BIODIVERSITAS ISSN: 1412-033X
Volume 21, Number 7, July 2020 E-ISSN: 2085-4722
Pages: 2878-2888 DOI: 10.13057/biodiv/d210702

Plant diversity and community analysis of Gesha and Sayilem Forest in Kaffa Zone, southwestern Ethiopia

ADMASSU ADDI[1,♥], TESHOME SOROMESSA[2], TURA BAREKE[3]
1 Department of Plant Biology and Biodiversity Management Addis, College of Natural Sciences, Ababa University. P.O. Box 3434, Addis Ababa, Ethiopia. ♥email: admassuaddi@gmail.com, tura_berake@iqqo.org
[2]Center for Environmental Science, Addis Ababa University. P.O. Box 1176, Addis Ababa, Ethiopia
[3]Oromia Agricultural Research Institute. Oromia, Ethiopia

Manuscript received: 7 May 2020. Revision accepted: 2 June 2020.

Abstract. *Addi A, Soromessa T, Bareke T. 2020. Plant diversity and community analysis of Gesha and Sayilem Forest in Kaffa Zone, southwestern Ethiopia. Biodiversitas 21: 2878-2888.* The study was conducted at Gesha and Sayilem districts of the Kaffa Zone with the objective of identifying the floristic compositions, plant community types, and associated environmental factors of the forest. Stratified random sampling technique was used. A total of 90 plots were used to collect vegetation data. The plant community classification was performed using agglomerative Hierarchical cluster analysis Ward's linkage method was applied in R-software. Species diversity and evenness were evaluated using the Shannon diversity and evenness indices respectively. The study revealed that the study area composed of 300 species that belong to 239 genera in 96 families. Asteraceae was the most abundant family followed by Fabaceae, Acanthaceae, Poaceae, Rubiaceae, and Euphorbiaceae accounting 37%, 15%, 14%, 13%, 12%, and 9% respectively. Five plant community types were identified and these were *Ilex mitis-Syzygium guineense*, *Pouteria adolfi-friedericii-Schefflera abyssinica*, *Millettia ferruginea-Sapium ellipticum*, *Arundinaria alpina* and *Schefflera volkensii-Masea-lanceolata* community types. Among the community types, *Pouteria adolfi-friedericii-Syzygium guineense* community was the most diverse whereas *Arundinaria alpina* community was the least diverse community. Canonical Correspondence of vegetation data analysis indicated that altitude, disturbance, slope, phosphorus, and the electrical conductivity were the environmental factors that significantly influence the plant communities. The high dependency of local communities on the forest resources is affecting the plant biodiversity. Thus, conservation of the forest through the introduction of sustainable forest management interventions including participatory forest management seems an appropriate action.

Keywords: Species composition, ordination, indicator species, disturbance, conservation

INTRODUCTION

Ethiopia has great geographic diversity with ten ecosystems (Abreham et al. 2013) and 18 major and 49 minor agro-ecological zones (EBI 2014). As a result, it is endowed with a great diversity of plant, animal, and microbial genetic resources Ethiopia (Ensermu and Sebsebe 2014). This diversity of physiographic features is unique in Africa and is responsible for the presence of a wide range of habitats suitable for the evolution and survival of various plant and animal species (Zerihun 1999). Ethiopia is the fifth major country in tropical Africa in terms of the diversity of flora (Ensermu and Sebsebe 2014). In the Horn of Africa region, Ethiopia is regarded as a major center of diversity and endemism for several plant species (Hedberg et al. 2009; Abreham et al. 2013). The flora of Ethiopia is diverse and is estimated to constitute about 6 000 species of higher plants with 647 (10.74%) endemic taxa (Ensermu and Sebsebe 2014). Endemism is relatively high in the Afro-alpine vegetation, in the dry montane forest and grassland complex of the plateau.

