker, 1992). Density was a count of the numbers of individuals of a species within the quadrat. It was computed on hectare basis; Basal area was calculated using the formula: $BA = \pi (d/2)^2$ where d is diameter at breast height; Relative density of a species = (Number of individuals of a species/ Number of individuals of all species)*100; relative frequency of species = (Number of plots in which a species occurred/ Total number of occurring species)*100; relative dominance = (Total basal area of a species/ Total basal area of all species)*100; and the importance value index (IVI) was calculated as a summation of relative density, relative frequency and relative dominance.

RESULTS

Floristic Composition:

This study has recorded 180 species of plants belonging to 139 genera representing 66 families. Of these, 171 species were recorded from sampling plots, while 9 species were found outside the sampling plots (Appendix A). Fifteen species-rich plant families contribute to 60% of the species in Susgen-Bosena Forest (Table 1). Species area curve was used to estimate the expected number of new species that may be encountered for given additional sampling efforts. In this study, over 142 (77%) species were sampled only from the first 15 (50%) sampling plots.

Density:

The density of woody species (DBH >10cm) in Susgen-Bosena forest was 240 individuals ha^{-1}. Of these, woody species, *Olea europaea* subsp *cuspidata* had 48.3 individuals ha^{-1}(20.1%), *Olinia rochetiana* had 25.0 individuals ha^{-1} (10.4%), *Allophyllus abyssinicus* 17.5 ha^{-1} individuals ha^{-1} (7.3%), *Juniperus procera* 15.8 individuals ha^{-1} (6.6%) and *Myrica salicifolia* 15.0 individuals ha^{-1} (6.3%) contributing to the largest proportion of woody species per hectare.

On Sapling densities, 2333.3 seedling/ha were counted in the forest. Of these species, *Myrsine africana* had 266.6 individual's ha^{-1}(11.4), *Maytenus senegalensls* 166. 6 ha^{-1} (7.1%), and *Olinia rochetiana* 133.3 ha^{-1} (7.1%), contributing to the leading proportion of individual seedling per hectare.

On seedling densities, 2800 seedling/ha was counted in the forest of Bosena. Of these densities species, *Myrsine africana* had 866.6 individuals ha^{-1}(30.9%), and *Maytenus arbutifolia* 266.6 ha^{-1} (9.52%) that contributed to the largest proportion of seedling individuals per hectare. Other species like *Juniperus procera*, *Olinia rochetiana* and *Ekebergia capensis* contributed to 133.3 individuals ha^{-1}(4.7%) proportion of individual seedling per hectare.

Table 1: Species rich plant families

Family Name	Gen.	Spec	Family Name	Gen.	Spec.	Family Name	Gen.	Spec.
Asteraceae	18	22	Rubiaceae	5	6	Solanaceae	4	6
Poaceae	13	16	Acanthaceae	4	5	Anacardiaceae	1	3
Lamiaceae	6	11	Apiaceae	5	5	Boraginaceae	2	3
Fabaceae	8	10	Rosaceae	5	6	Crassulaceae	1	3
Euphorbiaceae	4	6	Malvaceae	4	4	Hypericaceae	1	3

Where: Gen.= Genera; Spec.= Species

Basal Area and Important Value Index (IVI):

The total basal area of woody species in Susgen-Bosena Forest was 20m^2 ha^{-1}. *Olea europaea* subsp *cuspidata* exhibited the highest IVI (47.09), followed by *Ekebergia capensis* (35.01), *Podocarpus falcatus* (33.56), *Olinia rochetiana* (23.14), and *Juniperus procera* (19.84). These five species contributed to 58% of the total IVI.

Diameter and Height Class Distribution:

Analysis of the DBH indicated that the number of individuals decreases drastically from the lowest size classes to the highest size class (Fig. 3). The number of individuals decreased with increasing diameter classes. The tallest tree species in the forest are *Olinia rochetiana, Ekebergia capensis, Podocarpus falcatus, Juniperus procera, Prunus africana* and *Myrica salicifolia.*

value in the synoptic table. *Ekebergia capensis, Bersama abyssinica* and *Myrica salicifolia* community type-I occurs at altitudinal ranges from 2100 to 2400 masl. The community is comprised of 9 plots and 71 species; *Olea europaea, Nuxia congesta* and *Pittosporum viridiflorum* community type-II found at altitudinal ranges from 2300 to 2600 masl altitude. The community is comprised of 11 plots and 90 species; and *Olinia rochetiana* and *Juniperus procera* community type -III was located between 2400 and 2900 masl 10 plots and 106 species were associated with the community.

