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Floristic composition, diversity, and richness of woody species of Yerer Mountain natural forest in the central highland of Ethiopia

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Abstract

Ethiopia is one of the world's richest biodiversity countries, due to a wide range of favorable environmental conditions. Yerer Mountain natural forest is one of the remnant dry evergreen montane forests among the designated protected forests in Ethiopia. The study aimed to identify and document the floristic composition, diversity, and richness of woody species of the Mountain remnant natural forest in the central highlands of Ethiopia. The systematic sampling design was used to collect woody species data from 122 quadrats (20 m x 20 m area each) along 22 transect lines. A total of 93 woody species belonging to 73 genera and 46 families were identified in Yerer Mountain natural forest. Of these woody species, 13 were endemic, 79 were indigenous, and 1 was introduced species. Fabaceae Lamiaceae and Asteraceae were the most dominant families in the area. In the Mountain natural forest, five plant community types were identified with varying degrees of species diversity, richness, and evenness. The highest values of species richness (68), diversity (3.981), and evenness (0.943) were observed in community two. However, the least values of species richness (31), diversity (2.816), and evenness (0.820) were observed in community five. The overall species composition similarity coefficients among five plant communities were ranged from 36-78%. Generally, the results of the present study highlighted that the flora of Yerer Mountain natural forest is high rich heterogeneous woody species with a significant number of endemic taxa.

Keywords: floristic composition, natural forest, species diversity, woody community, woody species, Yerer Mountain

Introduction

Ethiopia is one of the world's richest biodiversity countries, due to a wide range of favorable ecological conditions ranging from 110 meters below sea level (at arid low lands in the East at Afar depression) to 4620 meters above sea level (at peak altitude in the northern part of Ras-Dashen mountain) that led to hosting a wide diversity of flora and fauna species in the country (FAO 2003 [14], IBC 2009 [26], IBC 2014) [27]. Ethiopia is a country of great natural, cultural, geographical, and climatic diversity with broad latitudinal spread, and immense altitudinal range, which contributes to putting the country as the fifth largest floral diversity in tropical Africa (Demissew *et al*. 2003, IBC 2009) [8, 26]. Altitude and rainfall strongly influence Ethiopia's extraordinary range of terrestrial and aquatic ecosystems and have contributed to a high diversity and endemism (FAO 2003 [14], Barry 2008 [1], IBC 2014) [27].

Forest is defined as the land which comprises a minimum area of land of 0.5 hectares with tree crown cover of more than 10% with the potential of trees to reach a minimum height of 5m at maturity in situ, and the purpose of land use is forest (FAO, 2005) [16]. According to FAO (2005) [16], the basic parameters to be considered in forest definition include Minimum tree crown cover (%), Minimum area coverage (ha), Minimum tree height (m) reach maturity, and purpose of land use. The significant role of forests in environmental service includes protecting soil and water erosion, biological diversity conservation, climate change mitigation by global carbon cycle as carbon sinks of the terrestrial ecosystem (Bhat *et al.,* 2013) [5], and combat desertification (Millennium Ecosystem Assessment (MEA) (2005) [36]. The ecosystem is a major part of the discipline of ecology that has become very important in the 21st century because of the highly accelerated rate of anthropogenic modification of natural systems through the use of fire, overexploitation of resources, and expansion of agriculture (FAO, 2005 [16], MEA 2005) [36]. Several socioeconomic and environmental challenges have strongly affected the capacity of forests to provide ecosystem services by deforestation and forest degradation (Teketay 2001) [43]. Natural forests in Ethiopia are declining rapidly due to their conversion to arable lands coupled with unwise and excessive utilization triggered by increasing population growth (Hundera 2010**)** **[24]**. The forest cover change in Ethiopia is mainly due to the transformation of natural high forests to cultivated land and grassland, especially in the more densely populated parts of the country (USAID, 2008) [47]. Ethiopia has been exposed to broad deforestation; gauges show that the nation is losing up to 140000 hectares of forestlands each year (FAO 2005) [16]. The floral diversity of Ethiopia is currently failed under fully threatened with the association of deforestation, and forest degradation problems (Woldie *et al*., 2015) [51]. Forest degradation in quality (species reduction) and quantity (shrinkage in volume/area), habitat conversion, unsustainable utilization of biodiversity resources, invasive species, and climate change are threatening the biodiversity resources of the country in all highland and lowland ecological systems (FAO 2003 [14], IBC 2014) [27]. The high population growth rate and the subsequent rising demands for crop and grazing

land, construction materials, fuel-wood, and charcoal are the main factors responsible for the decline of forest areas in Ethiopia (FAO 2007) [15].

Yerer Mountain natural forest is one of the protected dry montane forests in the central highlands of Ethiopia which administrated under state forests. The floristic woody composition, richness, and diversity are crucial elements to visualize the vegetation potential of the area. Hence, for proper forest management and conservation decisions, accurate data on forest resources is considered to be an essential requirement to ensure the sustainable utilization of the forest resources in the future (FAO, 2007) [15]. However, still, there is no scientifically well-organized document information concerning the woody floristic species composition, diversity, and richness in Yerer Mountain natural forest of central Ethiopia. The lack of such basic information is one of the serious problems that hamper sufficient conservation and management of the Yerer Mountain natural forest. The main research question of the present study was what is the potential of floristic compositions, diversity, and richness of woody species of Yerer Mountain natural forest in the central highland of Ethiopia? The significance of this study was to generated well scientifically organized information concerning the native woody species composition, richness, and diversity of Yerer Mountain natural forest. The objective of this study was to identify and documents the floristic composition, diversity, and richness of woody species in the Mountain natural forest of the central highlands of Ethiopia.

Materials and Methods

Description of the study area

Location

A field study was conducted in the central highland of Ethiopia, Oromia Regional State, East Shewa Zone, Yerer Mountain natural forest. Yerer forest is one of the remnant montane evergreen natural forests in the central highland of Ethiopia. The study area is located in the central-eastern part of Ethiopia at 40 km southeast far from Addis Ababa, and 17 km north of Bishoftu town. Yerer Mountain natural forest is geographical located between 8°50'84" - 8°54'00" N latitude and 38°54'64" - 38°59'05" E longitude, with altitudinal ranges between 2265 and 3105 m.a.s.l. (Fig. 1).