Even though the natural forests of Ethiopia make a significant contribution to the ecological wellbeing and economy of the country, most of the natural vegetation is today highly degraded (Demel 2001; Tadesse et al. 2017). Historical sources indicated that 35% of the country's area was once covered by natural high forest (EFAP 1994). However today, the forest cover in Ethiopia is estimated at about 2.5% (Badge 2001). The main causes for the shrinkage of the forest resource in Ethiopia are anthropogenic pressures like clearing and burning of natural forest for crop cultivation, settlements, and gathering of fuelwood and construction material (Sisay 2008; Tura et al. 2017; Yirga et al. 2019). These consequences reduce ecosystem services like carbon stocks, soil properties, and the hydrological cycle (Lal 2012).

The southwest montane forests are among the most affected ecosystems in Ethiopia. Reusing (1998) reported that the closed high forests of southwest Ethiopia dropped from a 40% cover between 1971 and 1975 to only ca. 18% by 1997, which is a loss of ca. 60% of the forest cover. In the 1900s almost all the southwestern highlands were covered by moist evergreen montane forest of which about 7.8% or 235400 ha of the forest was deforested between 1971 and 1997. The main causes of the decline of forest cover in the area are due to clearing forest for coffee and tea plantations and subsistence farming and unplanned movements of immigrant's (Ensermu and Teshome 2008). These factors made a significant contribution to the loss of forest cover and affecting the livelihood of the local communities. There is a lack of detailed studies on the ecology of the southwestern Ethiopian forests. Gesha and

Sayilem districts are one of the potential forest areas designated as part of the Bonga National Forest Priority area (NFPA). Thus, no in-depth study has been conducted on plant diversity, community types, and associated environmental factors such as altitude, slope, aspects, and soil factors affecting community structure of the Gesha-Sayilem forest. Hence, the aim of this study was to assess species composition, species diversity, and plant community types and associated with environmental factors (altitude, slope, and physical and chemical composition of soil). The study was conducted by raising the research questions stating that what are the major plant communities existing in the forest? What are the environmental gradients affecting plant diversity and richness? Furthermore, the intended to test the hypothesis that the plant diversity does not significantly vary among the plant communities and altitude and level of disturbance are not the major influencing environmental factors for differentiation of plant community types in Gesha-Sayilem forest.

MATERIALS AND METHODS

This study was conducted in the two districts of Gesha and Sayilem in Kaffa Zone. Gesha is located between, 70^o 35.36 N latitude and 35^o 45 E longitude while Sayilem is located between, 70^o 49.57 N latitude and 35^o 49.32 E longitude (Figure1). The total area coverage of the Gesha and Sayilem districts are 705.20 and 856.60 square kilometers respectively (Ayele 2011). The mean annual rainfall of Gesha and Sayilem districts are 2004 mm and 1153 mm respectively. The mean monthly temperature ranges between 9.5-29.5°C. The elevation of Gesha and Sayliem districts ranges from 1,600 to 3,000 m. The topography of the landscape is undulating, with valleys and rolling, plateau, and some with flat plains. The study area is dominated by broad leave moist forest from western part of study area while highly disturbed bamboo forest is found in eastern parts of the study area.

The data collection

Stratified random sampling design was used on the basis of altitudinal gradients. Vegetation and environmental data were collected from plot sizes of 625 m^2 following the methods developed by Kent and Coker (1992). All the plant species encountered in each sample plots were recorded using vernacular names. The canopy cover values were converted into a 1-9 scale (Westhoff and van der Maarel 1978; Kent and Coker 1992). The location of each plot was recorded both in degree and UTM using a Geographical Positioning System (GPS). During data collection, growth forms of plants were listed. Voucher specimens were collected, pressed, and dried and identified at the National Herbarium of Addis Ababa University and the identification of species was carried out using the account of Flora of Ethiopia and Eritrea. Angiosperm phylogeny classification of flowering plants (APG IV 2016) was followed to place species with their respective families.