Species richness, diversity and equitability in communities:

The Shannon – Wiener diversity index (H') was computed for each plant community types. Shannon evenness was 0.85 and 0.89 for community type-II and community type-III, respectively (Table 2).

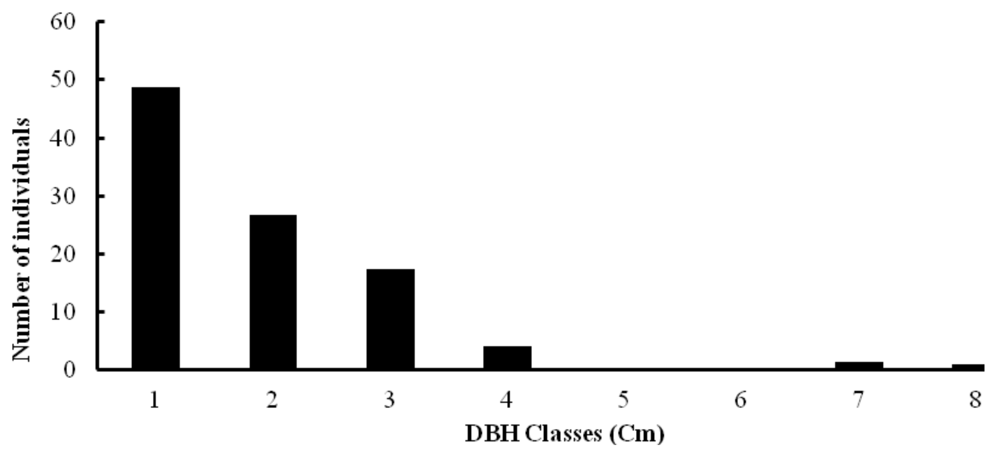

Fig. 3: DBH classes versus number of individuals in Susgen-Bosena Forest (Key: 1 = < 10; 2 = 10.1–30; 3 = 30.1–50; 4 = 50.1–70; 5 = 70.1–90; 6 = 90.1–110; 7 = 110.1–130; and 8 <130 cm)

Table 2: Diversity analysis of community types

Community	Richness	H	Shannon Evenness
1	71	3.79	0.89
2	90	3.87	0.86
3	106	3.95	0.85

Plant Community Classification:

Three major sets of plots were clearly distinguished from the output of the cluster analysis, using agglomerative hierarchical classification using similarity ratio (Fig. 4). The plant community types were named by using two or three dominant species that have the highest

Community-Environmental Variables Relationships:

The sampling plots and species highly correlated to a particular environmental variable are aligned along the vector direction of that environmental variable (Fig. 5). The ANOVA results showed significant differences ($P < 0.05$) with respect to elevation and slope. Elevation is the major discriminating variable and the slope is next to slope. Tukey's HSD tests for the pairwise comparisons of mean differences between communities showed significant differences ($P < 0.05$) between all pairs of communities with respect to altitude and communities pair II-I with respect to slope and elevation, but no significant difference with respect to other environmental variables.