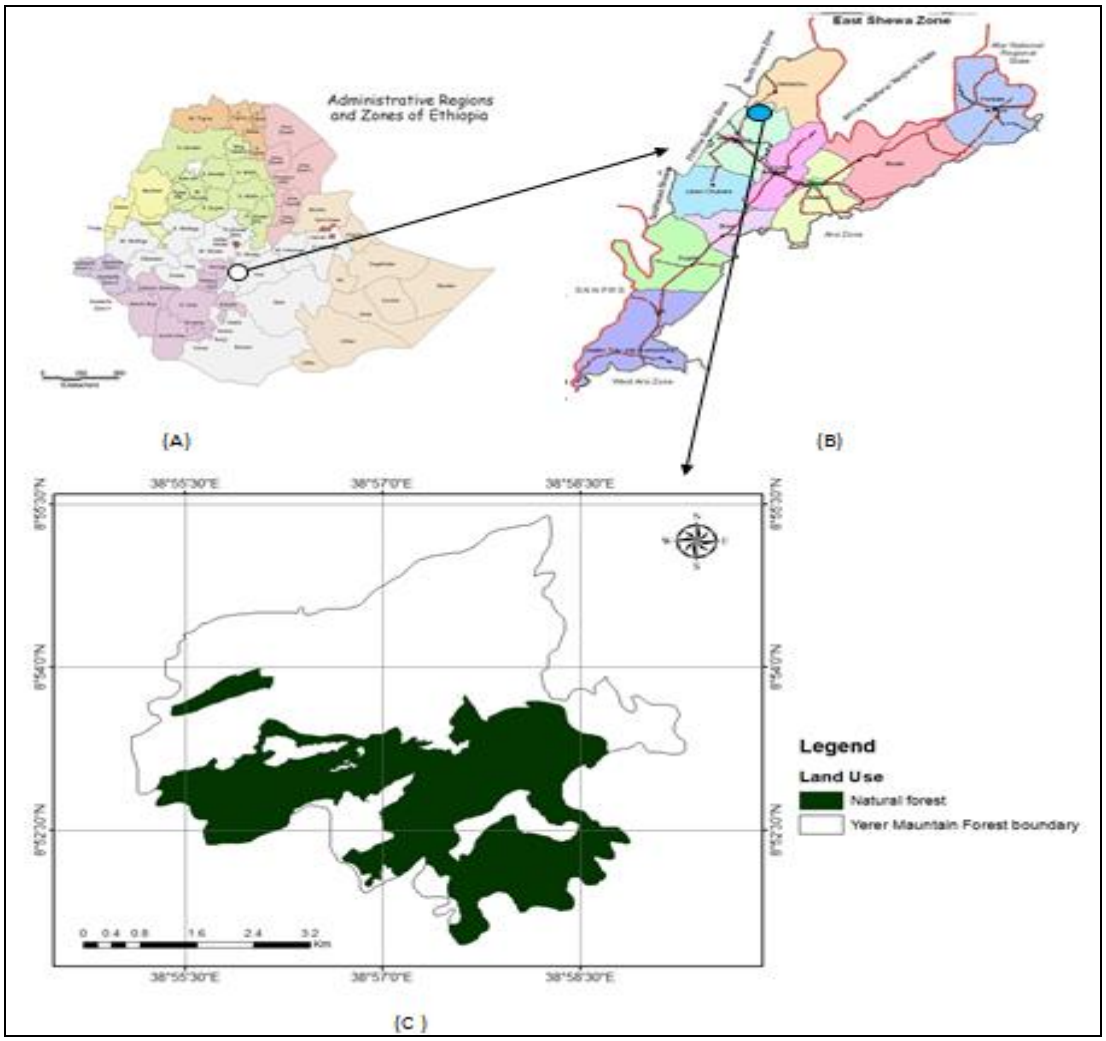

Fig 1: A) Map of Ethiopia, B) Map of East Shewa Zone in Oromia Regional State, C) Map of Yerer Mountain forest 1(developed using ArcGIS 10.4.1 Software).

Climate

Meteorological data (1988 – 2018) showed that the mean annual rainfall of the study area is 907 mm/year which is characterized by a bimodal rainfall having a long dry season (6-8 months). The area obtains the maximum rainfall during the rainy season between June to September and is followed between March and April Months. Short rains occur at any month of the dry season irregularly. The mean annual minimum and maximum temperatures were 11.1 ^{0}C, and 29.5 ^{0}C, respectively National Meteorology Service Agency (2019) (Fig. 2).

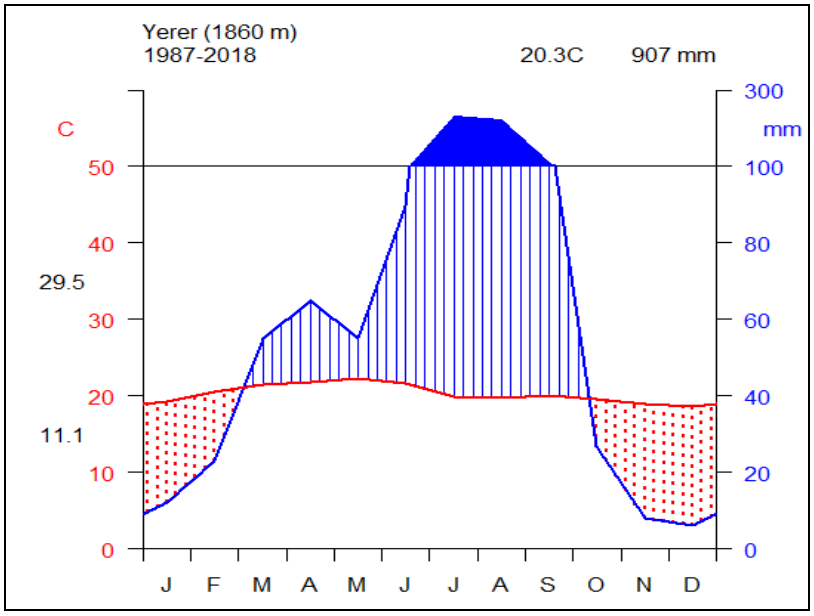

Fig 2: Climadiagram showing rainfall distribution and temperature variation from 1988-2018 at Yerer forest area