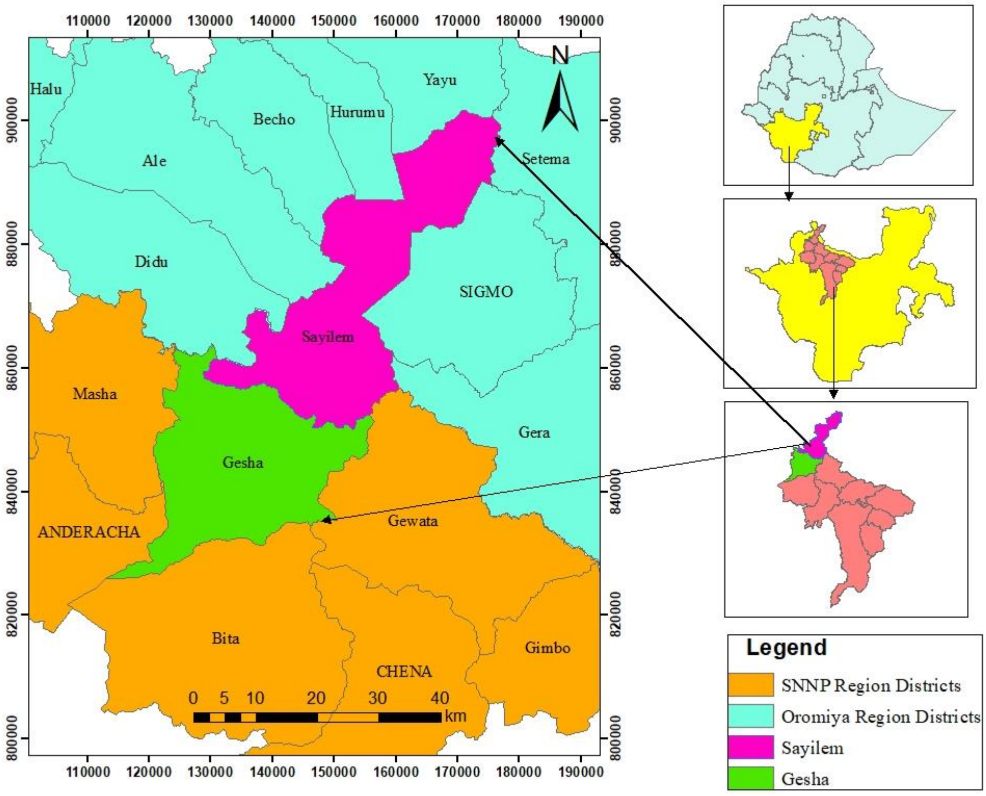

Figure 1. Map of Ethiopia, Oromia and SNNP Region, Kaffa zone, Gesha and Sayilem districts

The environmental data collection

Environmental data on soil samples were taken at the depth of 0-15 and 15-30 cm (Brady 1974; Muhammad et al. 2010; Indra and Arvind 2015). Soil samples were collected at four corners of the plot and one from the center than were mixed to produce the composite soil samples. A total of 90 soil samples were collected and brought to soil Laboratory of the Ethiopian Institute of Agricultural Research. The samples were air-dried, sieved with a mesh size of 2mm to remove coarse gravels, roots, and debris prior to chemical and physical analysis. Soil analyses were conducted based on standard procedures outlined in Allen et al. (1986). Analysis was conducted for pH, soil texture, phosphorus, available potassium, Organic matter, Electrical conductivity, Cation exchange capacity, and total nitrogen. The pH was measured using a pH meter. The soil texture was determined using Hydrometer method with the categories sand, silt, and clay (expressed as % weight) while total nitrogen was determined using Kjeldahl method. Walkley and Black method of titration were used to determine organic matter content. Cation exchange capacity was determined using Aluminum Acetate method and available phosphorus was determined Olsen method.

