The vegetation composition, structure and regeneration status of Gole Natural Forest, West Arsi Zone, Oromia Regional State, Ethiopia.

Mesfin Belete Hailemariam*, Tamiru Demsis Temam

Wolkite University, Gubrei, Wabe Bridge, Ethiopia

Abstract

This study was conducted in Gole natural forest (Dodola) West Arsi Zone of Oromia Regional State, Ethiopia. The study was intended to investigate the vegetation composition, structure, community types and the regeneration status. To collect the vegetation data, systematically 62 plots 20 m × 20 m (400 m²) were established at 100 m interval, starting from the top of the mountain. Tree and shrub species were counted and their cover abundance value was estimated. The data for herbaceous species were collected from five 2 m × 2 m sub-plots laid at the four corners each and one at the centre of the main plot. Height and diameter at breast height (DBH) of all woody species taller than 1.5 m and thicker than 2 cm were measured. R package was applied for cluster analysis. Indicator species analysis was performed in R Interpolated species accumulation curves. Estimate S 8.2 Software and Microsoft Excel were used to analyze the data. Rarefaction was applied to compare the species richness of the plant communities in the study area. Sorensen's similarity coefficient was used to detect similarities and dissimilarities among communities.

A total of 114 plant species belonging to 57 families and 94 genera were identified. The most dominant families were Asteraceae, followed by Acanthaceae and Lamiaceaae. Out of 114 species 17 were endemic to Ethiopia. The study showed that high density was seen at lower height and DBH classes. Five plant community types were identified. The rarefaction revealed that there is difference in species richness among communities. The Sorensen's similarity index showed that, there was a difference in the distribution of plant species composition among the five plant communities.

Introduction

Mountain ecosystems around the globe are known for their high biological diversity and usually have distinct biological communities and high level of endemism, due to their topography [1]. Forest provides a wide range of ecological, economical, social and cultural services and processes [2]. Forests regulate water regimes/as water catchments, cultural and aesthetic services and provide ecosystem services, including nutrient cycling, soil formation, oxygen production, carbon sequestration and prevention of air pollution [3-5]. Mountain forests have a high potential for securing livelihoods by providing non-timber forest products [5,6]. They also used locally to generate income and in traditional foods and medicine [3,5].

Ethiopia has great biodiversity resources due to the diversity in physical features, climate, topography, habitat, vegetation types and fauna [7]. Altitudes range from 126 meters below sea level in the Dalol (Afar) depression, to the highest mountain, Ras Dejen in the Semen Mountains 4,620 meters above sea level [8]. In Ethiopia, environmental degradation and deforestation have been taking place for hundreds of years. Forests in the entire country declined from the original 35% to 16% in 1952, 3.6% by 1980, 2.6% by 1987, and an estimated 2.4% in 1992 [9]. The major threats to the bio diversities are unsustainable utilization of natural resources, deforestation, conversion of natural vegetation to farmland, alien invasive species, climate change and lack of proper policy framework [4,10,11]. This remnant stands of natural forests are found in remote and inaccessible part of the country [12]. Therefore, the recognition of these threats to biodiversity has led to draw conservation strategies to protect from the threats. Thus, availability of accurate data on forest resources is an essential requirement for forest management and planning within the context of sustainable development. Various attempts have been made to study the forests in different parts of the country. Gole natural forest is highly valued for its socio-economic and ecological services. However, the assessment of vegetation composition, structure, distribution and other attributes has not been studied so far in the study area. Therefore, the present study attempts to provide information on the vegetation composition, structure and regeneration status of Gole forest.

Objectives of the Study

General objective

The general objective of this study is to investigate the vegetation of Gole natural forest which could serve as an important input for conservation of the forest in the study area.

Specific objectives

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- to analyze the vegetation structure and tree species population structure of Gole forest
- to identify main plant community types in Gole forest
- to investigate the regeneration status of woody species in Gole forest
- to investigate the similarity of Gole Forest with some other forests in Ethiopia regarding its composition.

Research questions

In order to realize the above mentioned research objectives, the following research questions should be answered in the course of this study:

- What plant species are common in Gole forest?
- What the vegetation structure of Gole forest looks like?
- What are the main plant community types in Gole forest?
- Does Gole Forest is similarity with other forests in Ethiopia?
- What does the regeneration status of main woody plants in Gole forest looks like?

Materials and Methods

Location of the study area

The Gole natural forest is found in Dodola woreda, West Arsi Zone of Oromia Regional state, Ethiopia. It is located in the south-east part of the country 320 km away from the capital city Addis Ababa. The study area is found between latitude 6^0 51' and 6^0 53' N and longitude 39^0 11' and 39^0 12'E, east of Dodola town in Deneba kebele. The altitudinal range of the study area is between 2728-3480 m a.s.l (Figure 1).

Climatic conditions

Rainfall is bimodal distribution, with the main rainy season occurring between June to September. The dry season lasts from November to February, followed by short rainy season during the months of March and April [13]. There is no metrological station in the study area but the climatic data for the Dodola town recorded by Agricultural shows that, the area has a mean annual rainfall of 733 mm and the temperature ranges from 7-24°C [14].

Vegetation

The vegetation of the study area mainly falls in to the Dry-evergreen afromontane forest (1600-3300 m) and the sub-afroalpine (3200-3500 m) vegetation type [3,15]. The forest formation changes along the altitudinal gradient. At the altitude between 2,850-3,000 m a.s.l., *Juniperus procera* is dominant in association with few *Podocarpus falcatus*. At the upper zone between 3,000-3,400 m a.s.l., *Hagenia abyssinica, Hypericum revolutum* and *Erica arborea* dominate the forest, sometimes mixed with *Juniperus procera*. *Erica arborea* occurs as a shrub at its uppermost distribution [16].

Socio-Economic conditions

The human population of the study area was estimated to be 237610 (117494 were male and 120116 were female) of which 27812 (14693 male and 13119 female) were living in the district capital of Dodola [17]. The farming systems are mainly characterized by the presence of subsistence mixed farming, of both livestock and agricultural crop production. There are also many households engaged in collecting and selling forest products. Forest is the main source of fuel wood demand for the whole communities. The forest is just on converting into

Vegetation data sampling methods

Systematically, plots of 20 m x 20 m (400 m²) were established at every 100 m interval between the plots, starting from the top of the mountain to the lower side. A total of 62 plots were laid for vegetation data collection. For tree and shrub assessment, the 400 m² plots were sampled. For the collection of herbaceous species 2 m x 2 m (4 m²) sub-plots, four at the four corner of the main plote and one at the center was laid [18].