Yerer Mountain natural forest history

Yerer Mountain natural forest is one of the protected forests among the designated protected forests in Ethiopia those recognized by legislation in 1965 as state forests. The forest resource management paradigm during Emperor Haile Selassie administration period was for environmental protection purposes, and additional the forests were preserved and protected for their economic value mainly as a source of domestic fuelwood, and construction material. Dry Evergreen Montane forest is a very complex vegetation type occurring from 1500 m to 3200 m altitude, with average annual temperature and rainfall of 14-25 C^{O} and 700-1100 mm, respectively (Zerihun, 1999). Accordingly, the Yerer Mountain natural forest belongs to this type of vegetation (Dry Evergreen Montane forest) category, which dominated by *Juniperus procera*, *Myrsine Africana, Ficus sur*, *Pterolobium stellatum, Carissa spinarum* , *Maytenus arbutifolia, Olea europaea,* Euclea racemosa, *Erica arborea, and Hypericum revolutum* woody species.

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Fig 3: Yerer Mountain natural forest

Yerer Mountain natural forest is part of the central highlands of National Forest Priority Areas in Ethiopia. The forest is part of the remnant dry ever evergreen montane forest of the central highlands of Ethiopia. For the effective conservation and management of forest resources since 2003, it is under the administration of the Oromia Forest and Wildlife enterprise. For effective management practice, participatory forest management (PFM) was introduced in the area by Oromia Forest and Wildlife Enterprise (OFWE) in 2010 as a new system of forest resources governance to mitigate the persistent problems of forest degradation and deforestation, and to improve better social and economic benefits of the local people. Yerer Mountain Forest was managed and conserved with multiple objectives, including contributing to environmental protection purposes (like soil, water, and climate), biodiversity conservation, and developing sustainable use of forest resources for economic and social values. Yerer Mountain natural forest is consists of a mixed deciduous native natural forest which covers about 1461 ha area.

Sampling Design and Sampling Procedure

The systematic sampling design was applied for the determination of aboveground woody species composition, diversity, and richness of the whole Yerer Mountain natural forest following the Muller-Dombois and Ellenberg (1974) [38] procedure. Woody species composition and related data collection within the Mountain natural forest was conducted by using transect lines laid parallel to each other along the altitudinal gradient from top to bottom with100m spacing between the two adjacent transect lines, and 100m distance intervals between the consecutive quadrats. The woody floristic data were collected from a total of 122 square quadrats with 400 m2 area each; along 22 transect lines following the procedure of Muller-Dombois and Ellenberg (1974) [38], and Esmailzadeh *et al***.** (2011) [13].

The matured woody species (trees, shrubs, and climbers) data were collected from a main square quadrat of 20 m x 20 m (400 m^2) area. In each of the main quadrat, five subquadrats (2 m × 2 m) were established for seedlings and saplings of woody species data collection by arranging four (4) subquadrats at each corner and one (1) subquadrat at the center as the procedure described by Muller-Dombois and Ellenberg (1974) [38]. All sample quadrats on transect lines at starting and ending points were located 15 m from forest stand edge/road to avoid edge effect.

Floristic data collection and identification

Prior to actual woody species data collection, a reconnaissance survey was conducted in the Yerer Mountain natural forest from the second to fourth weeks of December 2017 to collect the general information on the accessibility of the study area, to familiarize me with the study area, to get an insight of the forest structure, the size of the forest, topography, and other environmental conditions. The actual field data were collected in the whole Mountain natural forest from Mid-January 2018 to Mid-June 2018. In each main quadrat of 20 m x 20 m area, all a complete list of woody species (tree, shrub, and woody climbers) present were identified the species name, counted the stem density, measured diameter at breast height (DBH), height (H), and estimated the canopy cover of individual species.

For the whole Yerer Mountain natural forest floristic study, the data of woody species (trees, shrubs, climbers, seedlings, saplings) composition were collected in each quadrat. In each quadrat woody species those DBH > 2.5 cm, and height > 3m were considered as tree, shrubs, and woody climber, whereas species that DBH less than 2.5 cm and height less than 3 m were considered as seedling and sapling (Senbeta and Teketay, 2001 [43], Gillison, 2006) [18]. Woody species were measured their diameter at breast height (DBH) by using a caliper and their height by using a hypsometer in the main sample quadrats. The woody species of seedlings and saplings' diameter and height were measured simply by using a measuring tape. The diameter of a tree, shrub, sapling, and a woody climber was measured at breast height (1.3m height) from the ground. The diameters of seedlings were measured at a height of 20 cm above the ground. The percent cover-abundance value of individual woody species was estimated visually for each species related to a sampling quadrat proportional coverage area. The environmental gradients of altitude, slope, and aspect at each quadrat were measured by using GPS (Global positioning system), Compass, and clinometers, respectively.

Most of the native woody species were identified in the field by using botanical keys and local knowledge. However, some species that could difficult to identify in the field, the woody specimens were collected from the field following standard herbarium technique. The collected specimens of woody species were allotted collection numbers, pressed, and dried for identification at the National Herbarium of Ethiopia, Addis Ababa University. The specimens were identified by comparing it with already identified herbarium specimens and using taxonomic keys in the Flora of Ethiopia and Eritrea volumes 1 – 8 (Hedberg and Edwards, 1995; Edwards *et al*., 1995; 1997; 2000; Hedberg *et al*., 2003; Hedberg *et al*., 2004) [10, 9, 20, 21].

Data Analysis

Floristic composition analysis

Species composition was expressed through the total species richness which was computed as the total number of individuals by species, genus, and family across all 122 quadrants in the whole Yerer Mountain natural forest.