Slope and aspect of each plot were measured using Suunto Optical Reading Clinometer and compass, respectively. Values for aspect were coded following Zerihun et al. (1989) N=0, NE= 1, E= 2, SE=3, S=4, SW=3.3, W= 2.5, NW= 1.3. The level of forest disturbance including manmade and herbivory was determined based on Anderson and Curriers (1973). The disturbance level was scored using visible signs of tree cutting such as the presence of fresh or old stumps, broken branches and debris, and the occurrence of trampled seedlings and presence of beehives, in each plot. These were placed and scale of 0-5, with 0= (No disturbance), 1= (0-20% of the quadrat disturbed), 2= (21-40% of the quadrat disturbed), 3= (41-60% of the quadrat disturbed), 4= (61-80% of the quadrat disturbed), 5 = (81-100% of the quadrat disturbed)

Vegetation data analysis

Cluster analysis was performed to classify the vegetation data into community types (Woldu 2017). The entire data set was subjected to agglomerative Hierarchical cluster analysis using Similarity Ratio (S.R) and Ward's linkage method. Plant community types were further refined in a Synoptic table which is a product of the species frequency and average cover-abundance value. The community types were named based on the tree and shrub with high synoptic value. The Canonical Correspondence Analysis (CCA) was used to incorporates the correlation between floristic and environmental data within the ordination axis (ter Braak and Prentice 1988). Before running CCA ordination, each environmental variable were tested using a Monte-Carlo test to see the significance level of, 5% for identifying the most influential environmental variables.

Floristic richness and diversity

The Shannon-Wiener index was calculated using the following formula.

$$\text{Shannon Index } (H') = -\sum_{i=1}^{s} P_i \ln P_i$$

Where; **s** is the number of species, pi is the proportion of individuals or the abundance of the i^{th} species, and ln is the natural log, Σ is the sum of the calculations. The evenness of the species within the plant community was calculated to indicate, how the cover of the plant species within a plot is distributed. Evenness values range from 0 to 1 (Kent and Coker 1992). Equitability (evenness) is calculated using the following formula:

$$J = \frac{H'}{H'max} = \frac{H'}{lnS}$$

Where; H': the value of the Shannon-Weiner diversity index, S: number of species in the community, ln: log $base_n$, J: Evenness of species in sampling area, H'max: Maximum value of diversity.

RESULTS AND DISCUSSION

A total of 300 plant species belonging to 239 genera, and 96 families were identified in Gesha-Sayilem forest. The numbers of identified species were about 5.3% of the total Flora of Ethiopia and Eritrea. These species comprised 13 pteridophyte families, 9 monocotyledons, and 74 dicotyledons families. The Asteraceae, Acanthaceae, Fabaceae, Rubiaceae, Poaceae, and Euphorbiaceae represented the highest number of species (Figure2). These families include a number of genera and species. Among the plant families, only six plant families (Asteraceae, Acanthaceae, Fabaceae, Rubiaceae, Poaceae, and Euphorbiaceae) contributed over 31.21% of the total species composition of the area. The presence of the high number of species in the study area is attributed due to its location in the Eastern African Biodiversity hot spot. Previous studies in Ethiopia e.g. Friis (1992); Kumelachew and Tamrat (2002); Friis et al. (2011); Abreham et al. (2013) and Admassu et al. (2016) have confirmed that the montane moist forest ecosystems are the most diverse ecosystems in composition, structure and habitat types.

Out of the plant families identified, only six plant families were contributed over 28.17% of the total number of species in the forest. These are the families that are also reported to be the most species-rich families in the Flora of Ethiopia and Eritrea (Ensermu and Sebsebe 2014). In addition to this, study conducted by Tura and Admassu (2018) and Tura and Admassu (2019) on honey pollen analysis also indicated that Fabaceae and Asteraceae the dominant bee forage families. Asteraceae is one of the largest families of vascular plants and the most species-rich families comprising 133 genera and 472 species (Mesfin 2004; Ensermu and Sebsebe 2014). The Asteraceae became one of the successful families in Angiosperm phylogeny due to mode of pollination, seed dispersal, and adaption to different ecological niche and the same is expected in

Moist Afromontane Forest. Analysis of growth habits in the study forest revealed that the herbaceous flora contributes 56% of the total species composition of the area. This could be due to disturbance and the presence of canopy gaps in the Forest. Similar studies of the dominance of herbaceous flora with other forests in Ethiopia were reported by Haile et al. (2008); Fekadu et al. (2012) and Ermias (2014).

