ORIGINAL ARTICLE

Woody Species Diversity and Structure of Aba Sena Natural Forest, West Wollega Zone, Ethiopia

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ABSTRACT

Ecological study addressing species richness, diversity and vegetation structure is very important to produce data that could help conservationists to design a conservation strategy in the future. It was with this objective that the study was conducted on Aba Sena Natural Forest before it gets lost. Quadrats of 20m×20m (400 m²) were established at every 25 m elevation interval along five transect lines. Data on woody species richness, diversity, Diameter at breast Height (DBH) and Height were collected from 40 sampling quadrats. Species diversity was analyzed using Shannon-Wiener Diversity Index (H`). Importance value index (IVI) for woody species was determined by summing relative density, relative dominance and relative frequency. Hierarchical cluster analysis was carried out to determine plant community types. Overall, 69 woody species belonging to 67 genera and 36 families were identified. The overall Shannon-Wiener Diversity Index (H`) and the evenness values for the entire forest were 3.76 and 0.62, respectively. The most abundant woody species in their descending order were *Ficus sur, Pouteria adolfriederici, Terminalia macroptera, Ficus vasta, Syzygium guineense* and *Albizia grandibracteata*. The total basal area of the forest was 51.68 m^2 ha^{-1}. Five plant community types with different number of vegetation quadrats were determined using cluster analysis. The current study did not include all aspects of the forest such as species regeneration status, anthropogenic impacts and ethnobotanical contribution of the forest for the local community and hence we recommend farther study on these and other aspects of the forest.

Keywords: Aba Sena; Ecological study; Plant community; Species richness; Woody Species

INTRODUCTION

Ethiopia is one of the biodiversity rich countries in Africa (EFAP, 1994). The number of species of higher plant taxa in Ethiopia is 5757 (excluding Eritrea) of which about 9.4% are endemic to the country (Kelbessa and Demissew, 2014).The unwise use of forest resources in Ethiopia has resulted in forest degradation (Friis, 1992). Ethiopia lost more than two million hectares of forest cover, with an annual average loss of 140, 000 ha from 1990-2005 (FAO, 2015). However, community awareness on the importance of forest resources and its link with biodiversity, ecosystem services and human wellbeing in Ethiopia is increasing. Tree planting campaign has been in place throughout the country on an annual basis since 2008 and as a result forest cover has increased. Between 2010 and 2015 an increase in forested area has been recorded,

with an estimated gain of 40,000 ha/year (FAO, 2015). This partly resulted in a rise of Ethiopian forest cover to 11.5% of the total land area of Ethiopia (FAO, 2015).

Plant species richness is controlled by a variety of biotic and biotic factors (Huston, 1994). Rapid human population growth, poverty, forest clearing for agriculture, over grazing, exploitation of forests for fuel wood and construction materials without replacing and lack of proper policy framework are some of the major factors that contributed to the loss of forest resources in Ethiopia (Denu, 2006). Aba Sena Natural Forest is one of the forest areas in Oromia Regional State of Ethiopia with poor management and high intention of conversion to agricultural land. This study was initiated to gather data and record the woody species richness, diversity and vegetation structure before the forest is lost. This would help to design a sustainable conservation strategy for the forest before it is totally lost.

MATERIAL AND METHOD

The study was conducted on Aba Sena Natural Forest of Gimbi District, West Wollega Zone Oromia Regional State, Western Ethiopia (Figure 1). It is found at about 408 km west of Finfinne/Addis Ababa and at about 32 km east of Gimbi town. Its geographical location is 9°01′-9°17′N and 35°44′-36°09′E. The altitude of the study area ranges from 1300-2222masl. It receives mean annual rainfall of 1000-1800mm and has an average temperature of 24°c-28°c (EMA, 2017). The population of Aba Sena village was 3243; of these 1938 were males and 1305 were females (CSA, 2008).