Floristic Community Classification

The collected woody species abundance percent (%) cover raw data in the field were created the three-column data table by following the procedure of Hill (1979). The woody species abundance percent (%) cover was transformed to the appropriate modified 1-9 scale of Braun-Blanquet (van der Maarel, 1979) with R Software library (labdsv) by following the procedure of Roberts (2010) [42]. The vegetation data were classified into homogeneous subgroups employing hierarchical cluster analysis. The plant communities in the natural forest were analyzed by using agglomerative hierarchical cluster analysis R software version 3.5.2. The decision on the number of woody plant communities in the natural forest was based on the determining optimal number of clusters analysis with the R software program. The clustering of community types was distinguished from the output of the dendrogram hierarchical cluster analyzed plotted figure. Each community type was named by one or two dominated species characteristics based on the higher relative magnitude of synoptic cover-abundance values.

Floristic Diversity index analysis

For each plant community type, species diversity; richness; and evenness in the aboveground woody species were analyzed by using Shannon and Wiener's (1949) [44]. Diversity index. Shannon - Wiener diversity index is the most common method used to measure species diversity without affected by vegetation sample size, and it describes both species richness and evenness (Kent and Coker, 1992; Krebs, 1999) [30, 32].

Species diversity index (H') - was calculated according to Shannon-Wiener (1949) [44] by using the following formula:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \quad \text{…………………………………(1)}$$

Where, H' = Shannon diversity index; S = the number of species; Pi = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover; and ln = log base $_n$ (natural logarithm).

Species richness (R) is measured to know how many numbers of different kinds of species present in each plant community type (Krebs 1999) [32]. The computational formula is as follows:

$$R = (S'-1)/\text{LnN} \quad \text{………………………………………..(2)}$$

Where R is species richness; S' is the number of species of that taxonomic group observed and N is the total number of individuals species observed

Species evenness index (J') is a measure of how similar species are in their abundances in each plant community type. The Evenness of species was calculated by dividing H by Hmax as:

$$J' = H'/H'\text{max or } J' = H'/\ln S \quad \text{……………….…… (3)}$$

Where J' *is Species e*venness index, *H'* is Shannon-Wiener Diversity Index; *H'max* is equal to the natural logarithm of richness in S, and *ln* = log base $_n$ (natural logarithm); S is a total number of species in the study area, Hmax = lnS.

Floristic Composition Similarity analysis among communities

Similarity analysis was carried out to evaluate the relationship between possible pairs of communities based on the common presence of woody species to determine the degree of similarities in their species composition. Evaluation of species similarity index was conducted using Sorensen's similarity index. The species similarity index analysis among paired community's types is described by using the following formula (Kent and Coker, 1992) [30]:

$Ss = 2a/ (2a+b+c)$,

Where, Ss = Sorensen's similarity coefficient a = Number of species common to both sample quadrats; b= Number of species in sample quadrat 1; c = Number of species in sample quadrat 2.

Result

Floristic composition

A total of 93 woody plant species (trees, shrubs, and woody climbers) were identified from the Yerer Mountain natural forest, which belongs to 46 families and 73 genera. Out of the total woody species, 85 of the specimens were identified at the species level, 7 specimens at the subspecies level, and only 1 of them at the variety level. Of these plant species 13 were endemic, 79 were indigenous, and 1 introduced woody species. Of all the families, Fabaceae was the most dominant contributing fourteen species (15.05 %) to the total species followed by Lamiaceae, and Asteraceae with eight (8.60 %), and six species (6.45 %), respectively (Fig. 4).

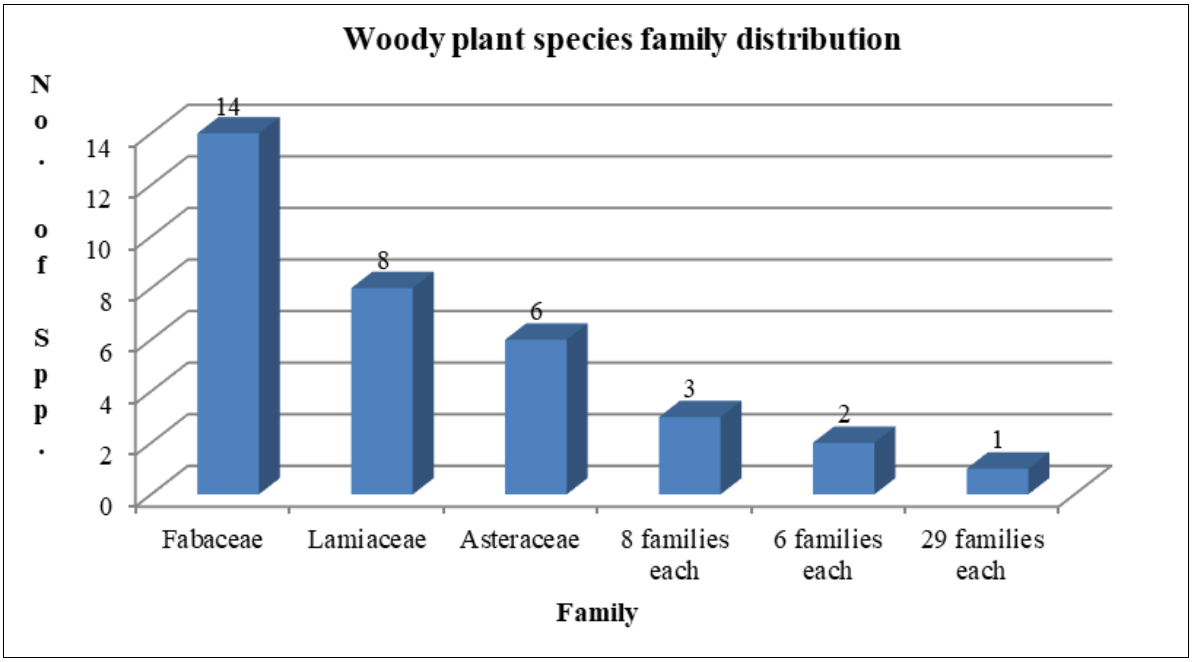

Fig. 4: Woody plant species families' distribution in Yerer natural forest

Woody species Growth Habit Proportion

Of the total 93 collected woody species were composed of 25 species (26.88%) trees, 55 species (59.14%) shrubs, and 13 species (13.98%) woody climber (Fig. 5).