All species from the study area were categorized into different growth forms, trees, shrubs, herbs, and lianas. The analysis of growth forms of plant species from study areas. Herbs represented the highest floristic composition (58%), followed by shrubs (14.67) trees (16%) and climbers/ lianas were (11.3 %).

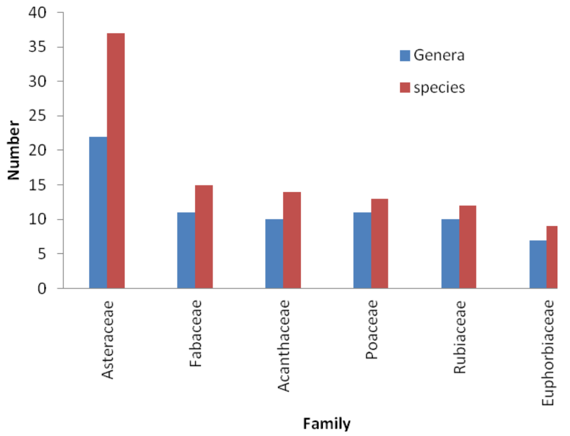

Figure 2. Number of species composition and genera in rich families in Gesha Sayilem forest

Endemic plant species

Based on the endemic flora of Ethiopia available in the published volumes of Flora of Ethiopia and Eritrea, from the 300 species, collected 26 were endemic, comprising 4.5% of the total endemic flora of the Ethiopia and Eritrea (Table1). Out of the identified endemic plant species, 8 are in IUCN Red List Categories of Flora of Ethiopia and Eritrea (Vivero et al. 2005). The presence of higher number of endemic flora as compare to similar studies in adjacent forest in southwest Ethiopia is due to adaptations of plants to topographic features and geological changes which can also lead to evolution and speciation of flora (Tadesse et al. 2017). The diverse topographic land features having various climatic conditions assisted Ethiopia to be a country of high biodiversity (Gebrehiwot and Hundera 2014).

Cluster analysis

Our study confirmed that the five groups have significant differences ($p < 0.001$). The agreement statistics A which describes within-group homogeneity compared to the random expectation was 0.108. The test statistics describe the separation between the groups (McCune and Grace 2002). The more negative, it is the stronger the separation between the clusters. The number of clusters is based on a synoptic table with the mean values of the cover-abundance of Cluster groups. The communities' types were identified at 0.1 to 1.5 dissimilarity levels. The species occurrences were summarized by synoptic cover-abundance values and the communities were named after tree and shrub species with high synoptic value (Table 2).

Table 1. Endemic plants of Ethiopia in Gesha-Sayilem forest (Addi 2018)

Plant species	Family	Habit
Acanthopale ethio-germanica Ensermu	Acanthaceae	Herb
Aframomum corrorima (Braun) Jansen	Zignberiliaceae	Herb
Amorphophallus gallaensis (Engl.) N. E. Br.	Araceae	Herb
Bothriocline schimperi Oliv. & Hiern ex Benth.	Asteraceae	Herb
Cirsium dender Friis	Asteraceae	Herb
Clematis longicauda Steud. ex A. Rich.	Ranunculaceae	Climber
Conyza abyssinica Sch. Bip. ex A. Rich.	Asteraceae	Herb
Satureja paradoxa (Vatke) Engl.	Lamiaceae	Herb
Scadoxus nutans (Friis & Bjornstad) Friis &Nordal	Amaryllidaceae	Herb
Crotalaria rosenii Pax Milne Redh. ex Polhill	Fabaceae	Herb
Rinorea friisii M. Gilbert	Violaceae	Herb
Dorsetnia soerensenii Friis	Moraceae	Herb
Solanecio gigas (Vatke) C. Jeffrey	Asteraceae	Shrub
Vepris dainellii (Pich.-Serm.) Kokwaro	Rutaceae	Shrub
Vernonia leopoldi (Sch. Bip. ex Walp.) Vake	Asteraceae	Herb
Brillantaisia grotanellii Pich.-Serm.	Acanthaceae	Herb
Euphorbia dumalis S. Carter	Euphorbiaceae	Herb
Impatiens rothii Hook.f.	Balsaminaceae	Herb
Mikaniopsis clematoides (Sch. Bip. ex A. Rich.) Milne-Redh.	Asteraceae	Climber
Millettia ferruginea (Hochst.) Bak.	Fabaceae	Tree
Peucedanummattirolii Chiov.	Apiaceae	Herb
Psycnostachys abyssinica Fresen.	Lamiaceae	Herb
Pittosporum abyssinicum Del.	Pittosporaceae	Shrub
Solanum marginatum L.f.	Solanaceae	Herb
Vernonia filigera Oliv. &Hiern	Solanaceae	Shrub