From each plot, local name (if the local name was not known code of voucher specimen) and voucher specimen for all plants were collected. Abundance and cover-abundance of trees, shrubs, liana and abundance of herbaceous plants were
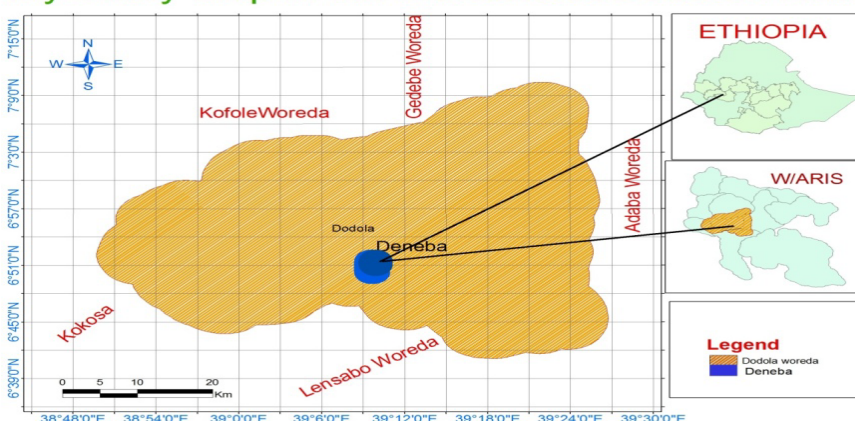

Figure 1. *Location Map of the Study area (Gole Forest).*

recorded. Height and Diameter at breast height (at 1.30 m above ground) of each woody species having DBH > 2 cm and height of each woody species higher than 1.5 m were recorded. Tree height was measured using Suunto clinometers and meter tape and diameter at breast height measured using meter tape, this measurement was obtained from circumference (d=c/π). Cover-abundance values were estimated following 1-9 Braun-Blanquette scale and converted into [19,20]. All plant specimens in the plots were recorded and voucher specimens were pressed and dried. Voucher specimens were

at National Herbarium of Addis Ababa University Ethiopia. The nomenclature of the plants was based on the published volumes of the Flora of Ethiopia and Eritrea [21-27]. The number of seedlings and saplings were collected to determine the regeneration status of the forest.

Data Analysis

All tree, shrub and herbaceous species recorded in all plots were used in the analysis of the vegetation structure. The percentages of various plant families, DBH and height classes of woody plants in the study area were summarized in pi-chart and bar graphs. Dominance curve was used to rank the relative abundance of the species   The vertical structure of tree species was described following the International Union Forestry Research Organization (IUFRO) scheme [28]. Seedlings (height less than 1.5 m) and saplings (height between 1.5-3 m) were considered as sapling [29], and measured using the meter tape to estimate the regeneration status of the forest.

and ordination methods were used to describe vegetation types and to examine the relationship between vegetation types and environmental variables. R statistical package [30] was used for cluster and ordination analysis. Indicator species analysis was performed to   indicator species characterizing the communities. Indicator species analysis was performed in R using package labdsv [31]. Interpolated species accumulation curves were used to display the expected number of species in each community type as a function of accumulated number of plots. Estimate S 8.2 software [32] was used to compute the expected species richness and species richness estimators. Sorenson's index was computed to assess the   similarity between the plant communities of the study area. Sorenson's index of similarity (Ss) was computed to assess the   similarity between the communities and to compare the association of Gole forest with other   forests in Ethiopia.

Results and Discussion

Floristic composition

A total of 114 species of vascular plants, belonging to 94 genera and 57 families were recorded from 62 plots laid in the forest (Appendix I). The families with the highest number of species were Asteraceae, represented by 21 species (18.42%) belonging to 14 genera, followed by Acanthaceae (5 species) belonging to 5 genera, Lamiaceae (5 species) belonging to 4 genera and Rosaceae (5 species) belonging to 4 genera 13.17% (4.39% each). The remaining families were represented by one or two species.

Growth forms

The collected species were composed of 25 (21.9%) trees, 27 (23.7%) shrubs, 43 (37.7%) herbs, 11 (9.6%) climbers, 6 (5.3%) grass and 2 (1.8%) fern. Herbs occupied the highest composition followed by shrubs and trees. Trees and shrubs 2).

Plant endemism in gole natural forest

Among the species collected, 17 plant species have been recorded to be endemic to Ethiopia. Herbs, shrubs and climbers constitute 58.82%, 35.29%, and 5.88% respectively. The presence of these endemic species in the forest shows the importance of the conservation process of the forest (Table 1) [33,34].

The density of selected plant species (Table 2).

The above table shows some of the most abundant tree, shrub, climber and herbaceous species in the study area.

DBH-Class distribution

A total of 2236 individuals whose DBH >2 cm were recorded and seven DBH classes were established for DBH analysis. DBH class1 (2-5), 2(5.01-20), 3(20.01-40), 4(40.01-60), 5(60.01-800, 6(80.01-100) and 7 (>100).
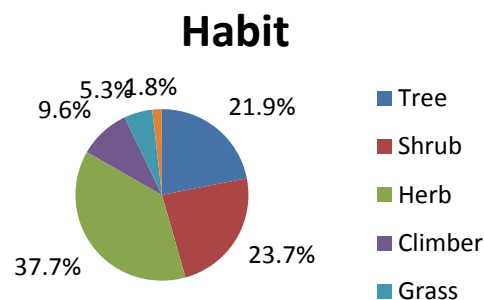

Figure 2. *The growth form of collected plant species.*

Table 1. *Endemic plant species occurring in Gole forest.*

No	Scientific Name	Family	Habit	IUCN Category
1	*Acanthus senii*	Acanthaceae	Sh	NT
2	*Bidens pachyloma*	Asteraceae	H	LC
3	*Conyza spinosa*	Asteraceae	Sh	
4	*Echinops ellenbekii*	Asteraceae	Sh	EN
5	*Echinops longisetus*	Asteraceae	H	LC
6	*Inula conifertiflora*	Asteraceae	Sh	NT
7	*Kalanchoe petitiana*	Krassulaceae	H	LC
8	*Kniphofia foliosa*	Asphodelaceae	H	
9	*Mikaniopsis clematoides*	Asteraceae	C	LC
10	*Mytenus addat*	Celastraceae	Sh	NT
11	*Sedum mooneyi*	Crassulacea	H	
12	*Senecio fresenii*	Asteraceae	H	
13	*Senecio myriocephalus*	Asteraceae	H	LC
14	*Solanecio gigas*	Asteraceae	Sh	LC
15	*Thymus schimperi*	Lamiaceae	H	LC
16	*Trifolium calocephalum*	Fabaceae	H	
17	*Urtica simensis*	Urticaceae	H	LC

Key: LC = Least Concern; NT = near threatened; EN=endangered; IUCN = International Union for the Conservation of Nature and Natural Resources.

