

Full Length Research Paper

Floristic composition, vegetation structure and regeneration status of Wabero forest, Oromia Regional State, Southeastern Ethiopia

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Wabero forest is one of the very few remnant moist evergreen montane forests in Southeast Ethiopia. However, basic data on vegetation structure and composition of the forest that could provide valuable information for possible conservation measures is lacking. The main objective of this study, therefore, was to investigate the woody species composition, vegetation structure and regeneration status of the forest. In the study 30 quadrants of 20 m by 20 m were used for woody species data and 5 m by 5 m for sapling and seedling in a nested form. The sample quadrants were laid down along transects at a distance of 300 m from each other. Diameters at breast height (DBH), basal area, frequency and importance value index were used for analysis of vegetation structure. In the study, a total of 47 woody plant species belonging to 43 genera and 33 families were recorded. The major families were Rubiaceae and Rutaceae each represented by four species followed by Sapindaceae, Moraceae and Oleaceae each represented by three species. The rest of the 28 families were represented by one or two species, only. The mean density of all the woody species recorded in the study site was 21,737 ha⁻¹. *Diospyros abyssinica*, *Podocarpus falcatus*, *Strychnos mitis*, *Celtis africana* and *Coffea arabica* were found to be the most dominant and frequent species with the highest importance value index. Results of regeneration status of the forest, which was analyzed by comparing number of seedling and sapling with mature trees, revealed that the forest is under good regeneration status. Therefore, based on the results of the study, awareness creation and implementation of participatory forest management strategy is recommended in order to sustain the forest.

Key words: Basal area, diameters at breast height (DBH), importance value index, Montane forest, woody species composition.

INTRODUCTION

Ethiopia is one of the tropical countries with highest floral diversity (Motuma et al., 2010). Between; 6,000-7,000 species of higher plants are estimated to exist in the country of which about 780-840 (12-13%) plant species are estimated to be endemic (Demel, 2001). However,

these biologically rich resources of Ethiopia are vanishing at an alarming rate due to extensive deforestation. It was mentioned that once upon a time about 35% of Ethiopia's land area was covered with forest (EFAP, 1994). Early 1950's, the area covered by forest in Ethiopia



Figure 1. Map of Wabero forest, Dello-mena district, Oromia.

estimated to be 9 million ha (16% of the land area) and in the 1980's; it was reduced to 3.6% and by 1989 to 2.7% (Gessesse, 2010). Even though several factors contribute for destruction of natural forests in Ethiopia, agricultural expansion is probably the dominant force (Mulugeta and Demel, 2006). This will result in the loss of biodiversity resources along with their habitats (Senbeta and Denich, 2006). Moreover, destruction of forests has an adverse effect on the environment, such as soil degradation, soil erosion and alteration of natural resources. Since forest serves as a source of food, household energy, construction and agricultural material, tourism and recreation values and medicines, its loss would have impact on the socio-economic setup of the communities (Hundera et al., 2007).

Ecological investigation of species composition and vegetation structure of a forest is essential to provide information on type of species of the forests, identify economically and ecologically useful plant species as well as to identify the most threatened ones for management and conservation (Tesfaye et al., 2013). The present study, therefore, stems from this understanding and aimed at studying species

composition and vegetation structure of Wabero forest.

MATERIALS AND METHODS

Description of the study area

The study was conducted on Wabero forest, which is located in Dello-mena district of Bale zone of Oromia Regional National State (Figure 1). The forest is located between 6° 27' 240" to 6° 31' 673" N latitude and 39° 42' 883" to 53° 26' 320" E. Its altitudinal range is between 1500-2500 m above sea level. The mean annual rainfall of the area is 700 mm. The mean annual minimum and maximum temperatures of the area ranges between 21 and 38°C while the mean annual temperature is about 29.5°C.

Sampling design

A systematic sampling technique was used to collect vegetation data in the Forest. In the present study, quadrats of 20 m × 20 m size were laid for woody species and subplots of 5 m × 5 m for seedling and sapling study. The subplots were laid at the four corners and one at the center of the large quadrat. Plots were laid systematically at every 300 m along transect lines, which were 1000 m apart from each other.