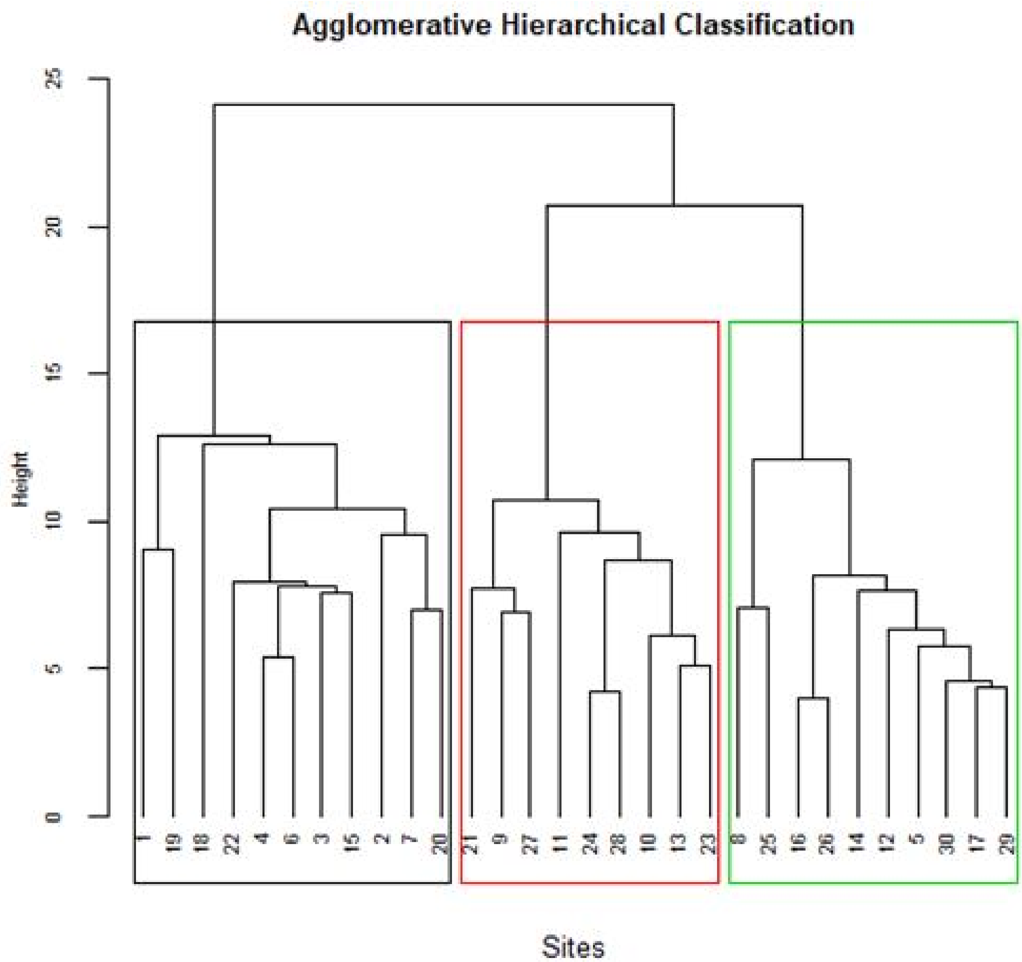

Fig. 4: Plant community as classified using Agglomerative Hierarchical Classification

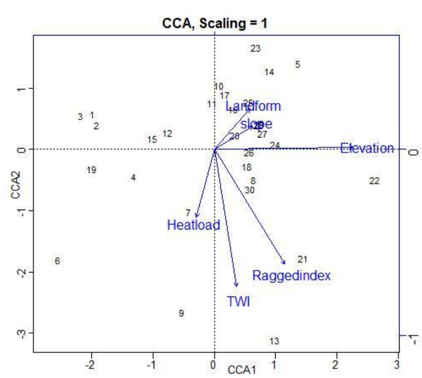

Fig. 5: vegetation community-environmental variables relationships

DISCUSSION

Plant Composition of Susgen-Bosena Forest:

The first question in this study sought to determine the composition of plant species in the study forest. The forest harbours 180 woody plant species suggesting that the remnant forest patches in the highlands of Wollo, Ethiopia. The forest patch harbours several treated plant species (Wassie et al., 2010). Herbaceous species outnumber in Forest when compared to the other growth forms. This could be related partly to the shallowness of the soil (Verelst & Wiberg, 2012), more conducive for herbs than trees.

Basal Area and Important Value Index (IVI):

The current study found that the total basal area of woody species in Susgen-Bosena Forest was $20m^2$ ha^{-1}. The Basal area of the forest was similar to basal area (19.4 m^2 ha^{-1}) of Tigray Forest, Ethiopia (Kidane et al., 2009). The results are low as compared with the basal area of other Dry Afromontane Forests in Ethiopia. For example, 64.32 m^2 ha^{-1} in Wof Washa Natural Forest (Fisaha et al., 2013) and 45.1 m^2 ha^{-1} in Denkoro Forest (Ayalew et al., 2006).

Olea europaea subsp *cuspidata* exhibited the highest important value index, followed by *Ekebergia capensis*, *Podocarpus falcatus*, *Olinia rochetiana*, and *Juniperus procera*. These five species contributed to 58% of the total IVI. These results are in agreement with those obtained by high density and high frequency coupled with high BA indicates the overall dominant species of the forest (Lamprecht, 1989).

Diameter class distribution:

The second question in this study sought to determine the diameter distribution of the forest. The the number of individuals decreases drastically from the lowest size classes to the highest size class. A possible explanation for this might be that the forest is under secondary succession after disturbance. Fisaha et al. (2013) reported similar result from Wof Washa natural forest. The forest shows good reproduction and recruitment potential. Similar result was reported by Senbeta & Teketay (2001).