Table 2. The most abundant plant species in Gole forest.

| Species	Habit	Density/ha	%
Juniperus procera	Tree	284.7	28
Myrsine melanophloeos	Tree	218.5	21.5
Hypericum revolutum	Tree	111.3	10.9
Podocarpus falcatus	Tree	95.6	9.4
Erica arborea	Tree	97.2	9.6
Mytenus arbutifolia	Tree	54.4	5.4
Myrisine africana	Shrub	75.4	13.5
Discopodium penninervum	Shrub	70.6	12.6
Rubus apetalus	Shrub	63.7	11.4
Inula conifertiflora	Shrub	58.9	10.5
Dovyalis abyssinica	Shrub	55.6	10
Mikaniopsis clematoides	Climber	81	33
Aspargus africanus	Climber	49.6	20.2
Caucanthus auriculatus	Climber	39.9	16.2
Ipomoea involucrate	Climber	15.7	6.4
Clematis hirsuta	Climber	13.7	5.6
Pterolobium stellantum	Climber	13.3	5.4
Helichrysum formosissmum	Herb	219.9	11.9
Kniphofia foliosa	Herb	170.6	9.6
Haplocarpha schimperi	Herb	160.5	9.1
Kalanchoe petitiana	Herb	152	8.6
Myosotis abyssinica	Herb	141.1	7.9
Minulopsis solmisii	Herb	108.9	6.1

The total number of woody species in each DBH class decreased with increasing DBH. The highest density of the populations, 864 (38.6%), were found in the lower DBH class (2-5 cm), while the rest 367 (16.4%), 324 (14.5%), 281 (12.6%), 218 (9.7%), 117 (5.2%), and 65(2.9%), were found between DBH classes 2-7 respectively. This was a normal DBH distribution pattern when viewed from the whole set of plant community, reversed J shape. They exhibited good reproduction and recruitment. But there would be variation when individual species was analyzed separately (Figure 3).

The DBH-class distribution of individual tree species having higher important value index was described below to see the likely future of these trees.

The DBH measurements of *Juniperus procera* (Figure 4A) shows that highest density 29.7% was found in the lowest DBH-class (2-5 cm) and 16.9%, 11.7%, 14.5%, 15.9%, 8.6% and 2.6% was found DBH class 2-7 respectively. The number of individuals of this tree decrease with increasing DBH class but there is slight increase in DBH class 4 and 5. They are represented by the broken up inverted 'J' curve structure, this shows good regeneration but discontinuous recruitment in to larger size. One of the possible reasons for the discontinuity could be selective cutting of a particular size of this tree for different purpose. The local people use medium size of these trees for roof cover of their huts and for making fence and the
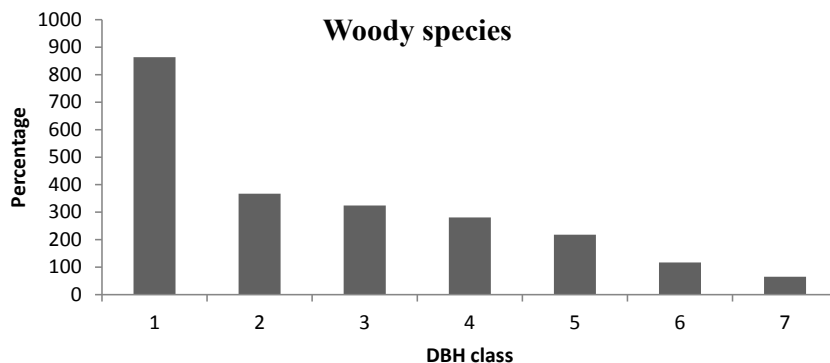
Figure 3. Percentage distribution of woody species in Gole Forest DBH-class (cm).
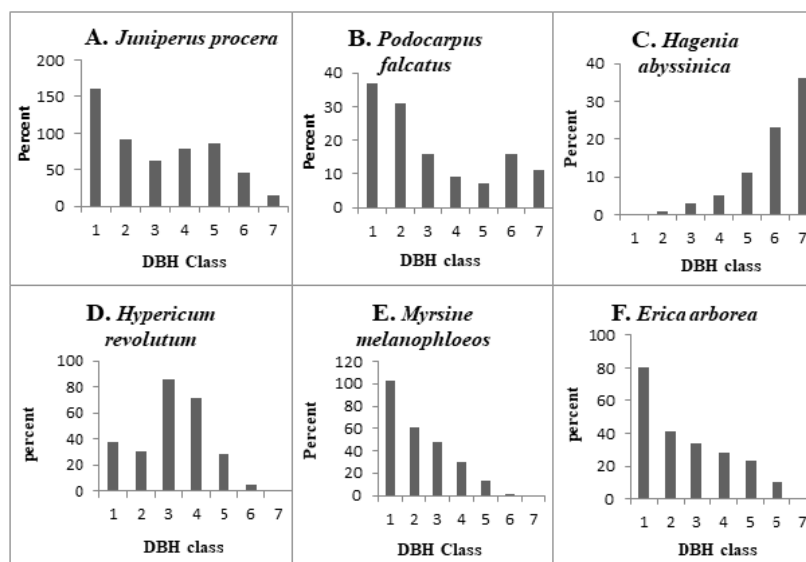
Figure 4. Percentage distribution of individual trees in Gole Forest in DBH-class (cm).

highest class for timber production as a result the density of these classes was lowered.

The DBH-class of *Podocarpus falcatus* (Figure 4B) indicates that the highest proportion (29.1%) of this species was found in lower DBH class (1). The trees having (24.4%) and (12.6%) are in the DBH-class 2 and 3 respectively. The remaining proportion (7.1%), 5.5% and 12.6% of these trees was observed to a DBH class between 4, 5 and 6 respectively. The highest DBH class (7) of this tree constitutes 8.7%. They show decreasing pattern of DBH classes up to some limits and then slight increase and decreases. This indicates irregular pattern of distribution, due to selective cutting of a particular size for construction, agricultural, fuel wood and other purpose. It indicates good reproduction but poor recruitment.

There was no *Hagenia abyssinica* (Figure 4C) in the lower DBH class (1). Small proportion of this tree species was found in the DBH-class 2, 3, 4 and 5, which accounts 1.3%, 3.8%, 6.3% and 13.9% respectively. The highest DBH-class 6 and 7 comprise 29.1% and 45.6% respectively. The number of individual of this tree increases with increasing DBH class, as the majority found above 80 cm. This is due to the fact that male and female individuals of *Hagenia abyssinica* were found on separate plant, which affects the reproductive capacity of the species, which in turn lowers reproduction. The other probable reason could be *Hagenia abyssinica* is one of the most useful medicinal plants in the area. The female   parts are used as a remedy for tapeworm infestation, which affects the production of viable seeds to germinate and enhance seedling and young population.