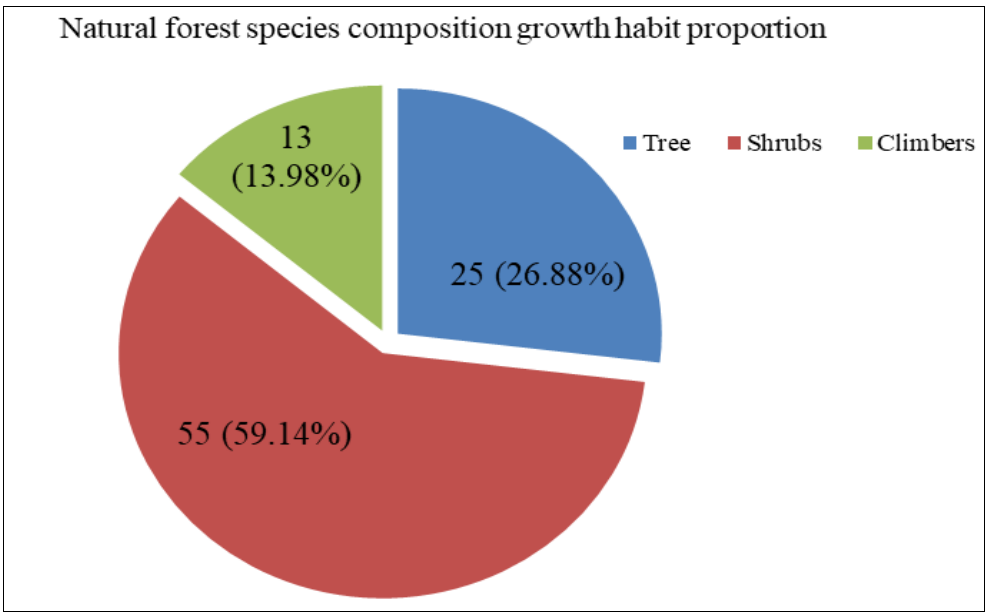

Fig 5: Distribution of woody species in their growth habits (tree, shrub, and climber)

Woody plant Communities Classification

The hierarchical classification of the woody species into different communities has been done by dendrogram hierarchical classification using a similarity ratio. Cluster analysis was used to identify groups of sites (sample quadrats) that are similar in terms of their woody species composition. Accordingly, from the Mountain natural forest area, five woody plant community types were identified (Fig. 6).

Cluster dendrogram

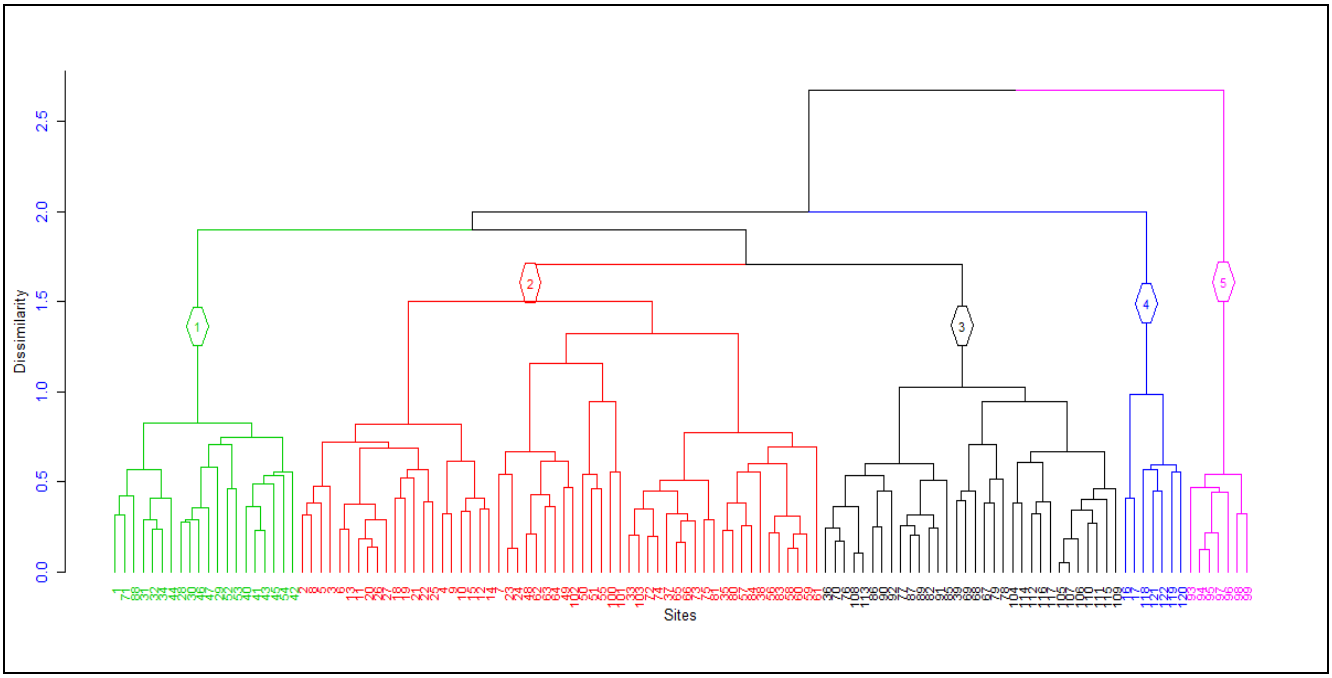

Fig 6: Dendrogram of the woody plant hierarchical cluster analysis showing sample quadrats in the community types

In all community types, along with their synoptic-cover abundance values, 64 woody species that having synoptic-cover abundance values of greater than or equal to 1.0 at least in one community type were identified. Each woody plant community type was described based on their altitudinal, and slope distribution range, and woody species composition in their growth habit categories (tree, shrub, and climber) (Table 1). The five different types of classified woody communities were described as follows.