***Ilex mitis-Syzygium guineense* community**

The Ilex mitis-*Syzygium* guineense community is occurring between altitudinal ranges of 1834-2408m above sea level and east-facing slope and which comprised 92 species. The characteristic species of the community are Ilex *mitis* and *Syzygium guineense* (Willd.) DC. The dominant tree species in the community were *Allophyllus abyssinicus* (Hochst.) Radlk., *Macaranga capensis* (Baill.) Sim., *Croton macrostachyus* Del. and *Apodytes dimidiata* E. Mey. exArn. While the shrubs include *Galiniera saxifraga* (Hochst.) ridson, *Brucea antidysenterica* J.F. Mill., *Clausena anisata* (Willd.) Benth. *Dracaena afromontana* Mildbr. And *Olea capensis* (C. A.Wright) Verdc. The herb layer comprises *Asplenium aethopicum* (Brum.f.) bech., *Hypoestes triflora* (Forssk.) Roem & Schult, *Alchemilla pedata* A. Rich. and *Achyranthes aspera* L.The Lianas common to this community were *Hippocratea africana* (Willd.) Loesand *Landolphia buchananii* Loes.

***Pouteria adolfi-friederici-Schefflera abyssinica* community**

Eighty-nine (89) species are recorded and *Pouteria adolfi-friederici-Schefflera* abyssinica community occurs between 1734-2803m and as found on moderate slope (26.2%) facing towards south. It is dominated in the upper canopy by (*Engl.) Baehni*, *Schefflera abyssinica* (Hochst. ex A.Rich.) Harms, *Albizia gummifera* J.f. Gmel.) C.A. Sm, *Ekebergia capensis* Sparrm, *Elaeodendron buchananii* Loes., *Ilex mitis* (L.) Radlk., *Olea welwitschii* (Knobl.) Gilg & Schellenb., *Alangium chinense* (Lour.) Harms and *Prunus africana* (Hook. f.) Kalkm. Among the shrub species, *Maytenus gracilipes* (Welw. ex Oliv.) Exell, *Ocotea kenyensis* (Chiov.) Robyns & Wilken, *Oxyanthus speciosus* DC., *Pavetta abyssinica* Fresen, *Vernonia auriculifera* Hiernand the tree fern *Cyathea manniana* Hook. The herb layer is dominated by *Acanthopale ethio-germanica* Ensermu, Acanthus *eminens* C.B.Clarke, *Piper capense*,L.f. *Commelina benghalensis L., Isoglossa somalensis* Lindau, and *Pilea bambuseti* Engl.. The climbers are frequent in this community were *Hippocratea pallens* Planchon ex Oliv. *Landolphia buchananii* (Hall. F.) Stapf. *Jasminum abyssinicum* Hochst.ex DC. And *Schefflera myriantha* (Bak.) Drake.