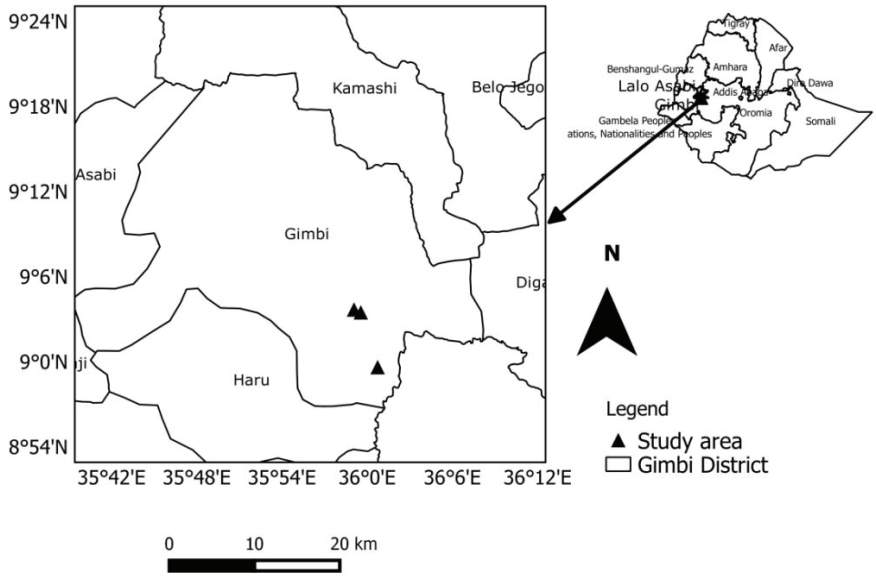

Figure 1. Map of the study area including Ethiopia, Oromia Region, the district and the study site

Research design

A reconnaissance survey was carried out to get overall information about the study site and to make decision where to put transect

lines for the study. Based on the information obtained during the reconnaissance survey, five transect lines were laid following the altitudinal gradients and quadrats of 20m×20m (400m^2) were put at 25m elevation interval.

Vegetation Data collection

Vegetation data on woody species were collected from 20m×20m quadrats. All the woody plant species collected from each sample quadrat were recorded using local names when possible and otherwise coded for later identification. Sample specimens were collected, pressed and taken to Jimma University Herbarium for identification. Species identification was made in the herbarium by using botanical keys. In each quadrat, the diameter of all woody species with DBH ≥ 2.5 cm was measured using diameter tape.

Data Analysis

The species diversity was determined using Shannon Wiener- diversity index (H`). The index takes the species richness and evenness into consideration. Shannon-Wiener Diversity Index (H') was calculated as:

$$H' = -\sum_{k=1}^{n} PilnPi$$

Where P_i is the relative abundance, n = total number of individuals. Species richness was undertaken from all species in all plots. Evenness was calculated by using: E = H'/lnS, where S stands for the number of species.

Diameter at breast height (DBH): was taken at 1.3 m from the ground using a diameter tape. Basal area (BA) was calculated from the diameter measurement using the following formula:

BA = $(DBH/2)^2\pi$, where $\pi = 3.14$

Density: is defined as the number of plants of a certain species per unit area.

$$\text{Relative Density} = \frac{\text{Stem count of a species}}{\text{Stem count of all species}} \times 100$$

Frequency: is defined as the probability or chance of finding a plant species in a given sample area or quadrat. It is calculated as:

$$\text{Percent Frequency} = \frac{\text{Number of quadrats in which a species occur}}{\text{Total number of quadrats}} \times 100$$

The frequencies of the Tree and Shrub species in all 40 quadrats were computed.

$$\text{RelativeFrequency} = \frac{\text{Frequencyofaspecies}}{\text{Frequencyofallspecies}} \times 100$$

Dominance was the product of mean basal areas of trees with the total numbers of trees per species while relative dominancy was given by the formula:

$$\text{Relativedominance} = \frac{\text{Dominanceoftreespecies}}{\text{Dominanceofthewholespecies}} \times 100$$

Importance Value Index (IVI) was computed from relative density, relative dominance and relative frequency as:

IVI = Relative Density + Relative Frequency + Relative Dominance

This index helps for comparison of stands in referring to species composition and

stand structure.