Population Structure:

Analysis of the population structure of the tree species in the forest shows five general patterns of population structure. *Olea europaea* subsp *cuspidata, Bersama abyssinica, Erica arborea* and *Galiniera saxifraga* showed an inverted J-curve population structure. It can thus be suggested that good reproduction and recruitment potential of the species in the forest.

The second pattern was formed by species having an irregular distribution over diameter classes. *Prunus africana, Cassipourea malosana,* and *Allophylus abyssinicus* are found to be the example. This irregular pattern may be due to selective cutting by the local people for construction and firewood. Another possible explanation for this pattern is that overgrazing which affects the seedlings under the mother tree (Tadele et al., 2013).

The third type shows a J - shaped distribution pattern where the number of individuals is low in the first and second DBH classes, but increases toward the higher classes. This type of regeneration pattern was observed in *Myrica salicifolia* and *Olinia rochetiana.* Such patterns show poor reproduction patterns and hampered regeneration. A possible explanation for this might be that because either most trees are not producing seeds due to age, or there are losses due to predators after reproduction. Bekele (1994) reported similar reasons for this pattern.

The fourth pattern was a U-shaped curve formed by species with few or no individuals in the middle DBH classes and represented only by the lower and higher DBH classes. Species with this type of population structure was *Ekebergia capensis*. Mohammed & Abraha (2013) reported similar reasons for this type of population structure.

The Fifth pattern depicting poor reproduction and complete absence of individuals in intermediate classes, as exemplified by *Hagenia abyssinica* for instance, indicate a vanishing population, (Ayalew et al., 2006) reported similar reasons for this pattern. Therefore, all species in the fifth regeneration pattern should be prioritized for conservation measures. Several reports have shown that the species with irregular population structure, selective logging may account for the observed findings. Schmitt et al. (2010) argues that diameter class distribution of plant species could indicated the general trends of a population dynamics and recruitment process of a given species. If the current exploitation of the species continues unrestricted, the species will probably endanger its population biology.

Plant Community Classification:

On the question of distinct plant community, this study found that there are three distinct plant community types in the study forests. According to Friis et al. (2010), the three community types can be roughly classified as Dry Afromontane forest types. Plant community type is part of the vegetation which shows certain remarkable features that identifies it from its surroundings (Maarel, 2005). Hence, community type-I was characterized by *Ekebergia capensis, Galiniera saxifraga, Prunus Africana* and *Myrica salicifolia,*

Appendix 1: List of plants recorded in Bosena Forest

Botanical Name	**Family Name**	***Botanical Name***	**Family Name**
Acacia abyssinica Hochst.	Fabaceae	*Helichrysum stenopterum* DC.	Asteraceae
Acacia seyal Del.	Fabaceae	*Heteromorpha arborescens* (Spreng.) Cham & Schlecht.	Apiaceae
Acacia sieberiana DC.	Fabaceae	*Hibiscus macranthus* Hochst. ex A. Rich.	Malvaceae
Achyranthes aspera L.	Amaranthaceae	*Hygrophila schulli* (Hamilt) M. R. & S. M. Almeida	Acanthaceae
Acmella caulirhiza Del.	Asteraceae	*Hyparrhenia anthistirioides* (Hochst. ex A. Rich) Stapf.	Poaceae
Adiantum poiretti L.	Pteridaceae	*Hyparrhenia coIeotricha* (Steud.) W.D. Clryton	Poaceae
Ageratum conyzoid L.	Asteraceae	*Hyparrhenia hirta* (L.) Stapf.	Poaceae