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Table 1. Density and percent contribution of five woody species in Wabero forest.

Species name	Density (ha ⁻¹)	%
<i>Strychnos mitis</i>	2521.42	11.60
<i>Diospyros abyssinica</i>	2350.82	10.82
<i>Celtisafricana</i>	2314.10	10.65
<i>Coffea arabica</i>	2093.32	9.63
<i>Podocarpusfalcatus</i>	1882.50	8.44
The rest 46 species	10574.89	48.64
Total	21737.00	100

Data collection

In each quadrat, all plant species were recorded. In addition, woody plant species occurring outside quadrats laid were also recorded only as 'present', but not used in the subsequent data analysis. Plant specimens were identified and deposited at the National Herbarium of Ethiopia (ETH), Addis Ababa University. In each plot, diameters at breast height (DBH) of all woody plant species with DBH ≥ 2.5 cm were measured. Individuals having DBH less than 2.5 cm were counted. Diameter tape was used to measure DBH of all the woody plant at 1.3 m above the ground. GPS (Garmin eTrex) was used to take location and altitude data.

Data analysis

Species importance value (IVI) and basal area were used to describe vegetation structure, tree density, frequency, and DBH. DBH was classified into the following 7 classes: Class-1: 2.5-10 cm, Class-2: 10.1-20 cm, Class-3: 20.1-50 cm, Class-4: 50.1-80 cm, Class-5: 80.1-110 cm, Class-6: 110.1-140 cm, and Class-7: >140 cm (Tesfaye et al., 2013). Basal area was calculated using the formula: $BA = \pi (d/2)^2$, where d is diameter at breast height. Density (number of individuals of a species within the sample area) was computed on hectare basis. Frequency calculated by dividing number of plots in which species "n" occurs by total number of sampled plots. In addition, relative density was calculated by dividing density of species "n" by total density of all species multiplied by 100. Relative dominance was calculated by dividing dominance for species "n" over total dominance of all species and multiplied by 100. Relative frequency was estimated by dividing the frequency value for species "n" by total of all frequency values for all species and then multiplied by 100. Finally, Importance Value Index (IVI) was computed as a summation of relative density, relative dominance and relative frequency.

RESULTS AND DISCUSSION

Floristic composition

A total of 47 woody plant species belonging to 33 families were identified in the 30 plots. Among these, families Rubiaceae and Rutaceae were relatively the two most dominant species-rich families, each represented by four species. Sapindaceae, Moraceae and Oleaceae were the second most species-rich families represented by three species. All the other families were represented only by one or two species (Appendix Table 1).

Vegetation structure

For the description of the vegetation structure of Wabero forest woody species whose DBH > 2.5 cm were selected and measured. The total density of woody species of the forest was estimated to be 21.737 ha⁻¹. The five densest species in the forest were *Strychnos mitis* (2521.42 density ha⁻¹), *Diospyros abyssinica* (2350.82 density ha⁻¹), *Celtis africana* (2314.1 density ha⁻¹), *Coffea arabica* (2093.32 density ha⁻¹), *Podocarpus falcatus* (1882.5 density ha⁻¹). These five species contributed to 51.4% and the remaining 46 species together accounted for 10574.89 density ha⁻¹ (48.6%) (Table 1). Among all woody species, *Allophylus abyssinicus* and *Acalypha volkensii* were species with the lowest densities (13.2 and 15.7 individuals ha⁻¹, respectively).

DBH class distribution

The different DBH class distribution of woody species in Wabero forest is given in Figure 2. The number of individuals in DBH class less than 10 cm is 5007 per ha. The number of individuals gradually decreases toward the higher DBH classes as the DBH class size increases. DBH class distribution of all individuals in different size classes showed a reversed J-shape distribution (Figure 2). The current funding suggests the existence of good reproduction and recruitment potential of woody species in Wabero forest. The result is in agreement with that of Tesfaye et al. (2013).