***Juniperus procera* - *Myrsine africana* community type (C1)**

This community type is distributed between the altitudinal range of 2448 - 2754 m a.s.l, and the slope gradient range of 22-65%. The community was comprised of 43 (51.19%) woody species richness. This community consists of a total of 14 indicator species (5 trees, 8 shrubs, and 1 woody climber) those having cover-abundance greater than or equal to 1.0. The major importance of species *Juniperus procera*, *Myrsine africana*, *Rosa abyssincia*, *Dodonaea angustifolia*, *Rhus glutinosa*, *Calpurnia aurea*, and *Rumex nervosus* are constancy/common species that occurs in all forest communities but dominantly found in this community type. The important climber species of this community are *Clematis longicauda*, *Helinus mystacinus*, *Stephania abyssinica*, *and Clematis simensis*. *Phoenix reclinata*, *Millettia ferruginea*, and *Podocarpus falcatus* are diagnostic species that occur only in this community type.

Table 1: the communities, sample quadrats, and species composition distribution with their altitudinal and slope ranges

Community type	Community Name	Number of quadrats	No. of species richness				Slope Range	Altitudinal Range (m.a.s.l.)
			Tree			Total		
C1	*Juniperus procera - Myrsine africana*	20	9	24	10	43	22-65%	2448-2754
C2	*Ficus sur - Pterolobium stellatum*	56	26	31	11	68	9-65%	2294-2763
C3	*Carissa spinarum - Maytenus arbutifolia*	32	21	29	10	60	5-55%	2330-2575
C4	*Olea europaea - Euclea racemosa*	7	19	35	9	63	11-26%	2265-2309
C5	*Erica arborea - Hypericum revolutum*	7	10	21	0	31	20-44%	2964-3103

***Ficus sur* - *Pterolobium stellatum* community type (C2)**

This community is distributed within the altitudinal range of 2294 and 2763 m a.s.l, and slope gradient ranges of 9 % - 65%. This community is characterized by medium to high altitude, steep slope, valley/gorge, and partial mountainous topography. As compared to other the rest four forest communities, this community contains the largest number of 56 quadrats (45.90%) and 68 species richness (80.95%) of the total identified species in the area. It also contains the largest number of indicator species those having a cover-abundance value greater than one, and the most species richest community. This community consists of a total of 35 indicator species (14 trees, 14 shrubs, and 7 woody climber species) those having cover-abundance greater than or equal to 1.0.

***Carissa spinarum* - *Maytenus arbutifolia* community type (C3)**

This community was laid at the altitudinal range of 2330 - 2575 m. a.s.l and slope from flat (5%) to steep (55%). This community consists of 32quadrats (26.23%) and 60 species richness (71.43%) out of the total identified species. This community consists of a total of 6 indicator species (1 tree, and 5 shrub species) those having cover-abundance greater than or equal 1.0. The only tree species found in this community is *Prunus africana*, however, the shrub species include *Carissa spinarum*, *Maytenus arbutifolia. Var. sidamoensis*, *Heteromorpha trifoliate*, *Rhamnus stadd*, and *Otostegia integrifolia*.

***Olea europaea* - *Euclea racemosa* community type (C4)**

This community type is located within the elevation range of 2265 and 2309m a.s.l, and slope ranges of 11-26%. This community is characterized by the lowest altitude, and medium slope range. As compared to the three communities (C1, C2, and C3), the community type four has higher species richness (63), and the least number of 7 quadrats. However, among 63 woody species composition, only 3 indicator species (1 tree, and 1 shrub, and 1 woody climber species) those having cover-abundance greater than or equal to 1.0 were found in this community.

***Erica arborea* - *Hypericum revolutum* community type (C5)**

This community type is found relatively at a higher elevation between the altitudinal ranges of 2964 and 3103 m a.s.l. as compared to the rest communities in the area and its slope gradient was varied within 20% - 44%. This community type contains 7 quadrats (5.74%) and 31 woody species (36.90%). This community consists of a total of 6 indicator species (only shrub species) those having cover-abundance greater than or equal to 1.0. The major dominant shrub species are *Erica arborea*, *Hypericum revolutum*, *Inula confertiflora*, *Hypericum quartinianum*, *Lippia adoensis*, and *Solanum glganteum*.

Woody Species Diversity, Richness and Evenness

The Shannon – Wiener diversity index (H') was computed the woody species diversity for each five plant community types of Yerer Mountain natural forest. The different values of diversity index (H') for the communities reflect the difference in their species richness and evenness. The Shanon-Wiener diversity index shows that different species diversity and richness values in the natural forests were varied among five communities (Table 2).

Table 2: Species richness, evenness, and Shannon-Weiner diversity index of plant community types

Community Type	Community name	Altitudinal range (m)	Species Richness	Species diversity (H')	Species evenness (J)
1	*Juniperus procera - Myrsine africana*	2448-2754	43	3.32	0.88
2	*Ficus sur - Pterolobium stellatum*	2294-2763	68	3.98	0.94
3	*Carissa spinarum - Maytenus arbutifolia*	2330-2575	60	3.41	0.84
4	*Olea europaea - Euclea racemosa*	2265-2309	62	3.42	0.83
5	*Erica arborea - Hypericum revolutum*	2964-3103	31	2.82	0.82

Generally, community two has the highest species diversity and richness followed by community four; however, community 5 has the least species diversity and richness values in natural forests. The highest species evenness was observed in community two, followed by community one, and the least species evenness was observed in community five of the natural forest.

Floristic Species Similarity among plant community types

Sorenson's coefficient of similarity was computed to evaluate the continuous or discontinuous species similarity composition among five plant community types (C) in Yerer Mountain natural forest. According to Sorenson's similarity coefficient, community types two and four were the highest, while, community types one and five were the least similar in Yerer's Mountain natural forest. The distribution of plant species among the communities indicates different similarity patterns (Table 3).