***Millettia ferriguinea-Sapium ellipticum* community type**

This community type is found between 1722-2316m. It occurs on gentle slope (22.2%). Eighty-five plantspecies were recorded in it from 15 plots. The dominant trees in the community are *Millettia ferruginea* (Hochst.) Bak., *Ficus sur* Forssk., *Olea welwitschii* (Knobl.) Gilg & Schellenb., *Albizia gummifera* Oliv., *Polyscias fulva* (Hiern) Harmsand *Sapium ellipticum* Krauss) Pax while shrubs include *Oxyanthus speciosus* DC., *Vepris dainellii* (Pich.-Serm.) Kokwaro, *Coffea arabica* L. And *Rytigynia neglecta* (Hiern) Robyns. The herbs comprise *Pteris pteridioides* (Hook.) Ballard, *Aframomum corrorima* (Braun) Jansen, and *Desmodium repandum* (Vahl) DC. The climbers/lianas included, *Clematis simensis* Fresen., *Landolphia buchananii* Planchon ex Oliv., *Hippocratea pallen* Planchon ex Olivs, *Jasminum abyssinicum*, *Urerahypselo dendron* (A. Rich.) edd. and *Tiliacora troupinii* Cufod.

***Arundinaria alpine* community type**

This community occurs between 2350-2506m. It found at lower slope (17.2%) facing the southwest. Forty-three species were recorded with dominant one being the highland bamboo, *Arundinaria alpina* K. Schum., *Schefflera volkensii* (Engl.) Harms, *Hagenia abyssinica* (Bruce) J.F. Gmel.and*Dombeya torrida* (J.F. Gmel.) P.Bamps. The shrubs are *Maesa lanceolata* Forssk.,*Galiniera saxifraga* (Hochst.) Bridsonand *Vernonia amygdalina* Del. The herb layer included *Alchemilla abyssinica* Fresen, *Commelina benghalensis* L., and *Cissampelos mucronata* A. Rich

***Schefflera volkensi-Maesa lanceolate* community type**

This community type occurs between 1968-2800m and the community was distributed on medium slope (20.2%), facing towards the northeast. Sixty-six species were recorded and the dominant trees are *Hagenia abyssinica* (Bruce) J. F., *Schefflera volkensii* (Engl.), (Baill.) Sim., *Maesa lanceolata* Forssk., *Dombeya torrida* (J.F. Gmel.) P. Bamps, *Ekebergia capensis* Sparrm. And (Hook. f.) Kalkm..The shrub layer comprises *Dracaena afromontana* Mildbr., *Bersama abyssinica* Fresen. and *Maytenus undata* (Thunb.) Blakelock, *Nuxia congesta* R. Br. *Ex* Fresen. and *Hypericum revolutum*. The herb layer was dominated by *Satureja paradoxa* (Vatke) Engl., *Trifolium polystachyum* Fresen, *Bidens prestinaria* (*Sch. Bip.)* Cufod. and wetland species which include, *Juncus effusus* L., *Cyperus fischerianus* A. Rich., *Alchemilla pedata* A. Rich. And *Helichrysum formosissimum* Sch. Bip. ex A. Rich.

In this study, five different plant community types were identified and these plant communities are diverse and rich in species composition (Figure 3). The difference in plant communities could be directly related to environmental factors that make the plant communities have their own distinct or characteristic species (Feyera 2006). The *Ilex mitis-Syzygium guineense* and the *Pouteria adolfi-friederici-Schefflera* had the highest number of plant species compared to other communities. This could be attributed due to their location away from human disturbances since they are located in difficult terrains such as sloppy and deep gorges. These communities also hold economically important tree species such as *Schefflera abyssinica* (Hochst. ex A.Rich.) Harms, *Croton macrostachyus* Del. And *Pouteria adolfi-friederici* (Engl.) Baehni for honey production. In addition, the community three (*Millettia ferruginea-Sapium ellipticum* community type) is found at gentle slopes and dominated by economically important plant species such as *Coffea arabica* L., *Piper capense* L.f. and *Afromomum corrorima* (Braun) Jansen.

The *Arundinaria alpina* community type comprises a low number of species compared to other plant communities which was found at higher altitude. This is in agreement with common views that the species richness tends to decrease at higher elevations (Vetaas and Gryytnes 2002). In addition, this community is highly disturbed due to anthropogenic influences and grazing pressures. The *Schefflera volkensi-Maesa lanceolata* community is distributed in wide-ranging altitudes between1968-2800m. This community shares certain species with wetland species and highly disturbed due to human influences and overgrazing. It is dominated by shrubs, sapling, and seedling classes and could be late succession stage where a large number of species co-exist and grow together. This agrees with views that species diversity is high in successional communities (Silvertown 2004).