The DBH class distribution of *Hypericum revolutum* (Figure 4D) also indicate considerable proportion was found in the DBH class 14.6% and in the second class DBH 11.9%. The largest proportion (33.1%) and (27.7%) was recorded in the third and fourth DBH class respectively. The individuals belonging to the   DBH class was 10.8%. The smallest proportion 1.9% of this tree was in the sixth DBH-class. There is no *Hypericum revolutum* in the seventh DBH class; this is due to the nature of the plants not to grow to higher DBH class.

The DBH class distribution of *Myrsine melanophloeos* and *Erica arborea* (Figure 4E and 4F) was shown that high density in the lower DBH class (40.2% and 37%) respectively. The density of *Myrsine melanophloeos* and *Erica arborea* decreases with increasing DBH class. They represented by inverted 'J' curve structure, this pattern shows good reproduction and regeneration potential. On the other hand the low level of mature trees   that the forest affected by collection of fuel wood, for

household consumption, for sale and construction. There is no *Myrsine melanophloeos* and *Erica arborea* in the highest DBH class; this is due to the nature of the plants not to grow to higher DBH class (Figure 4).

Height-class distribution

Seven height classes 1) 1.5-5 m, 2) 5.01-10 m, 3) 10.01-15 m, 4) 15.01-20 m, 5) 20.01-25 m, 6) 25.01-30 m, 7) >30.01 m were established. The number of individuals in each successive height class decreased beginning from the lower height class (1.5-5 m) to the highest height class (>30.01 m). Most of the woody species in the study area belongs to the lower height class. The highest height class comprises 9.3/ha (1%) occupied by *Juniperus procera* (82.6%) and *Podocarpus falcatus* (17.4%). *Juniperus procera* is the emergent tree and grow above all trees (Figure 5).

The height distribution patterns of Gole Forest was characterized by fewer individuals at matured stage than middle and young age, suggesting that the Forest was dominated by low height individuals, indicating good regeneration but low recruitment.

The separate analysis of *Juniperus procera* from the lower height class (1.5-5 m) to the highest height class (>30.01 m) shows that, 22.7%, 15%, 6.5%, 20.8%, 22.5%, 8.9% and 3.5% respectively. This indicates irregular or Zigzag pattern due to selective cutting for different purpose by the local people, which lower the proportion of medium height class and highest height-classes (Figure 6A).

In *Podocarpus falcatus,* there is many individuals in the (37.8%) and second (31.5%) height class but less individuals in third (0.8%), fourth (7.9%),   (4.7%) and seventh (3.1%) height classes and medium number of individuals in the sixth (14.2%) height class. This indicates an irregular pattern of distribution. This kind of distribution is observed when there is selective cutting of trees for a particular purpose (Figure 6B).

Hagenia abyssinica shows slightly a bell-shaped distribution pattern (Figure 6E) due to highest density in the third (20.3%) and fourth (21.5%) height classes, less in the   (7.6%) and second height class (15.2%) and medium height in the (18.9%) and sixth (16.5%) height classes. There is no *Hagenia abyssinica* in the highest height class. This is due to timber production and the separation of male and female plant reduces the number of lower height class.

In *Erica arborea* (Figure 6C)*, Myrsine melanoploeos* (Figure 6D) *and Hypericum revolutum* (Figure 6E and F) respectively, all have high density in the lower height class and gradually
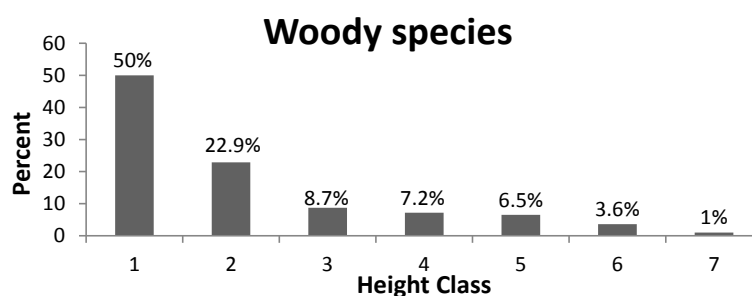

Figure 5. Percentage distribution of woody species in Gole Forest Height-class (m).
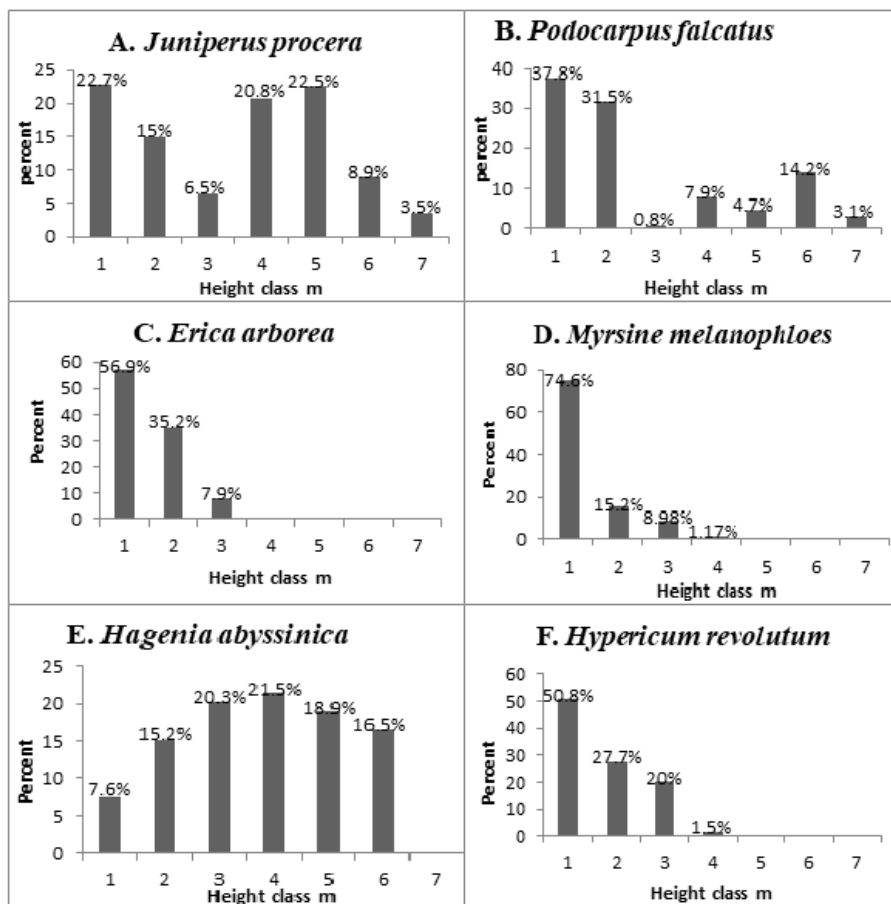
Figure 6. Percentage distribution of individual tree species in Gole forest in height class (m).

decreases with increasing height class. They show an inverted "J" shape pattern of height distribution. This is due to less human interference as they are found at the highest altitude and the nature of the tree not to grow in to the highest height class (Figure 6).