Plant community analysis

Plant community types were determined by hierarchical cluster analysis using PC-ORD ecological program. Bray-Curtis was used as a distance measure and group average as a group linkage method. Communities were named by two species having relatively higher cover abundance values.

RESULT

Woody species composition

Overall, 69 woody species belonging to 67 genera and 34 families were collected and identified from Aba Sena Forest. Of these, 51 (ca.74%) were trees, while 18 (ca.26%) were shrubs. Asteraceae was the species rich family (n = 7) followed by Moraceae, Fabaceae, Rubiaceae, Combretaceae and Euphorbiaceae with 5 species each. Rutaceae, Celastraceae, Sapotaceae, Myrtaceae, Tiliaceae and Apocyanaceae were composed of 2 species each. Each of the remaining families was represented by one species. The Shannon-Wiener Diversity Index (H`) for Aba Sena Natural Forest with species richness of 69 was 3.76, while the evenness was 0.62.

Density of Woody Species

The overall density of woody species of Aba Sena Forest was 819ha^{-1}. Ten woody species with the highest density in decreasing order were *Pouteria adolfi-friederici*, *Combretum molle*, *Ficus sur*, *Terminali amacroptera*, *Stereospermum kunthianum*, *Dombeya quinqueseta*, *Ochna holstii, Terminalias chimperiana, Gardenia ternifolia* and *Millettia ferruginea* were poorly represented in this study.

Basal Area

The total basal area of Aba Sena Forest was 51.68 m^2 ha^{-1}. Species with higher basal area could be considered as the most important species in the study forest. *Ficus sur*, *Pouteria adolfi-friederici, Terminalia macroptera*, *Ficus vasta*, *Syzygium guineense subsp. afromontanum*, *Ochna holstii* and *Albizia grandibracteata* (Table 1) *contributed* more to the BA of Aba Sena Natural Forest.

Table 1. Woody species with BA>1ha^{-1} in Aba Sena Natural Forest

Species	BA	BA/ha^{-1}	Dom	R.Dom	Rank
Ficus sur	14.68	9.17	5.73	17.75	1
Pouteria adolfi-friederici	6.81	4.25	2.66	8.23	2
Terminalia macaroptera	5.68	3.55	2.22	6.86	3
Ficus vasta	5.6	3.5	2.19	6.77	4
Syzygium guineense subsp. afromontanum	3.38	2.11	1.32	4.09	5
Ochna holstii	3.35	2.09	1.31	4.05	6
Ficus ovata	3.21	2.01	1.25	3.88	7
Albizia grandibracteata	3.11	1.94	1.22	3.76	8
Sapium ellipticum	2.86	1.79	1.12	3.46	9
Warburgia ugandensis	2.73	1.71	1.07	3.31	10
Combretum molle	2.61	1.63	1.02	3.16	11
Bridelia micrantha	2.53	1.58	0.99	3.06	12
Podocurpus falcatus	2.13	1.33	0.83	2.58	13
Albizia schimperiana	2.02	1.26	0.79	2.45	14
Dombeya quinqueseta	2.01	1.26	0.79	2.43	15
Grewia bicolar	1.96	1.23	0.77	2.38	16
Combretum molle	1.78	1.11	0.7	2.16	17
Celtis africana	1.77	1.1	0.69	2.14	18
Stereospermum kunthianum	1.76	1.1	0.69	2.13	19
Mimusops kummel	1.61	1.01	0.63	1.95	20
Ficus sycomorus	1.46	0.91	0.57	1.77	21
Cordia africana	1.44	0.9	0.56	1.74	22
Croton macrostachyus	1.14	0.71	0.44	1.37	23

Key: BA = basal area, Dom = Dominance, R.Dom = relative dominance

Frequency

The woody species with the highest occurrence in the study area were *Combretum molle* and *Ficus sur* followed by *Pouteria adolfi-friederici, Stereospermum kunthianum* and *Mimusops kummel.*

Diameter class of woody species

The general pattern of DBH class distribution of wood species in Aba Sena Natural Forest showed an inverted J-curve distribution. This pattern of DBH classes indicates a good potential of reproduction and recruitment of the forest.