Basal area

The total basal area of Wabero Natural Forest is 88.89 m²ha⁻¹ (Table 2). About 43.06 m²ha⁻¹ (48.43%) of the total basal area was covered by eight tree species: *D. abyssinica* (9.11%), *P. falcatus* (9.49%), *S. mitis* (7.03%), *Mimusops kummel* (6.12%), *Filicium decipiens* (4.34%), *Olea welwitschii* (4.22%), *C. africana* (4.08), and *Galiniera saxifrage* (4.04). However, the remaining 43 species together contributed for 45.83 m²ha⁻¹ (51.57%) of total basal area. The species with the largest contribution

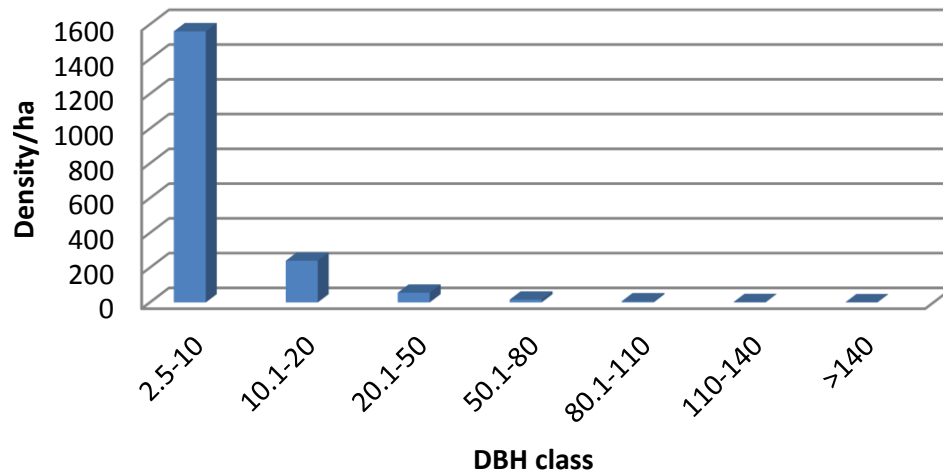


Figure 2. Density of individuals under different DBH classes.

Table 2. The highest basal area (m^2ha^{-1}) of species.

S/N	Scientific name	Basal area (m^2ha^{-1})	%
1	<i>Podocarpus falcatus</i>	8.44	9.49
2	<i>Diospyros mespiliformis</i>	8.09	9.11
3	<i>Strychnos mitis</i>	6.25	7.03
4	<i>Mimusops kummel</i>	5.44	6.12
5	<i>Filicium decipiens</i>	3.86	4.34
6	<i>Olea welwitschii</i>	3.75	4.22
7	<i>Celtis africana</i>	3.63	4.08
8	<i>Galiniera saxifraga</i>	3.60	4.04
9	The remaining 43 species contributed	45.83	51.57
Total		88.89	

Table 3. The five highest frequented species in study area.

S/N	Scientific Name	Family of species	Relative frequency (%)
1	<i>Celtisafricana</i>	Ulmaceae	6.83
2	<i>Diospyros mespiliformis</i>	Ebenaceae	6.68
3	<i>Coffea arabica</i>	Rubiaceae	6.30
4	<i>Strychnos mitis</i>	Podocarpaceae	6.19
5	<i>Podocarpus falcatus</i>	Loganiaceae	5.87

in basal area can be considered the most important woody species in the forest.

The basal area of Wabero Forest ($88.89 \text{ m}^2 \text{ha}^{-1}$) is greater than basal area of many forests in Ethiopia. As Tesfaye et al. (2013) reported that the value of Masha Anderacha ($49.80 \text{ m}^2 \text{ha}^{-1}$), Dindin ($49 \text{ m}^2 \text{ha}^{-1}$), Alata-Bolale ($53.33 \text{ m}^2 \text{ha}^{-1}$) and Jibat Natural Forest ($60.9 \text{ m}^2 \text{ha}^{-1}$). However, basal area of Wabero Natural Forest is less than that of Belete Natural forest ($90.6 \text{ m}^2 \text{ha}^{-1}$).