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Botanical Name	**Family Name**	***Botanical Name***	**Family Name**
Alchemilla abyssinica Fresen.	Rosaceae	*Hypericum peplidifolium* A. Rich.	Hypericaceae
Alchemilla pedata A. Rich.	Rosaceae	*Hypericum quartinianum* A. Rich.	Hypericaceae
Allophyllus abyssinicus (Hochst.) Radik.	Sapindaceae	*Hypericum revolutum* Vahl	Hypericaceae
Aloe camperi Schweinf.	Aloaceae	*Hypoestes forskaolii* (Vahl.) R. Br.	Acanthaceae
Aloe pulcherrima Gilbert & Sebsebe	Aloaceae	*Hypoestes triflora* (Forssk.) Roem.& Schult.	Acanthaceae
Amaranthus graecizans L.	Amaranthaceae	*Inula confertiflora* A. Rich.	Asteraceae
Andropogon abyssinicus Fresen.	Poaceae	*Jasminum grandiflorum* L.	Oleaceae
Anethum graveolens L.	Apiaceae	*Juniperus procera* L.	Cupressaceae
Anthemis tigreensis L.	Asteraceae	*Justicia schimperiana* (Hochst. ex Nees.) T. Anders.	Acanthaceae
Anthoxanthum aethopicum I Hedberg	Poaceae	*Kalanchoe petitlana* A. Rich.	Crassulaceae
Argyrolobium arabicum (Decne.) Iaub. & Spach.	Fabaceae	*Kalanchoe marmorata* Bak.	Crassulaceae
Arthraxon prionodes (Steud) Dandy	Poaceae	*Kalanchoe quartiniana* A. Rich.	Crassulaceae
Asparagus africanus Lam.	Asparagacea	*Kniphofia foliosa* Hochst.	Asphodelaceae
Asplenium ethiopicum	Aspleniaceae	*Laggera crispata* (Vahl.) Hepper. & Wood.	Asteraceae
Barleria ventricosa Hochst.ex Nees.	Acanthaceae	*Laggera tomentosa* (Sch.Bip.ex A.Rich.) Olivo.& Hiern.	Asteraceae
Bersama abyssinica Fresen.	Melianthaceae	*Lippiali adoensis* Hochst.ex Walp.	Verbenaceae
Bidens pilosa L.	Asteraceae	*Malva verticilata* L.	Malvaceae
Bidens prestinaria (Sch. Bip) Cufod.	Asteraceae	*Maytenus arbutifolia* (A. Rich.) Wilczek.	Celastraceae
Buddleja Polystachya Fresen.	Loganiaceae	*Maytenus senegalensls* (Lam.) Exell.	Celastraceae
Caesalpinia decapetala (Roth) Alston.	Fabaceae	*Medicago polymorpha* L.	Fabaceae
Calpurnia aurea (Ait.) Benth.	Fabaceae	*Melinis repens* (Willd.) Zizka	Poaceae
Capparis persicifolia Lam.	Capparidaceae	*Merendera schimperiana* Hochst.	Colchicaceae
Carissa spinarum L.	Apocynaceae	*Momordica foetida* Schumach.	Cucurbitaceae
Cassipourea malosana (Baker) Alston	Rhizoghoracea	*Myrica salicifolia* A.Rich.	Myricaceae
Caylusia abyssinica (Fresen.) Fisch. & Mey.	Resedaceae	*Myrsine africana* L.	Myrsinaceae
Celtis africana Burm. F.	Ulmaceae	*Nuxia congesta* R.Br.ex Fresen.	Loganiaceae
Cheilanthes farinosa (Forssk.) Kaulf.	Sinopteridaceae	*Ocimum lamiifolium* Hochst.ex Benth.	Lamiaceae
Cineraria abyssinica Sch. Bip. ex A. Rich.	Asteraceae	*Olea europaea* subsp *cuspidata* (Wall. Ex DC.) Cifferri.	Oleaceae
Clematis hirsute Perro & Guill.	Ranunculaceae	*Olinia rochetiana* A. Juss.	Oliniaceae
Clematis simensis Fresen.	Ranunculaceae	*Osyris quadripartita* Decne	Santalaceae
Clerodendrum myricoides (Hochst.) Vatke.	Lamiaceae	*Otostegia fruticosa* (Forssk.) Schweinf. ex Penzig.	Lamiaceae