Vertical structure

The vertical structure of tree species was analyzed in to three vertical layers. These are upper storey (top height > 30 m), middle storey (height between 15-30 m) and lower storey (height <15 m) [28].

The lower storey contributed to 77.3% of all tree species. The most dominant trees in the lower story was *Hypericum revolutum* (18.3%), *Myrsine melanophloeos* (18%), *Juniperus procera* (17%), *Erica arborea* (15.4%), *Mytenus arbutifolia* (6.9%), *Podocarpus falcatus* (6.4%) and the remaining accounts less than 3% each. The middle storey (15-30 m), contributed about 21.4% of the tree species. This layer was dominated by *Juniperus procera* (76.8%), *Hagenia abyssinica* (11.6%), *Prunus africana* (1.3%), *Podocarpus falcatus (8.8%), Ficus sur* (1.5%) and the remaining contributed less than 1% each. The upper storey contributes only 1.3% of the total individual's trees in the forest. The two dominant emergent tree species in this layer were *Juniperus procera* (82.6%) and *Podocarpus falcatus* (17.4%). Only two tree species (9%) were common to all storeys. In general, the percent of tree densities in lower, middle and upper storey was found to be 564.1/ha, 156.5/ha and 9.3/ha respectively (Table 3).

Table 3. The percentage distribution of trees in lower, middle and upper strata.

Storey	Density/ha	No of species	%
Lower	564.1	22	77.3
Middle	156.5	12	21.4
Upper	9.3	2	1.3

Basal area

The total basal area of tree species in Gole Forest was calculated from DBH data and it was found to be 49.2 m^2/ha. About 90.8% of the total basal area is contributed by *Juniperus procera* 33.3%, *Hagenia abyssinica* 17.9%, *Hypericum revolutum* 11.6%, *Podocarpus falcatus 8.9%, Erica arborea* 7.9%, *Mytenus arbutifolia* 5.9% and *Myrsine melanophloeos* 5.3%. Species with the highest basal area do not necessarily have the highest density, indicating size difference between the species [35]. *Myrsine melanophloeos* have highest density but low in basal area and *Hagenia abyssinica* have low density but high in basal area. Therefore, the trees belonging to higher DBH classes contribute higher to the total basal area than trees with low DBH class. Basal area provides a better measure of the relative importance of the species than simple stem count [36]. Thus, Species with the largest basal area can be considered as the most important species in the forest (Table 4).

Frequency

Frequency is the indication of homogeneity and heterogeneity of given vegetation in which the higher number of species in

Table 4. The Basal area of trees (m²/ha) and their percentage contributions.

No	Species	Basal Area m²/ha	%
1	*Allophylus abyssinicus*	0.02	0.04
2	*Buddleja polystachya*	0.01	0.02
3	*Dombeya torrida*	0.9	1.8
4	*Ekebergia capensis*	0.1	0.2
5	*Erica arborea*	3.9	7.9
6	*Ficus sur*	0.4	0.8
7	*Galiniera saxifraga*	0.6	1.2
8	*Hagenia abyssinica*	8.8	17.9
9	*Hypericum revolutum*	5.7	11.6
10	*Ilex mitis*	0.1	0.2
11	*Juniperus procera*	16.4	33.3
12	*Maesa lanceolata*	0.1	0.2
13	*Myrsine melanophloeos*	2.6	5.3
14	*Mytenus arbutifolia*	2.9	5.9
15	*Nuxia congista*	0.7	1.4
16	*Olea europea sub.sp.cuspidata*	0.6	1.2
17	*Olinia rachetiana*	0.1	0.2
18	*Pittosporum viridiflorum*	0.1	0.2
19	*Podocarpus falcatus*	4.4	8.9
20	*Prunus africana*	0.3	0.6
21	*Rhamnus staddo*	0.2	0.4
22	*Schefflera volkensii*	0.3	0.6
	Total	49.2	100

higher frequency classes and low number of species in lower frequency classes show similar species composition while large number of species in lower frequency classes and small number of species in higher frequency classes indicates higher heterogeneity (Table 5) [37].

The above table shows the most frequent herb, climber, shrub and tree species of Gole forest. Gole forest is heterogeneous in its diversity.

Importance value index (IVI)

The importance value index of tree species in Gole Forest is given in Table 6. The highest IVI of *Juniperus procera* was as a result of high relative frequency, relative density and relative dominance. In *Hagenia abyssinica* the highest basal area made the species to have large value of relative dominance and hence got the highest Importance value index (Table 6).

The most dominant and ecologically important tree species of Gole Forest were *Juniperus procera*, *Myrsine melanophloeos*, *Hypericum revolutum*, *Hagenia abyssinica*, *Podocarpus falcatus* and *Erica arborea*. The leading dominant and ecologically most species might also be the most successful species [36]. Priority for conservation should be given based on their Importance value index values. i.e. the priority for species with least Importance value index because they are at risk of local extinction and the last priority of conservation for species with highest Importance value index.

Vegetation community classification

The plant community types were recognized using Agglomerative hierarchical cluster analysis. Communities were on the basis of quadrats grouping by similarity [38,39]. Agglomerative hierarchical cluster analysis revealed that there

are main plant communities in the study area, designated as community 1, 2, 3, 4, and 5 as shown in (Figure 7).

Community1: includes plot: 1, 2, 3 and 4

Community2: includes plot: 5,6,7,8,9,10,12,13,14,15,16,17,18,19,22 and 23

Community 3: includes plot: 11,20,21,24,25,26,27,28,29,30 and 31

Table 5. List of the most frequent plant species in Gole Forest.

Species	Habit	No of plot present	Total plot sampled	%
Erica arborea	Tree	18	62	29
Hagenia abyssinica	"	26	62	41.9
Hypericum revolutum	"	28	62	45.2
Juniperus procera	"	55	62	88.7
Myrsine melanophloeos	"	47	62	75.8
Mytenus arbutifolia	"	24	62	38.7
Podocarpus falcatus	"	24	62	38.7
Rubus apetalus	Shrub	49	62	79
Discopodium penninervum	"	28	62	45
Rosa abyssinica	"	26	62	42
Mikaniopsis clematoides	Climber	40	62	65
Aspargus africanus	"	35	62	56.5
Caucanthus auriculatus	"	24	62	39
Helichrysum formosissmum	Herb	42	62	68
Kalanchoe petitiana	"	31	62	50
Myosotis abyssinica	"	31	62	50
Carduus nyassanus	"	30	62	48
Haplocarpha schimperi	"	29	62	47
Kniphofia foliosa	"	27	62	44
Cyanoglossum amplifolium	"	27	62	44

Table 6. Importance value index of trees species in Gole Forest.