Frequency

Frequency is the number of quadrats in which a given species occurred in the study area. Based on the results the five most frequently observed woody species in the forest (Table 3) were *C. africana* (6.83%), *D. abyssinica* (6.68%), *C. arabica* (6.3%), *S. mitis* (6.19%), and *P. falcatus* (5.87%). Moreover, the three lowest percent frequency species were *Trichilia emetic*, *A. abyssinicus*

Table 4. Important Value Index (IVI) of the first five most important woody species.

S/N	Scientific name	RD (%)	RF (%)	RDO (%)	IVI
1	<i>Diospyros mespiliformis</i>	10.87	6.68	9.87	27.40
2	<i>Strychnos mitis</i>	11.68	6.19	7.62	25.40
3	<i>Podocarpus falcatus</i>	8.66	5.87	10.30	24.80
4	<i>Celtis africana</i>	10.58	6.83	4.43	21.80
5	<i>Coffea arabica</i>	9.62	6.30	3.21	19.10

RD=Relative Density, RDO=Relative Dominance, RF=Relative Frequency.

and *A. volkensii* and each constituting less than 0.25% relative frequency. Frequency gives an approximate indication for homogeneity and heterogeneity of vegetation. As Lamprecht (1989) pointed out that high value in high frequency and lower value in the lower frequency classes indicate vegetation homogeneity. Conversely, high percentage of number of species in the lower frequency class and low percentage of number of species in the higher frequency classes indicates high degree of floristic heterogeneity (Simon and Girma 2004).

Species importance value index (IVI)

Based on their IVI value, *D. abyssinica* (27.4), *S. mitis* (25.4), *P. falcatus* (24.8), *C. africana* (21.8) and *C. arabica* (19.1), respectively, were the leading, the highest IVI, and ecologically most significant woody species in Wabero Natural forest (Table 4). These species might also be the most successful species in regeneration, pathogen resistance, growth in shade, and competition with other species, least preferred by animals, least attracted by pollinators and seed predators that facilitate seed dispersal within the existing environmental conditions of the study area. In contrast, the woody species, which exhibited the lowest IVI values ($IVI < 1$), were *Ficus sycomorus*, *Ficus thonningii* Blume, *Carrisa spindrum*, *Trema guineensis*, *Vernonia amygdalina*, *A. volkensii*, and *A. abyssinicus*. According to Curtis and McIntosh (1951), IVI gives a more realistic figure of dominance from structural point of view. It is also useful to compare the ecological significance of species (Lamprecht, 1989) where a high IVI value indicates that the species sociological structure in the community is high. As a result, ecologists consider IVI as one of the most important tool in a vegetation study (Curtis and McIntosh, 1951).

Population structure of the forest

The study revealed that the woody species recorded from the study site demonstrated more or less the same patterns of population structures. The documented woody species have shown stable population structures

composed of the highest density of individuals at the lowest DBH class followed by gradually declining densities of individuals with increasing DBH classes (Figure 3). Information on population structure of a tree species indicates the history of the past disturbance of that species and the environment; and hence, is used to forecast the future trend of the population of that species. According to Simon and Girma (2004), population structure has significant for sustainable use and conservation of the forest.

Regeneration status of the forest

Regeneration status of the forest was analyzed by comparing seedling and saplings with mature trees according to Dhaukhundi et al. (2008) and Tiwari et al. (2010). In Wabero forest the seedling, sapling, and matured tree accounted for 69, 23, and 8% density ha^{-1} of individuals, respectively (Figure 4). Density ha^{-1} of individuals of species showed that the seedling >sapling> matured tree in the forest. According to Dhaukhundi et al. (2008), the density values of seedling and saplings are considered as regeneration potential of the species. Based on the criteria of Dhaukhundi et al. (2008) and Tiwari et al. (2010) the forest of Wabero is categorized among forests with good regeneration potential.