Table 3: Sorensen's similarity coefficient **(**Sc**)** among five communities.

	C1	C2	C3	C4	C5
C1	0				
C2	0.6	0			
C3	0.76	0.75	0		
C4	0.63	0.78	0.74	0	
C5	0.36	0.59	0.42	0.54	0

The Sorenson's coefficient of similarity results indicates that the degree of common species shared between communities two and four (78%), one and three (76%), two and three (75%), and three and four (74%) were high and relatively have similar weight. However, the least degree of species similarity was observed between communities one and five (36%) and followed by communities three and five (42%).

Discussion

Floristic composition

A total of 93 woody species belonging to 73 genera and 46 families were identified from the Yerer natural forest. As compared the potential of Yerer natural forest woody floristic composition with other similar dry evergreen Montane forests in Ethiopia, the result indicated that the number of woody species composition in Yerer natural forest is higher than the majority of other Dry Afromontane forests but less than a few Dry Afromontane forests. These variations of species composition among similar forest types could happen with related to the altitudinal range variation because altitude plays a vital role in plant distribution and richness, environmental factors (like soil properties, climate), land-use history, and anthropogenic factors (human disturbance level). Accordingly, the lower number of woody species compositions than Yerer natural forest (93 species) were reported in Aba Asrat Monastery Forest (81 species) (Bayeh *et al*., 2013) [2], Biteyu Forest (76 species) (Biru *et al*., 2003) [60], Wof-Washa forest (51 species) (Teketay and Bekele, 1995) [46], and Gole Natural Forest (63

species) (Hailemariam and Temam 2018) [19]. However, the woody species composition of Yerer natural forest (93 species) is less than similar Dry Afromontane forests, for example, Gedo forest (145 species) (Kebede *et al*. 2014) [29], and Menagesha-Suba forest (113 species) (Beche 2011) [3].

Among the identified 46 families of woody species, Fabaceae (14 species), Lamiaceae (8 species), and Asteraceae (6 species) are the three dominant families in the area that constituted 28 species (30.11%) of the total species richness. The existence of these three dominant families in the area might be due to well-favorable environmental conditions (soils, water, and climate) of the area that could contribute to their dispersal, adaptation, and successful survival by satisfying their growth ecological requirement. In line with the present study results, Mohammed and Abraha (2013) [37] from Yegof natural forest in North Wello Zone, and Kebede *et al*., (2014) [29]. from Gedo forest in the west Shewa zone were reported as the most diverse families of Fabaceae, Asteraceae, and Lamiaceae. Among the identified woody species, eight families (Acanthaceae, Asclepidaceae, Moraceae, Myrsinaceae, Oleaceae, Rhamnaceae, Rosaceae, and Solanaceae) each consists of three species, six families (Anacardiaceae, Apiaceae, Ebenaceae, Hypericaceae, Ranunculaceae, and Sapindaceae) each consists two species, and the rest twenty-nine families each consists one species. In line with the present study results, Mohammed and Abraha (2013) [37]. from Yegof natural forest in North Wello Zone, and Kebede et. al. (2014) [29]. From Gedo Dry Evergreen Montane Forest in the west shewa zone were reported that the most diverse families of Fabaceae, Asteraceae, and Lamiaceae in similar forest types.

Regarding the distribution of woody growth habits, shrubs (55 species) occupied the highest woody floristic composition followed by trees (25 species) and woody climbers (13 species) in the natural forest. The difference in the distribution of woody growth habits may be due to the various factors of selective cutting of trees, insufficient ecological growth requirements for tree species e.g. soil properties, and dispersal variation among species. In line with the present finding, other workers also reported the dominance of shrubs and followed by trees, and climbers in similar vegetation types of Boda dry evergreen Montane forest (Erenso *et al*., 2014) [12], Gedo dry evergreen Montane Forest (Kebede *et al*., 2014) [29], Yegofa dry evergreen Montane Forest (Mohammed and Abraha, 2013) [37]. And Biteyu dry evergreen montane forests (Biru *et al*., 2003) [60].

Plant Community types

The hierarchical classification showed that the sample quadrats are close together in corresponding to sites that are similar in species composition were categorized under the same community. Plant communities are the collection of plant species that are growing together in a particular location that shows a definite association with each other (Kent and Coker 1992) [30]. Based on the hierarchical cluster analysis of woody species, five plant community types were recognized from the natural forest. These communities are *Juniperus procera - Myrsine africana* (community 1), *Ficus sur - Pterolobium stellatum* (community 2), *Carissa spinarum - Maytenus arbutifolia* (community 3), *Olea europaea - Euclea racemosa* (community 4), *and Erica arborea - Hypericum revolutum* (community 1). The results from cluster analysis showed that the categorized community types varied in the number of species composition ranging from 31-68 species. The variations could be attributed due to environmental gradients variation (altitude, aspect, slope), and environmental factors (soil nutrients, and moisture stress) that can limit the ecological distributions of plant species from a specific area to area in the forest. The variability of species diversity, richness, and evenness among plant communities within a forest due to different factors also reported by other workers (Bekele 1993, Huston 1994 [25], Liu and Brakenhielm, 1996 [33], Fosaa, 2004 [17], Kebede *et al*. 2014 [29], Kalema, 2010, Lulekal 2013) [35].