No	Species	Relative Frequency	Relative density	Relative dominance	Importance value index
1	*Allophylus abyssinicus*	0.9	0.2	0.04	1.14
2	*Buddleja polystachya*	0.6	0.2	0.02	0.82
3	*Dombeya torrida*	2.5	1.8	1.8	6.1
4	*Ekebergia capensis*	1.9	0.6	0.2	2.7
5	*Erica arborea*	5.5	9.6	7.9	23
6	*Ficus sur*	0.3	0.5	0.8	1.6
7	*Galiniera saxifraga*	4.6	1.3	1.2	7.1
8	*Hagenia abyssinica*	7.9	3.3	17.9	29.1
9	*Hypericum revolutum*	8.6	10.9	11.6	31.1
10	*Ilex mitis*	0.3	0.08	0.2	0.58
11	*Juniperus procera*	16.9	28	33.3	78.2
12	*Maesa lanceolata*	0.6	0.5	0.2	1.3
13	*Myrsine melanophloeos*	14.5	21.5	5.3	41.3
14	*Mytenus arbutifolia*	7.4	5.4	5.9	18.7
15	*Nuxia congista*	4.9	1.7	1.4	8
16	*Olea europea sub. sp.cuspidata*	4.6	2.5	1.2	8.3
17	*Olinia rachetiana*	1.9	0.5	0.2	2.6
18	*Pittosporum viridiflorum*	1.9	0.4	0.2	2.5
19	*Podocarpus falcatus*	7.4	9.4	8.9	25.7
20	*Prunus africana*	0.9	0.3	0.6	1.8
21	*Rhamnus staddo*	1.2	0.6	0.4	2.2
22	*Schefflera volkensii*	4.6	0.9	0.6	6.1
	Total				299.94
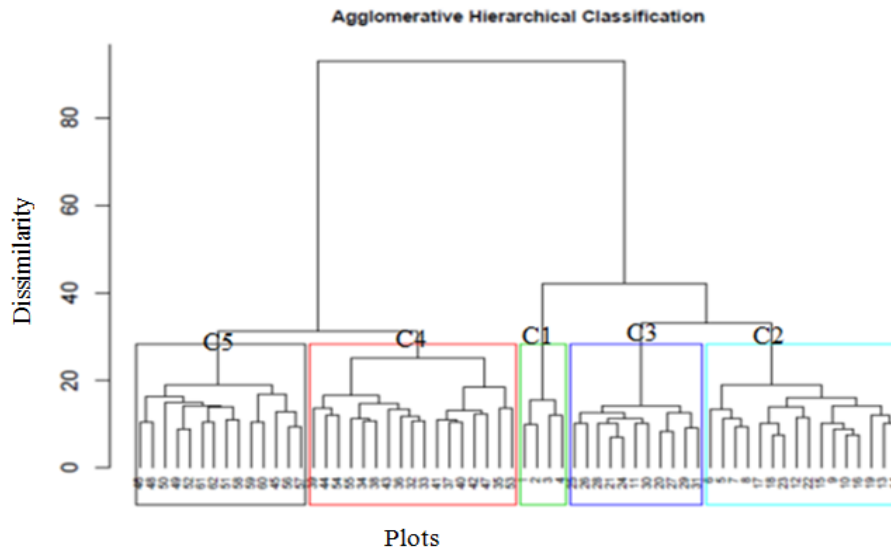
Figure 7. Denrogram showing five plant community types in Gole Forest.

Community 4: includes plot: 32,33,34,35,36,37,38,39,40,41,42,43,44,47,53,54 and 55

Community 5: includes plot: 45,46,48,49,50,51,52,56,57,58,59,60,61 and 62

The species with highest indicator values are bolded and used for naming the communities. The indicator values are determined by combining the relative abundance and relative frequencies of each species. The indicator values of the species are considered as   if the respective probability values are less than 0.05 (Table 7) [40].

The   plant communities which were   in the study area are described as follows:

Community 1: *Erica arborea-Conyza spinosa* community type: This community type was found at the highest altitude ranging between 3388 and 3480 m a.s.l. This community resulted from 4 plots and 27 species. The tree layer was highly dominated by *Erica arborea* and the shrub layer by *Conyza spinosa*. The dominant herbaceous species of this community was *Thymus schimperi, Isolepis setacea, Crepis reupeli, Helichrysum splendidum, Crinium abyssinicum, Gnaphalium rubriflorum* and *Trifolium quartinianum* and the grass species of this community was *Cyprus fischirianus* and *Festuca abyssinica*.

Community 2: *Hypericum revolutum* community type: There were 16 plots and 50 species included in this community and found at an altitude between 3173 and 3350 m a.s.l. The tree layer was dominated by *Hypericum revolutu*. The herbaceous species of this community type includes *Bidens pachyloma, Carduuus nyassanus, Cyanatis berbata, Stellaria senni* and *Periploca linearifolia*.

Community 3: *Hagenia abyssinica-Myrsine melanophloeos-Juniperus procera* community: This community type was found at an altitudinal ranging between 3050 and 3275 m a.s.l. The community consists of 11 plots and 40 species. The tree layer of this community was dominated by *Hagenia abyssinica, Myrsine melanophloeos, Juniperus procera* and the dominant

shrub of this community was *Discopodium penninervum* and the herbaceous species of this community was *Kalanchoeo petitiana* and *Kniphofia foliosa*.

Community 4: *Nuxia congista-Myrsine africana-Osyris quadripartita* community type: This community type was composed of 17 plots and 78 species and located at an altitude between 2758 and 3040 m a.s.l. The tree layer was dominated by *Nuxia congista, Dombeya torrida, Olea europea* subsp. *cuspidata* and the dominated shrub of this community was *Myrsine africana, Osyris quadripartita* and *Inula conifertiflora*. The dominated herbacious species was *Minulopsis solmisii* and *Dryopteris anthamantica*.

Community 5: *Podocarpus falcatus-Mytenus arbutifolia-Dovyalis abyssinica* community type: This community type was found at the lowest altitude ranging between 2728 and 2863 m a. s. l. The community consists of 14 plots and 75 species. The dominant tree species of this community type was *Podocarpus falcaatus, Mytenus arbutifolia* and *Prunus africana*, and the shrub layer of this community was dominated by *Dovyalis abyssinica, Rosa abyssinica* and *Mytenus addat*. The herbaceous species dominating this community was *Myosotis abyssinica and Carduus camaecephalus,* and the dominant climber of this community was *Mikaniopsis clematoids*.

Community Similarity Analysis

Sorenson's   of similarity was computed to see whether communities and species composition is discontinuous or continuous (Table 8).

Sorenson's   of similarity on the species composition between communities indicates that, community one shares more species with communities two (26%) and three (22%) but relatively low with community four (18%) and   (11%). Community two shares more species with community three (41%) and four (36%) and relatively less species with community   (26%). Community three shares more species with community four (44%) than with community   (40%). Community four share more species with community   (59%) than any other communities.