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Botanical Name	**Family Name**	***Botanical Name***	**Family Name**
Clutia abyssinica Jaub.& Spach.	Euphorbiaceae	*Pavetta abyssinica* Fresen.	Rubiaceae
Commelina africana L.	Commelinaceae	*Pennisetum thunbergii* Kunth.	Poaceae
Conium maculatum L.	Apiaceae	*Pentaschistis pictigluma* (Steud.) Pilg.	Poaceae
Conyza abyssinica Sch.Bip. ex A. Rich.	Asteraceae	*Peperomia abyssinica* Miq.	Piperaceae
Cordia africana Lam.	Boraginaceae	*Periploca linerifolia* Quart.Dill. &A.Rich.	Asclepiadaceae
Cotula abyssinica Sch.Bi.ex A. Rich.	Asteraceae	*Physalis peruviana* L.	Solanaceae
Crassocephalum macropappum (Sch.Bip.ex A. Rich.) S. Moore.	Asteraceae	*Phytolacca dodecandra* L. Herit.	Phytolaccacea
Craterostigma pumilum Hochst.	Scrophulariaceae	*Pittosporum viridiflorum* Sims.	Pittosporaceae
Crepis rueppellii Sch.Bip.	Asteraceae	*Plantago lanceolata* L.	Plantaginaceae
Crotalaria lachnophora Hochst. ex A. Rich.	Fabaceae	*Plectranthus lanuginosus* (Hochst. ex Benth.)	Lamiaceae
Croton macrostachyus Del.	Euphorbiaceae	*Podocarpus falcatus* (Thun.) Mirb.	Podocarpaceae
Cupressus lusitanica Miller.	Cupressaceae	*Polygala steudneri* Chod.	Polygalaceae
Cynodon dactylon (L.) Pers.	Poaceae	*Premna schimperi* Engl.	Lamiaceae
Cynoglossum coeruleum Hochst. ex A. DC in DC.	Boraginaceae	*Prunus africana* (Hook.f.) Kalkm.	Rosaceae
Cynoglossum lanceolatum Forssk.	Boraginaceae	*Psydrax schimperiana* (A.Rich.) Bridson.	Rubiaceae
Cyperus fischerianus A. Rich.	Cyperaceae	*Pterolobium stellatum* (Forssk.) Brenan	Fabaceae
Cyphostemma adenocaule (Steud. ex A. Rich.)	Vitaceae	*Rhamnus prinoides* L. Herit.	Rhamnaceae
Dichondra repens J.&G. Forst.	Convolvulaceae	*Rhoicissus tridedtata* (L.f) Wild. & Drummond	Vitaceae
Discopodium penninervium Hochst.	Solanaceae	*Rhus glutinosa* A. Rich.	Anacardiaceae
Dodonaea angustifolia L. f.	Sapindaceae	*Rhus retinorrhoea* Oliv.	Anacardiaceae
Dombeya torida (J.F. Gmel.) P. Bamps.	Sterculiaceae	*Rhus vulgaris* Meikle	Anacardiaceae
Dovyalis abyssinica (A. Rich.) Warb.	Flacourtiaceae	*Rosa abyssinica* Lindley	Rosaceae
Dovyalis caffra (Hook.f & Harv.) Hook. f	Flacourtiaceae	*Rubia cordifolia* L.	Rubiaceae
Ekebergia capensis Spamn.	Meliaceae	*Rubus Steudneri* Schweinf.	Rosaceae
Eleusine floccifolia (Forssk.) Spreng.	Poaceae	*Rumex nepalensis* Spreng.	Polygonaceae
Enchinops Kebercho Mesfln	Asteraceae	*Rumex nervosus* Vahl.	Polygonaceae
Epilobum hirsutum L.	Onagraceae	*Salvia merjamie* Forssk.	Lamiaceae
Eragrostis racemosa (Thun.) Steud.	Poaceae	*Salvia nilotica* Jacq.	Lamiaceae
Eragrostis schweinferthii Chiov.	Poaceae	*Satureja abyssinica* (Benth.) Briq.	Lamiaceae
Erica arborea L.	Ericaceae	*Satureja punctata* (Benth.) Briq.	Lamiaceae