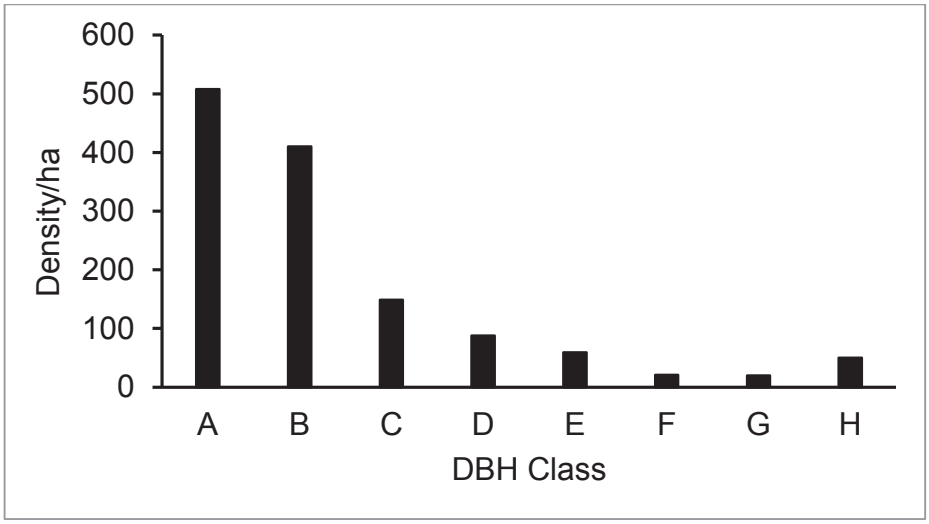

Figure 2. Density ha^{-1} of woody species in DBH classes (A = 2.5-10 cm, B = 10.1-20 cm, C = 20.1-30 cm, D = 30.1-40 cm, E = 40.1-50 cm, F = 50.1-60 cm, G = 60.1-70 cm, H >70cm)

The highest woody species density ha^{-1} was recorded for the DBH class 2-5cm while the least (1.5%) was recorded for DBH class 30.1-35 cm. About 39% of individuals are in the lower DBH class (2-5cm). Species like *Ficus sur*, *Pouteria adolfi-friederici*, *Terminalia macroptera*, *Ficus vasta, Syzygium guineense*, *Ochna holstii*, *Ficus ovata*, *Albizia grandibracteata*, *Sapium ellipticum* and *Warbur giaugandensis* were found in the higher DBH classes. The middle DBH classes were also dominated by these species.

Height class distributions

The height class distribution of woody species in Aba Sena Natural Forest indicated that about 67% of the individual woody stems were in the height class less than 10m (Figure 3). Trees representing the highest height classes, dominating the upper canopy, were *Pouteria adolfi-friederici*, *Prunus africana*, *Ficus sur*, *Albizia grandibracteata*, *Warburgia ugandensis* and *Terminalia macaroptera*. *Pouteria adolfi-friederici* is the emergent tree and grows above all the canopy trees in Aba Sena Natural Forest. Generally, the highest proportion of species is concentrated in the lower height (lower story) class followed by the middle height (middle story) and upper height (upper story) classes.