Conclusion

Wabero forest is one of the remnant natural forests in southeastern Ethiopia. It consists of 47 woody species belonging to 33 families. Rubiaceae and Rutaceae were the two most species-rich families. Among the collected woody species, *D. abyssinica*, *P. falcatus*, *S. mitis*, *C. africana* and *C. arabica* were found to be the most dominant and frequent species with the highest importance value index. Results of regeneration status of the forest, which was analyzed by comparing number of seedling and sapling with mature trees, revealed that the forest is in good regeneration status. Therefore, the government, NGO and the community should work jointly in order to save and use the forest resources in a sustainable manner.

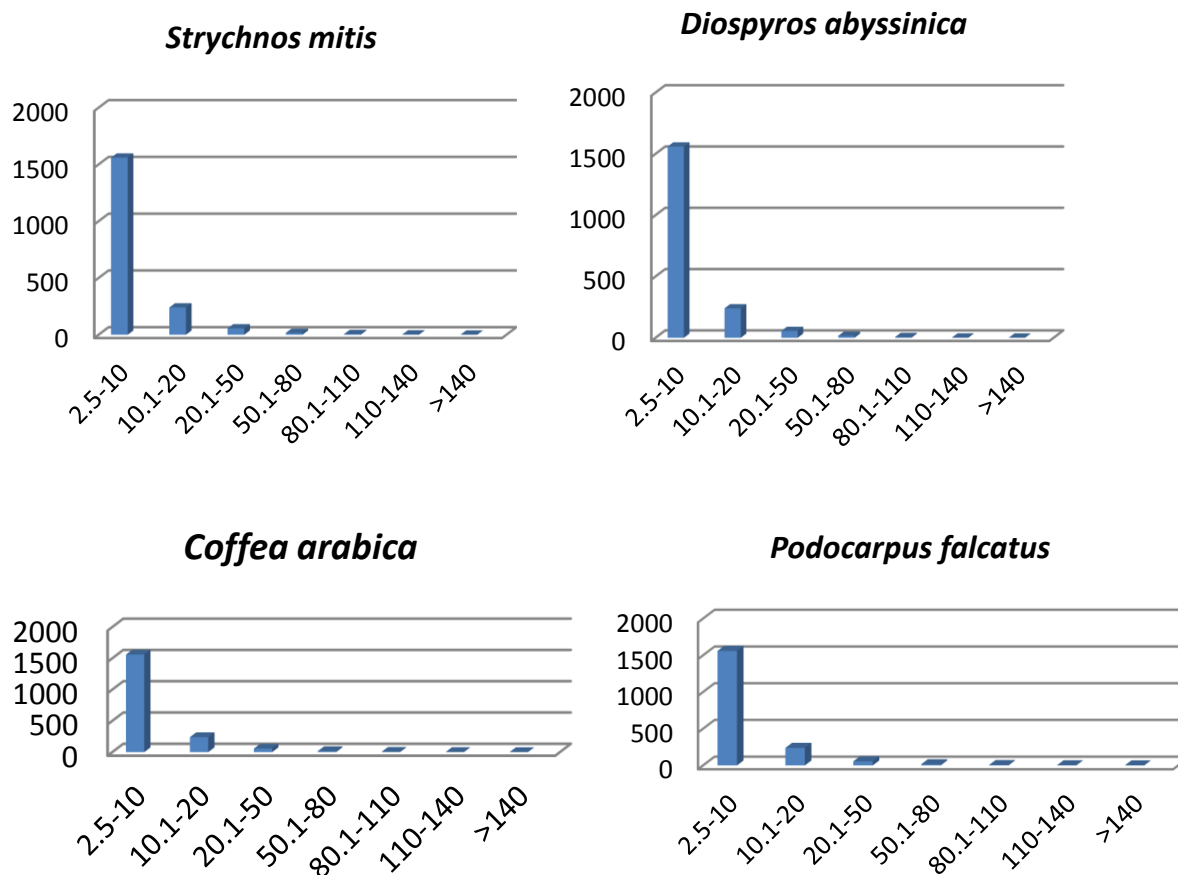


Figure 3. Vegetation structure of five woody species in Wabero forest.