Appendix 1: List of plants recorded in Bosena Forest

Botanical Name	**Family Name**	***Botanical Name***	**Family Name**
Euclea racemosa Murr.	Ebenaceae	*Saturja paradox* (Vatke) Engl. ex Seybold.	Lamiaceae
Euphorbia ampliphylla Pax.	Euphorbiaceae	*Scabiosa columbaria* L.	Dipsacaceae
Euphorbia dumalis S. Carter	Euphorbiaceae	*Senecio lyratus* Forssk.	Asteraceae
Euphorbia tirucalli L.	Euphorbiaceae	*Senra incana* Cay.	Malvaceae
Ferula communis L.	Apiaceae	*Setaria Sphacelata* (Schumach.) Moss.	Poaceae
Festuca abyssinica Hochst. ex A. Rich.	Poaceae	*Sida schimperiana* Hochst.ex A .Rich.	Malvaceae
Ficus glumosa Del.	Moraceae	*Snowdenia petitiana* (A. Rich.) C. E. Hubb.	Poaceae
Ficus sur Forssk.	Moraceae	*Solanecio gigas* (Vatke.) C. Jeffrey.	Asteraceae
Foeniculum vulgare Mill.	Apiaceae	*Solanum dasyphyllum* Schumach.	Solanaceae
Galiniera saxifraga (Hochst.) Bridson.	Rubiaceae	*Solanum nigrum* L.	Solanaceae
Galinsoga parviflora Cav.	Asteraceae	*Solanum anguivi* Lam.	Solanaceae
Galium aparinoides Forssk.	Rubiaceae	*Stephania abyssinica* (Dillon. & A. Rich.) Walp.	Menispermaceae
Galium thunbergianum Eckl. & Zeyh.	Rubiaceae	*Trgia cinerea* Gilbert & Radcl.-Smith.	Euphorbiaceae
Geranium aculeolatum Olivo.	Geraniaceae	*Trifolium campestre* Schreb.	Fabaceae
Geranium arabicum Forssk.	Geraniaceae	*Turraea holstii* Gurke.	Meliaceae
Gomphocarpus purpurascens A. Rich.	Asclepiadaceae	*Urera hypselodendron* (A. Rich.) Wedd.	Urticacea
Guizotia scabra (Vis.) Chiov.	Asteraceae	*Urtica simensis* Steudel.	Urticaceae
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	*Verbascum sinaiticum* Benth.	Scrophulariaceae
Halleria lucidal L.	Scrophulariaceae	*Vernonia leopoldi* (Sch Bip. ex Walp.) Vatke.	Asteraceae
Haplocarpha schimperi (Sch. Bip.) Beauv.	Asteraceae	*Withania somnifera* (L.) Dunal.	Solanaceae
Helichrysum schimperi (Sch. Bip. ex A. Rich.)	Asteraceae	*Zehneria scabra* (Linn.f.) Sond.	Cucurbitaceae

Podocarpus falcatus, Ficus sur and Ehretia cymosa; Senra incana Clutia abyssinica, Phytolacca dodecandra, Discopodium penninervum and *Dovyalis caffra* are the dominant shrubs and *Helichrysum schimperi* and *Laggera tomentosa* are found to be the dominant herbs.

Community type-II occurs at a relatively lower altitude. *Olea europaea, Pittosporum viridiflorum, Nuxia congesta* and *Bersama abyssinica* are the dominant tree species. *Rhus glutinosa, Grewia ferruginea, Allophyllus abyssinicus, Jasminum grandiflorum* and *Clerodendrum myricoides* are the dominant shrubs*; Argyrolobium arabicum ,Crassocephalum macropappum , Asplenium ethiopicum* and *Arthraxon prionodes* are the dominant herbs.

Juniperus procera, Olinia rochetiana and *Crassocephalum macropappum* are the dominant tree species in community type-III. *Myrsine africana* and *Dodonaea angustifolia* are the dominant shrubs. *Clematis hirsuta* and *Stephania abyssinica* are the dominant lianas. *Scabiosa columbaria Hyparrhenia hirta* and *Saturja paradox* are the dominant herbs.

Community-Environmental Variables Relationships:

Several studies showed that there is a strong relationship between floristic composition and diversity to environmental gradients (Schmitt et al. 2010; Aynekulu et al., 2012). Similarly, results showed significant differences ($P < 0.05$) with respect to elevation and slope. Elevation is the major discriminating variable and the slope is next to altitude. Generally, the values of α diversity measures were higher for community type III (2400 and 2900 m), these result are in agreement with Aynekulu et al. (2012).

In conclusion, the present study provides additional evidence with respect to the contribution of forest patch in harboring plant species. Despite variation in species composition and diversity, Susgen-Bosena forest contains 180 species of vascular plants. This study has argued that there are three distinct plant community types in the study forests. This study has identified that the density of tree species in the forest decreases with increasing DBH and Height classes, which shows that the forest of Yegof and the surrounding patches are in the second stage of development. This implies that the forest is not primary forest in which human interference prevails. Based on the finding of this study the following recommendation are forwarded for better management of Susgen- Bosena Patch Forest: (i) Enrichment planting for species that have low densities or broken population structures is required; (ii) Species having a higher value of IVI and density per hectare can be used for mother tree selection. (iii) The present study was limited to floristic composition and structure of woody plants. This requires further studies on disturbance, and land use management system in the area

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