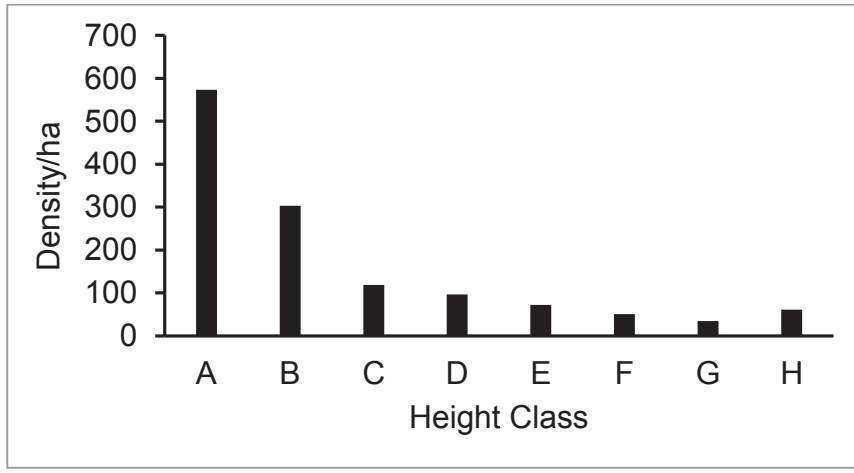

Figure 3. Density of woody species in different height classes (A = 2-5m, B = 5.1-10m, C = 10.1-15m, D = 15.1-20m, E = 20.1-25m, F = 25.1-30m, G = 30.1-35m, H =>35m)

Important Value Index

The ten most important woody species with the highest Important Value Index **(**IVI) in decreasing order are shown in Table2.

Table 2. Ten top woody species in terms of IVI in Aba Sena Natural Forest

Species	R. Den	R. Dom	RF	IVI
Ficus sur	4.5	17.75	3.57	25.82
Pouteria adolfi-friederici	5.8	8.23	3.4	17.43
Terminalia macroptera	4.35	6.86	3.06	14.27
Combretum molle	5.49	3.16	3.57	12.22
Ochna holstii	4.2	4.05	3.06	11.31
Stereospermum kunthianum	4.35	2.13	3.23	9.71
Ficus vasta	0.99	6.77	1.7	9.46
Dombeya quinqueseta	4.27	2.43	2.72	9.42
Syzygium guineense	2.75	4.09	2.55	9.39

Key: R.DEN = relative density, R.Dom = relative dominance, RF = relative frequency, IVI = importance value index

Plant community types

Five plant community types were determined from Aba Sena Natural Forest (Figure 4). Some most important woody species in each community types were addressed below.

Community I: *Ficus sur-Mimusops kummel* community type

This community was composed of 13 quadrats. It was named after two tree species (*Ficus sur* and *Mimusops kummel*) with relatively higher cover abundance values. The woody species in this community type with cover abundance values >2 include *Terminalia macroptera, Podocarpus falcatus, Cordia africana, Syzygium guineense, Millettia ferruginea, Celtis africana, Diospyros abyssinica, Bersama abyssinica, Albizia grandibracteata, Warburgia ugandensis, Ficus vasta* and *Bridelia micrantha* (Table 3).

Community II: *Celtis africana-Terminalia macroptera* community type

The two woody species with the higher cover abundance values were *Celtis africana* and *Terminalia macroptera* and hence the community name was derived from these two species. This community was made up of five quadrats. The woody species distributed in this community type with cover abundance value >2 were *Bridelia micrantha, Podocarpus falcatus, Albizia grandibracteata, Sapium ellipticum, Phoenix reclinata, Combretum molle, Cordia africana, Bersama abyssinica, Croton macrostachyus, Flacourtia indica, Stereospermum kunthianum* and *Terminalia schimperiana* (Table 3).

Community III: *Syzygium guineense-Flacourtia indica* community type

This community is composed of only three quadrats. *Syzygium guineense* and *Flacourtia indica* are the two tree species with relatively higher cover abundance values. Other woody species like *Bridelia micrantha, Stereospermum kunthianum, Combretum molle, Ficus sur, Bauhinia tomentosa, Polyscias fulva, Croton macrostachyus, Grewia bicolor, Celtis africana, Ficus vasta* and *Schefflera abyssinica* are also found in this community. Species with minimum cover abundance values in this community include *Cordia africana* and *Ximenia americana* (Table 3).

Community IV: *Stereospermum kunthianum-Combretum molle* community type

This community is the largest and is composed of 16 sample quadrats. It is distributed over a wider area. The two species with the highest cover abundance values were *Stereospermum kunthianum* and *Combretum molle* (after which the community was named). Seven woody species (including the two by which the community was named) have the cover abundance values above 2. These are *Terminalia schimperiana*, *Dombeya quinqueseta*, *Grewia bicolor*, *Bauhinia tomentosa* and *Ficus vasta* (Table 3).