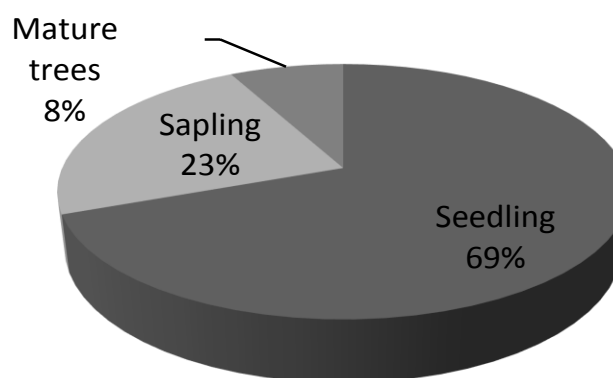


Figure 4. Density ha⁻¹ of seedling, sapling and mature trees.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix Table 1. List of woody plant species in Wabero forest.

Scientific name	Family name
<i>Acalypha volkensii</i>	Euphorbiaceae
<i>Allophylus abyssinicus</i>	Sapindaceae
<i>Apodytes acutifolia</i>	Icacinaceae
<i>Bersama abyssinica</i>	Melanthaceae
<i>Buddleia polystachya</i>	Buddlejiaceae
<i>Calpurina aurea</i>	Fabaceae
<i>Canthiune uryoides</i>	Rubiaceae
<i>Capparis tomentosa</i>	Capparidaceae
<i>Carrisa spindrum</i>	Apocynaceae
<i>Cassipourea malosana</i>	Rhizophoraceae
<i>Celtis africana</i>	Ulmaceae
<i>Citrus aurantium</i>	Rutaceae
<i>Coffea arabica</i>	Rubiaceae
<i>Cordia africana</i>	Boraginaceae
<i>Croton macrostachyus</i>	Euphorbiaceae
<i>Diospyros abyssinica</i>	Ebenaceae
<i>Dobera glabra</i>	Salvadoraceae
<i>Ehretia cyamosa</i>	Boraginaceae
<i>Euclea schinperi</i>	Ebenaceae
<i>Fagaropsis angolensis</i>	Rutaceae
<i>Ficus sur</i>	Moraceae
<i>Ficus sycomorus</i>	Moraceae
<i>Galiniera saxifraga</i>	Rubiaceae
<i>Mimusops kummel</i>	Sapotaceae
<i>Myrsine africana</i>	Myrsinaceae
<i>Mytenus senegalensis</i>	Celastraceae
<i>Ococotea kenyensis</i>	Lauraceae
<i>Olea capensis</i>	Oleaceae
<i>Olea welwitschii</i>	Oleaceae
<i>Olinia rochetiana</i>	Oliniaceae
<i>Podocarpus falcatus</i>	Podocarpaceae
<i>Pouteria adolf-friedericii</i>	Sapotaceae
<i>Poyiscias fulva</i>	Araliaceae
<i>Pruns africanus</i>	Rosaceae
<i>Rhamnus prinoids</i>	Rhamenaceae
<i>Rhus ruspolii</i>	Anacardiaceae
<i>Rothmanniaur celliformis</i>	Rubiaceae
<i>Schrebera alata</i>	Oleaceae
<i>Strychnos mitis</i>	Loganiaceae
<i>Syzygium macrocarpum</i>	Myrtaceae
<i>Teclea nobilis</i>	Rutaceae
<i>Trema guineensis</i>	Ulmaceae
<i>Trichilia emetica</i>	Meliaceae
<i>Vepris dainelli</i>	Rutaceae
<i>Vernonia amygdalina</i>	Astreaceae
<i>Vernonia leopoldi</i>	Astreaceae
<i>Warburgia ugandensis</i>	Canallaceae