Table 7. List of Species with significant indicator values (in percentage) in each community and the montecarlo test of significance (P).*

Species	Community	Indicator value	P* Value
Thymus schimperi	1	89.47	0.001
Isolepis setacea	1	75	0.001
Erica arborea	1	65.91	0.001
Cyprus fischerianus	1	65.25	0.001
Crepis reupeli	1	55.44	0.004
Arsaema schimperiana	1	50	0.007
Festuca abyssinica	1	47.06	0.005
Helichrysum splendidum	1	47.06	0.004
Conyza spinosa	1	46.85	0.002
Helichrysum foetidium	1	46.67	0.002
Crinium abyssinicum	1	42.58	0.004
Gnaphalium rubriflorum	1	41.8	0.008
Trifolium qurtinianum	1	29.34	0.032
Bides pachyloma	2	56.62	0.002
Hypericum revolutum	2	46.36	0.003
Carduus nyasanus	2	36.84	0.022
Cyanatis berbata	2	26.77	0.045
Stellaria senii	2	25.62	0.041
Periploca linearifolia	2	25	0.023
Discopodium penninervum	3	46.48	0.001
Hagenia abyssinica	3	43.59	0.009
Myrsine melanophloeos	3	34.49	0.002
Kalanchoe petitiana	3	34.23	0.036
Kniphofia foliosa	3	31.33	0.035
Juniperus procera	3	31.16	0.001
Myrsine africana	4	72.37	0.001
Osyris qudripartita	4	40.64	0.007
Inula conifertiflora	4	39.68	0.008
Nuxia congista	4	38.96	0.007
Minulopsis solmisi	4	36.31	0.014
Dombeya torrida	4	34.83	0.013
Olea europea sub sp cuspidata	4	30.35	0.038
Dryopteris anthemantica	4	26.89	0.028
Podocarpus falcatus	5	76.76	0.001
Mytenus arbutifolia	5	59.95	0.001
Dovyalis abyssinica	5	53.97	0.002
Solanum indicum	5	46.76	0.009
Rosa abyssinica	5	44.46	0.009
Mikaniopsis clematoids	5	38.68	0.003
Myosotis abyssinica	5	34.31	0.032
Mytenus addat	5	24.85	0.04
Carduus camaecephalus	5	21.43	0.022
Prunus africana	5	21.43	0.023

Gradual change in species composition and diversity was observed in the study area. The overall similarity ranges from 11-59% among all the communities. The highest similarity was observed between community four and (59%), three and four (44%) and two and three (41%). This is due to existence of most quadrates adjacent to each other and similarity in altitudes that shows the availability of nutrient needed by those species and the adaptation of plants to that particular environment. The lowest similarity was observed between community one and (11%), one and four (18%) and one and three (20%), this shows that community having nearly similar altitude have more species in common than communities occupying different altitude. If two sites have similar vegetation

they have similar environment and if two sites have different vegetation they have different environment [41].

Species richness comparison

The rarefaction curves shows that, species richness was greater in community four (50), followed by community (44), while species richness in community two (34) was intermediate but in community three (28) and one (27) is less. The species evenness also greater in community four, as the rarefaction curve is steeper followed by community Less even distribution of species was observed in community one, three and two as the rarefaction curve is relatively less steep (Figure 8).

The reason why community four has the highest species richness is that there are fewer disturbances in this community and mainly cover with shrubs which is less valuable woody species for commercial purpose and also resistant to wild animal and livestock grazing, like *Osyris quadripartita* and *Myrsine africana*. In community at low elevation, even if disturbance level is greater, species richness is high next to community four; this is because of moderate conditions which permit rapid resource acquisition which is favorable for most plant growth. In community three and two the decrease in species richness than community four and is due to disturbance and increase in altitude. The decrease in species richness of community one which is found at the highest altitude could be due to eco-physiological constraints, such as reduced growing season, low temperature and low productivity and other factors such as soil fertility and soil acidity. The soil pH decreases with increasing altitude and as a result the soil acidity increases with rising altitude and this could affect the chemical reaction between plant roots and nutrients and microbial activity. These could be the possible reasons for declining of species richness and diversity with increasing altitude [35].

Regeneration status of gole forest

The regeneration status of a forest was summarized based on the total count of seedlings and saplings of each species across all plots. From the study area a total of 710 seedlings (286.3/ha) of 15 tree species and 471 saplings (189.9/ha) from 17 tree species were recorded.

These tree species contribute 21.9% of the total composition of the study area. Fifteen species contributes 28% and seventeen species contributes 18.7% of the total seedling and sapling count respectively. *Scheﬄera volkensii, Pittosporum abyssinicum, Olinia rachetiana, Ilex mitis, Prunus africana, Allophylus abyssinicus* and *Ficus sur* do not have seedlings. The other *Hagenia abyssinica, Pittosporum abyssinicum, Galiniera saxifraga, Maesa lanceolata* and *Ilex mitis* do not

Table 8. Sorenson's coefficient of Similarity between the Plant Communities of Gole Forest.

Community	1	2	3	4	5
1	1	-			
2	0.26	1	-		
3	0.2	0.41	1	-	
4	0.18	0.36	0.44	1	-
5	0.11	0.26	0.4	0.59	1

have saplings. The two species *Pittosporum abyssinicum* and *Ilex mitis* do not have both seedling and saplings. All the rest have both seedling and sapling. Accordingly, tree species with the largest (more than 5%) contribution to the seedling counts were *Myrsine melanophloeos* (40.3%), *Juniperus procera* (23.7%), *Podocarpus falcatus* (15.5%), *Mytenus arbutifolia (5.4%)*, and *Olea europea* sub.sp. *cuspidata (5.2%)*, show the highest seedling counts of the tree species.

The ratio of parent plant to seedling was 1:3.5 and that of parent to sapling was 1:5. The tree species that lacks seedling and sapling or either of the two should be given priority for conservation. Thus, *Pittosporum abyssinicum*, *Ilex mitis*, *Schefflera volkensii*, *Olinia rachetiana*, *Prunus africana*, *Allophylus abyssinicus* and *Ficus sur* need priority conservation (Figure 9).