Community V: *Terminalia schimperiana-Dombeya quinqueseta* community type

This community was composed of three quadrats. The woody species with relatively higher cover abundance values include: *Terminalia schimperiana, Dombeya quinqueseta, Combretum molle, Bauhinia tomentosa, Ficus sycomorus, Securidaca longepedenculata, Polyscias fulva, Combretum collinum, Stereospermum kunthianum* and *Grewia bicolor* (Table 3).

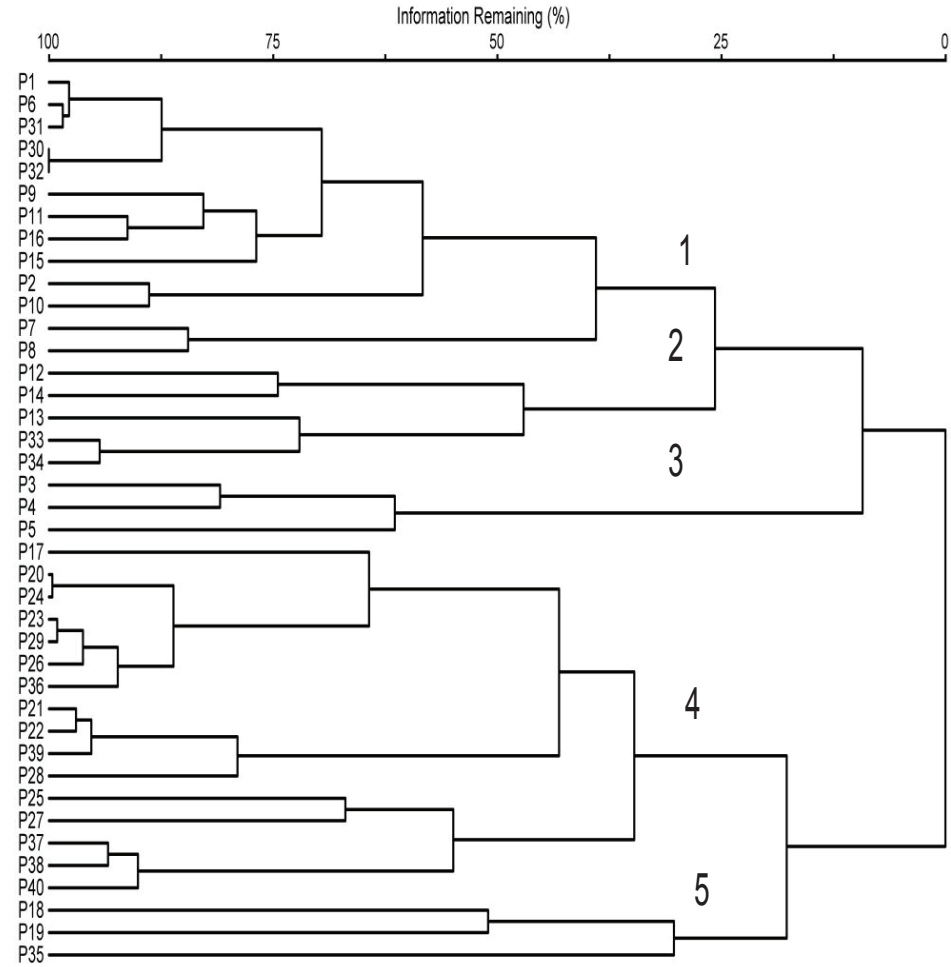

Figure 4. Plant community types of Aba Sena Natural Forest (1 = Community 1; 2 = Community 2; 3 = Community 3;
4 = Community 4; 5 = Community 5)

Table 3. Synoptic table for the five plant community types of Aba Sena Natural Forest