Woody Species Diversity, Richness and Evenness

Species diversity in a given forest community is used to interpret the relative variation among the communities. The overall Shannon-Wiener diversity index of woody species in Yerer natural forest showed that the different values of species diversity (2.82 – 3.98), richness (31 – 68), and evenness (0.82 – 0.94) among five plant communities. The possible reason for the variations of species diversity, richness, and evenness among plant communities within a natural forest may be occurred due to the influence of environmental factors such as soil properties, micro-climate, elevation, slope, aspect, and degree of disturbance of each community. The variability of species diversity, richness, and evenness among plant communities within a forest due to different factors also reported by other workers (Huston 1994 [25], Liu and Brakenhielm, 1996 [33]. Khumbongmayum *et al*. 2006 [31], Kalema, 2010)

In the present study, the highest species diversity (3.98), richness (68), and evenness (0.94) were observed in community 2 than other communities in a natural forest. The possible reasons for high species diversity, richness, and evenness in plant community 2 might be attributed due to an intermediate wide variation of altitudinal range (2265 - 3103 m.a.s.l) of a community (because intermediate altitude could be associated with moderately favorable environmental conditions that permit rapid resource acquisition to favor for different plant species or heterogeneous species ecological growth requirement satisfy with microclimate, nutrient, and moisture), fewer disturbances (found at the center of the forest), the community found the surrounding river and stream area in both eastern and western directions, and a large number of quadrats (56) distribution. Similar findings were also reported by different researchers (Huston 1994 [25], Brown and Lomolino, 2001 [34]. Ram *et al*. 2004 [41], Wana and Woldu 2005 [49], Barry 2008 [1], Beche, 2011 [3], and Bayeh *et al*. 2013) [2]. According to Kent and Coker (1992) [30]. Were recommended, Shannon-Weiner index (H') values range between 1.5 and 3.5, (which indicate that: if H' > 3 = good, If H; value is between 3.0 and 2.0 = medium, and if H' < 2.0 = low species diversity). The overall Shannon-Wiener diversity index of woody species in Yerer natural forest was 3.39; indicating that the diversity index is relatively high, which grouped under good species diversity (a better combination of the number of species and their relative abundance) as compared with the recommended diversity index values.

The nature of plant communities largely depends on the ecological characteristics in sites, species diversity, and regeneration status of species (Khumbongmayum *et al*. 2006) [31]. Plant community type five was dominated by

shrubs species particularly by *Erica arborea* and *Hypericum revolutum*. Among the identified communities, the least species diversity (2.82), richness (31), and evenness (0.82) were recorded in community 5. This could be due to a plant community 5 lies along the margin of a forest, at the higher elevation of peak Mountain (2964 - 3103), a small number of quadrats (7) distribution and at a vicinity of local people settled area that subjected to high anthropogenic influenced by selective cutting of matured trees and shrubs, grazing and browsing by domestic animals. Because many local people had settled near to the top mountain during the Derge regime (from 1988 to 1990) in settlement program as compare to the other plant community types sites. Similarly, other workers were reported that low species evenness occurred in a particular plant community type within a forest due to the extreme environmental disturbances, variable conditions for regeneration, and selective exploitation of some species (Wassie and Teketay, 2006 [50], Bayeh *et al*. 2013 [2], and Erenso et. al. 2014) [12].

Floristic Species Similarity among plant community types

Generally in Yerer Mountain natural forest, the variations of species composition and diversity were observed among communities. The overall species composition similarity coefficients among the five plant communities were ranged from 36 - 78%. Among the communities in comparison, community two has the highest similarity with community 4 (78%) and followed with community 3 (75%) in floristic species composition. The possible reason for the highest species similarity between these communities could be due to the existence of some quadrats adjacent to each other, geographical proximity, the close similarity of altitude and slope ranges (i.e. at lower level community 4 and 3 are found within a community two ranges in both altitude and slope) that reveals the ecological requirement of nutrients availability by those plant species that adapt to a specific environmental conditions. Similarly, Wana and Woldu (2005) [49]. Reported, in addition to the altitudinal gradient, other environmental factors such as aspect, slope, and soil Physico-chemical properties have sound effects on patterns of plant species composition among communities. If two communities have similar vegetation species they need similar environmental conditions (Oksanen, 2004) [40].

However, the lowest species similarities were observed between community five and one (36%), and five and three (42%). This implies that for all communities, Sorenson's similarity coefficient values were below 0.5, indicating the existence of low similarities and higher dissimilarity among the stated communities. The possible reasons for the higher species dissimilarities between communities might arise from the different number of sample quadrat sizes (7, 20, 32), altitudinal differences, slope differences, degree of human impact (anthropogenic) action variation, climatic conditions, and species growth ecological requirement variation. A similar finding was reported by Enerso, *et al*., (2014). If two communities have different vegetation species, they require different environmental conditions for proper growth (Oksanen, 2004) [40].

Conclusion

Yerer Mountain natural forest is one of the remnants of protected forests in Ethiopia and was recognized by legislation in 1965 in the form of state forests for environmental protection purposes. In Yerer Mountain natural forest, a total of 93 woody species (trees, shrubs, and woody climbers) belonging to 73 genera and 46 families were identified. From the identified families Fabaceae was found to be the most dominant followed by Lamiaceae, and Asteracae families which commonly contribute about 30.12% of woody species composition. The natural forest is dominated by shrub and small-sized tree species in the remnant secondary stage of the natural forest, which reflects the dominance of small-sized individuals, due to the presence of high regeneration of woody species found in the lower DBH and height class sizes.

In Yerer Mountain natural forest, five plant community types were identified as those having varying degrees of species richness, evenness, and diversity due to different factors of anthropogenic, altitude, soil moisture, and soil nutrients variations among communities. Among the recognized communities, plant community two has comprised the highest species diversity (3.98), richness (68), and evenness (0.94), whiles, on the contrary, the least species diversity (2.82), richness (31), and evenness (0.82) were observed in community type five. The analyses of Sorenson's coefficient of similarity on the species composition among communities were varied between 0.36% and 0.78%, due to the variations of the number of sample quadrat sizes, geographical distance, altitude, slope, and degree of an anthropogenic factor on some species among plant communities.

Abbreviations

DBH: Diameter at Breast Height
FAO: Food and Agricultural Organization of the United Nations
Fig.: Figure
IBC: Institute of Biodiversity Conservation

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Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The data can be available in Additional files and for detail

upon please request the Corresponding Author.

Code availability
Not applicable

Authors' contributions
All authors played a vital role to accomplish this manuscript. The corresponding author, YB develops the idea of the research, designed the research method, vegetation data collection, plant identification, statistical analysis, and wrote the manuscript. TB and SD were contributed significant input into the successful completion of the manuscript by supervising the study, consistent and inspiring guidance, valuable suggestions; constructive comments, and reviews on the manuscript preparation.

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