The pattern of distribution shows maximum number of matured plant than saplings and seedlings. These might be seeds in seed banks are eaten before they germinate, or death of seedlings with unsuitable resource or with herbivores and pathogens. And also the environmental conditions of soil moisture, temperature and light conditions alter the germination and/or survival of seedlings.
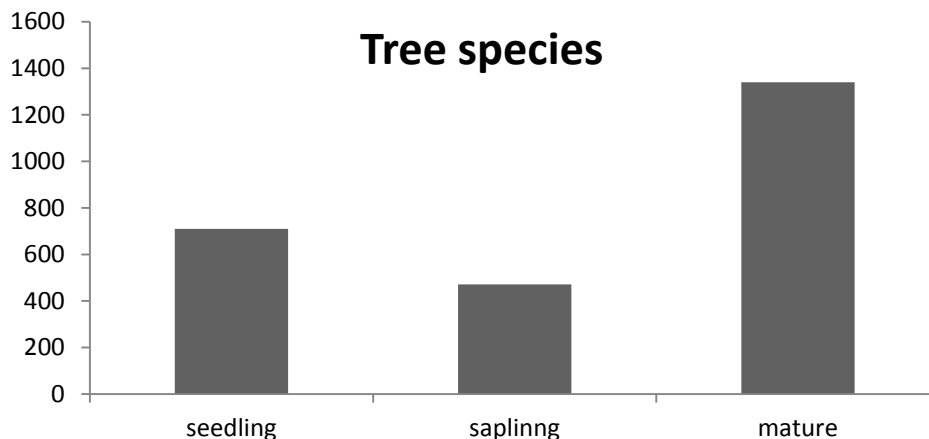
Phyto-geographical comparison

The direct comparison of the species diversity of one forest with other forests is not feasible due to variations in size, survey methods used, and objective of the study among forests [42]. However, the overall species richness of the forest can give more or less a general impression of their diversity and phyto-geographical similarity. In this regard Gole forest was compared with other forests in the country to see the distribution pattern of plant species in the study area and to know the relative similarity in its plant species composition (Table 9).

Sorenson's index of similarity indicates that, Denkoro and Sanka meda forests have highest similarity (39%) with Gole forest than the other mentioned forests followed by Gedo and Biteyu forests with similarity of 37% and 35% respectively. Bibita forest shows the lowest similarity 17% with Gole forest.

The probable reason for the highest similarity between Denkoro forests and Gole forest is that both the range of altitude and both are dry evergreen afromontane forest. Sanka meda forest and Gole forest also show highest similarity, this is because both are dry evergreen afromontane forest. Gedo and Biteyu forest also show good similarity with Gole forest due to the range of
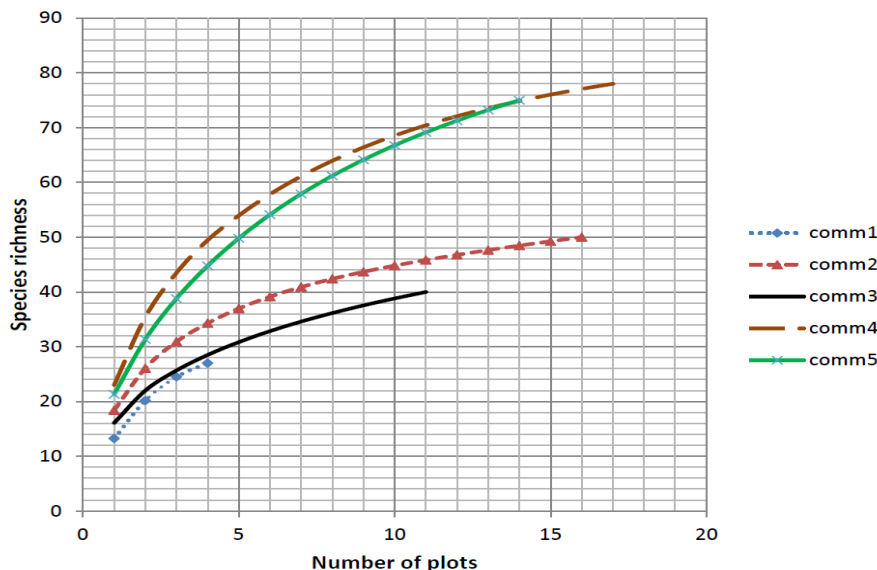
Figure 8: Comparisons of species richness between plant communities using rarefaction measurements.

Figure 9: The regeneration pattern of Gole Forest represented by tree species.

Table 9. *Phytogeographical comparison between Gole forest and other five Forests.*

Forest	Altitude range	No of species	a	b	c	Ss	Source
Gole forest	2728 -3480 m a.s.l	114					
Bibita forest	900 - 2200 m a.s.l	196	26	88	170	0.17	[35]
Gedo forest	1300 - 3060 m a.s.l	235	65	49	170	0.37	[36]
Biteyu forest	2590 - 2890 m. a. s.l	177	51	63	126	0.35	[43]
Denkoro forest	1500 - 3500 m.a.s.l	174	57	57	119	0.39	[44]
Sanka meda forest	2400 - 2748 m a.s.l	140	49	65	87	0.39	[45]

altitude and vegetation type both are dry evergreen afromontane forest. Bibita forest which is moist evergreen afromontane forests is much less similar with Gole forest due to difference in altitude and difference in their vegetation type.

Conclusion and Recommendation

From the study area, 114 species of plants belonging to 94 genera and 57 families were   . Asteraceae had the highest number of species. Out of 114 species 17 were endemic to Ethiopia. The density of woody species in Gole Forest decreases with increasing DBH and Height classes. Few species occur in all DBH and Height classes showing variation in population size. Three layers were   from the vertical (the upper, the middle and the lower storey). IVI   six dominant tree species which is ecologically important species of the forest and they contributed 84.9% of the total basal area. Five plant community types were   There are variations in species composition and diversity among the communities. The species richness was high in communities 4 and 5 but relatively less in community 2, 3 and 1. The regeneration status of tree species showed that there are two major types of tree species, species able to regenerate and others with   to regenerate.

Gole natural forest was one of the remnant forests with in Adaba-Dodola forest priority area in Ethiopia. To conserve this forest appropriate management strategy is vital. This study was done only on one site of Adaba-Dodola forest priority area. The study of the whole Adaba-Dodola Forest is recommended to know the current status of the vegetation of the area [43-45].

Further studies are needed to   the gap of this work such as analysis of soil sampling.

Seventeen plant species were found to be endemic to Gole natural forest (Ethiopia). This shows that the area has a potential for the presence of more endemic species. Thus, further study on the whole Adaba-Dodola Forest is recommended.

The vegetation of Gole Forest was disturbed through grazing and browsing by domestic livestock and other human uses (selective cutting), these further affects the regeneration processes of the forest. Therefore, this forest needs to be protected and utilized in a sustainable way.

Even though it is not included in this study, people in the area uses the vegetation in the forest for different purpose like for medicine (i.e. *Hagenia abyssinica* for intestinal worm, *Vernonia amygdalina* for fever of domestic animals and others). Thus detailed ethinobotanical study on Gole Forest is highly recommended.

Finally, Gole forest is not well known, this may be because of its remoteness and lack of infrastructure. So the concerned bodies should give attention to solve infrastructure problems and researchers should devote more time to investigate this poorly known area.

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***Correspondence to:**

Researcher and instructor
Biology Department
Wolkite University, Gubrei,
Wabe Bridge, Ethiopia
E-mail: msbd2006@gmail.com