Species	C1	C2	C3	C4	C5
Ficus sur	**7.50**	0.00	5.00	1.71	0.00
Mimusops kummel	**7.00**	1.00	0.00	0.00	0.00
Terminalia macroptera	6.67	**8.00**	0.00	0.00	0.00
Podocarpus falcatus	6.61	5.33	1.75	0.00	0.00
Cordia africana	5.22	2.67	1.00	0.00	0.00

Syzygium guineense	4.72	0.00	**6.20**	0.00	0.00
Millettia ferruginea	4.39	0.00	0.00	0.00	0.00
Celtis africana	3.67	**8.20**	2.00	1.29	0.00
Diospyros abyssinica	3.33	0.00	0.00	0.00	0.00
Bersama abyssinica	3.17	2.33	1.75	0.00	0.00
Albizia grandibracteata	2.78	5.00	0.00	1.14	0.00
Warburgia ugandensis	2.61	1.67	1.75	0.00	0.00
Ficus vasta	2.44	0.00	2.00	3.57	1.00
Bridelia micrantha	2.22	7.67	5.25	0.00	0.00
Phoenix reclinata	1.94	3.33	1.75	0.00	0.00
Sapium ellipticum	1.78	4.67	1.25	0.00	0.00
Dracaena steudneri	1.67	1.00	0.00	0.00	0.00
Flacourtia indica	1.44	2.00	**5.75**	0.00	0.00
Croton macrostachyus	1.44	2.33	2.25	0.00	0.00
Vepris daniellii	1.33	0.00	0.00	0.00	0.00
Stereospermum kunthianum	0.94	2.00	5.25	**7.57**	3.50
Grewia ferruginea	0.94	1.00	1.75	0.00	0.00
Chionanthus mildbraedii	0.94	0.00	0.00	0.00	0.00
Schefflera abyssinica	0.44	0.00	2.00	0.00	0.63
Lepidotrichia volkensii	0.44	1.00	1.25	0.00	0.00
Terminalia schimperiana	0.39	2.00	1.25	6.71	**8.13**
Vernonia auriculifera	0.33	0.00	0.00	0.57	0.00
Combretum molle	0.17	3.00	5.00	**7.57**	5.88
Dombeya quinqueseta	0.00	0.00	1.75	6.57	**6.00**
Bauhinia tomentosa	0.00	0.00	5.00	5.29	5.25
Ficus sycomorus	0.00	0.00	1.25	0.71	5.13
Securidaca longepedunculata	0.00	0.00	0.00	0.00	4.50
Polyscias fulva	0.00	0.00	3.00	1.14	4.38
Combretum collinum	0.00	0.00	0.00	0.86	4.38
Grewia bicolor	0.00	0.00	2.25	5.71	2.75

Key: C1 = Community 1; C2 = Community 2; C3 = Community 3; C4 = Community 4; C5 = Community 5

DISCUSSIONS

Aba Sena Natural Forest has relatively low woody species richness compared to Belete Forest (Hundera and Gadissa, 2008); Gera Forest (Mulugeta *et al*., 2015). The woody species composition of Aba Sena Natural Forest is higher compared to Debresena forest (Wassie, 2002; Ayanaw and Dalle, 2018). Compared to Harenna forest (Senbeta, 2006) Aba Sena Natural Forest has relatively higher species diversity. There are differences in the distribution of plant species among different plant families. Asteraceae was the species rich

family followed by Euphorbiaceae, Combretaceae and Moraceae. A study by Hundera and Gadissa (2008) on Belete Natural forest indicated that the dominance of Fabaceae family was relatively high while it stood second in Aba Sena natural forest. This might be due to either adverse environmental situations or random distribution of available resources in the study area. Anthropogenic disturbances such as livestock trampling, grazing and unwise extraction of resources from the forest could also be the possible reasons for the rarity of most plant species in the study forest. The forest vegetation of Aba Sena is categorized into five plant community types. This could be due to variation in the distribution of resources along the elevation gradients.

The inverted J-curve distribution of the DBH class of the forest shows a good potential of reproduction and recruitment of the forest. Similar results were reported by Abdena (2010). High species diversity and evenness could be attributed to the presence of optimum environmental factors such as altitude, slope and topography of the forest. Reports from other studies indicated that species richness and diversity tend to peak at an intermediate altitude and decline at the lower and upper elevations (Wassie, 2002). The result of the present study agrees with Wassie (2002) in terms of species richness. Above 95% of the total density of the forest was restricted in the lower and middle diameter classes, whereas, about 5% of density was found to be in the higher diameter classes (>60 cm). This might be due to extraction of the forest resources for different purposes like fencing and fuel wood extraction by the local community, or trampling, grazing and browsing by livestock (Personal observation).

Density is affected by quadrat size and pattern of species growth. Species-abundance measures are ways of expressing not only the relative richness but also evenness and there by assessing diversity. According to Abdena (2010), higher number of large-sized individuals in the upper height class in the natural forest implies the presence of a good number of adult tree species for reproduction. This argument holds not true for Aba Sena Natural Forest. This is partly due to the presence of large scale timber use. As a result, most trees that are used for timber production such as *Cordia africana*, *Prunus africana and Podocarpus falcatus* were less in number in this study forest. Basal area provides the measure of relative importance of the species than simple stem count (Abdena, 2010). Species with largest contribution in dominance value through higher basal area could be considered as the most important species in the study forest. In this study, basal area analysis across individual species revealed that there was high dominance by very few woody species. The basal area of the forest is 51.68m² ha^{-1}, which is higher than some forests like Bibita (Gura Ferda) natural forest (Denu, 2006), Masha Anderacha (Tesfaye and Berhanu, 2006). This also indicates that species with the highest basal area do not necessarily have the highest density, indicating size difference between species (Shibru and Balcha, 2004; Denu, 2006).

Frequency reflects the pattern of distribution and gives an approximate indication of the heterogeneity of a stand (Abdena, 2010). The most frequent species in this study was *Ficus sur* and *Combretum molle* occurring in 21quadrats. In addition, *Ficus sur* has highest IVI than all the rest. The species might have a wide range of seed dispersal mechanisms like by wild, animals (livestock, birds and insects). High values in the lower and low values in the higher frequency classes on the other hand show a high degree of floristic heterogeneity (Shibru and Balcha, 2004). In the present study, high values were

obtained for lower frequency classes, whereas, higher frequency classes had lower values. Thus, Aba Sena Natural Forest is floristically heterogeneous.

Importance value index indicates the structural importance of a species within a stand of mixed species and it is calculated by summing up the relative percentages of basal area, density and frequency of species in the study area. As indicated by Abdena (2010), it is used for comparison of ecological significance of species in which high IVI value indicates that the species sociological structure in the community is high. Species with the highest importance value index are relatively dominant in vegetation (Shibru and Balcha, 2004). Species with high contribution to the total IVI in this study were *Ficus sur, Pouteria adolfi-friederici, Terminalia macroptera, Combretum molle*, *Ochna holstii*, *Stereospermum kunthianum*, *Ficus vasta, Dombeya quinqueseta* and *Syzygium guineense* whereas, species with the least contribution to the total IVI were *Hyperecum quartinianum, Crepis rueppellii*, *Grewia mollis, Echinops macrochactus*, *Vanguaria volkensi*, *Allophylus abyssinicus*, *Manilcar abutuji* and *Rytigyni aneglecta.*

CONCLUSION

The study provides useful information on the present condition of the woody species diversity and vegetation structure of Aba Sena Natural Forest. The study showed that only few species have high density and basal area scores. The forest is composed of woody species of moist montane forests, dray afromontane forests and lowland vegetation type. Ecologically, the most important tree species in this study was *Ficus sur* followed by *Pouteria adolfi-friederici, Terminali amacroptera,* and *Combretum molle*. Economically important indigenous species such as *Cordia africana*, *Prunus africana*, and *Podocurpus falcatus* were poorly represented in this forest. The current study focused only on woody species. To have a complete set of information about the forest and to design a sustainable conservation strategy, farther study on all aspects of biodiversity is required.

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