Indicators plant species are plants that are easily monitored and predict the condition of the environment where they are found (Cairnsand Pratt 1993; Bartell 2006). Indicator species concept is commonly applied in environmental monitoring for watersheds, wildlife conservation, habitat management, and ecosystem restoration. Based on this, the cluster one has 92 plant species and it has two indicator species. Cluster two had no indicator species indicating each species are occurring with other communities. Cluster three has 85 species and it has four indicator species. Cluster four has 43 species and two indicator species. The cluster five has 66 species and it has four indicator species (Table 3).

Community 2 has the highest species diversity followed by communities 3,1and 5. Relatively community four was lower species diversity (Table 4). The species richness also varied among the communities. Community 2 had the highest number of species richness or diversity followed by community1, 3, 5, and the least for community 4. The community five relatively higher evenness value, followed by community three and two whereas the community one and four relatively lower evenness value respectively. The overall plant diversity (Shannon diversity index) and evenness in the study area are 3.56 and 0.85 respectively. The beta diversity of the study area worked out was 0.73 which denotes high habitat diversity among the communities.

Table 2. Species list with Synoptic cover-abundance value in cluster groups for GeshaSayilem forest

Species	**C1**	**C2**	**C3**	**C4**	**C5**
Ilex mitis	5.85	1.69	2.47	0.83	0.5
Syzygium Guineans	5.30	1.97	4.13	0.00	0.2
Dracaena afromontana	3.56	2.45	0.93	0.00	0.2
Cyathea manniana	2.59	0.72	0.53	0.00	0.2
Deinbollia kilimandscharica	2.15	1.28	1.60	0.00	0.2
Galiniera saxifraga	2.48	2.69	2.60	1.00	1.1
Macaranga capensis	3.30	1.69	0.93	0.50	0.0
Rytigynia neglecta	1.37	1.10	1.00	0.33	0.3
Pouteria adolfi-friederici	1.78	5.07	0.93	0.00	0.2
Schefflera abyssinica	3.74	3.17	2.33	0.67	0.2
Allophyllus abyssinicus	1.48	2.21	2.07	0.00	0.2
Croton macrostachyus	0.81	2.38	2.20	0.17	0.2
Apodytes dimidiata	1.22	1.45	1.13	0.00	0.0
Cassipourea malosana	0.85	1.52	1.13	0.00	0.0
Ekebergia capensis	0.52	1.79	0.13	0.00	0.2
Elaeodendron buchananii	0.19	1.28	0.40	0.00	0.0
Hypoestes triflora	0.07	1.10	1.33	0.50	0.5
Isoglossa somalensis	0.96	1.55	0.53	0.00	0.0
Maytenus gracilipes	1.78	1.86	0.87	0.17	0.0
Millettia ferruginea	1.15	0.62	7.73	0.50	0.0
Sapium ellipticum	0.11	0.21	3.3	0.0	0.0
Bersama abyssinica	1.15	1.66	1.53	1.17	0.5
Lepidotrichilia volkensii	1.63	2.62	2.20	0.00	0.6
Albizia gummifera	0.22	0.31	2.00	0.00	0.0
Olea capensis	0.78	0.66	1.73	0.00	0.0
Oplismenushirtellus	0.26	0.31	1.07	1.00	0.0
Coffea arabica	0.00	0.03	1.80	0.00	0.0
Alangiumchinense	0.56	0.34	1.13	0.00	0.0
Arundinaria alpina	0.00	0.00	0.00	9.00	0.7
Alchemilla abyssinica	0.07	0.28	0.40	1.67	0.9
Maesa lanceolata	0.04	0.10	0.00	0.00	3.6
Schefflera volkensii	0.59	0.07	0.00	0.00	3.5
Schoenoplectus corymbosus	0.00	0.00	0.00	0.00	1.2
Alchemilla pedata	0.00	0.00	0.00	0.00	1.3

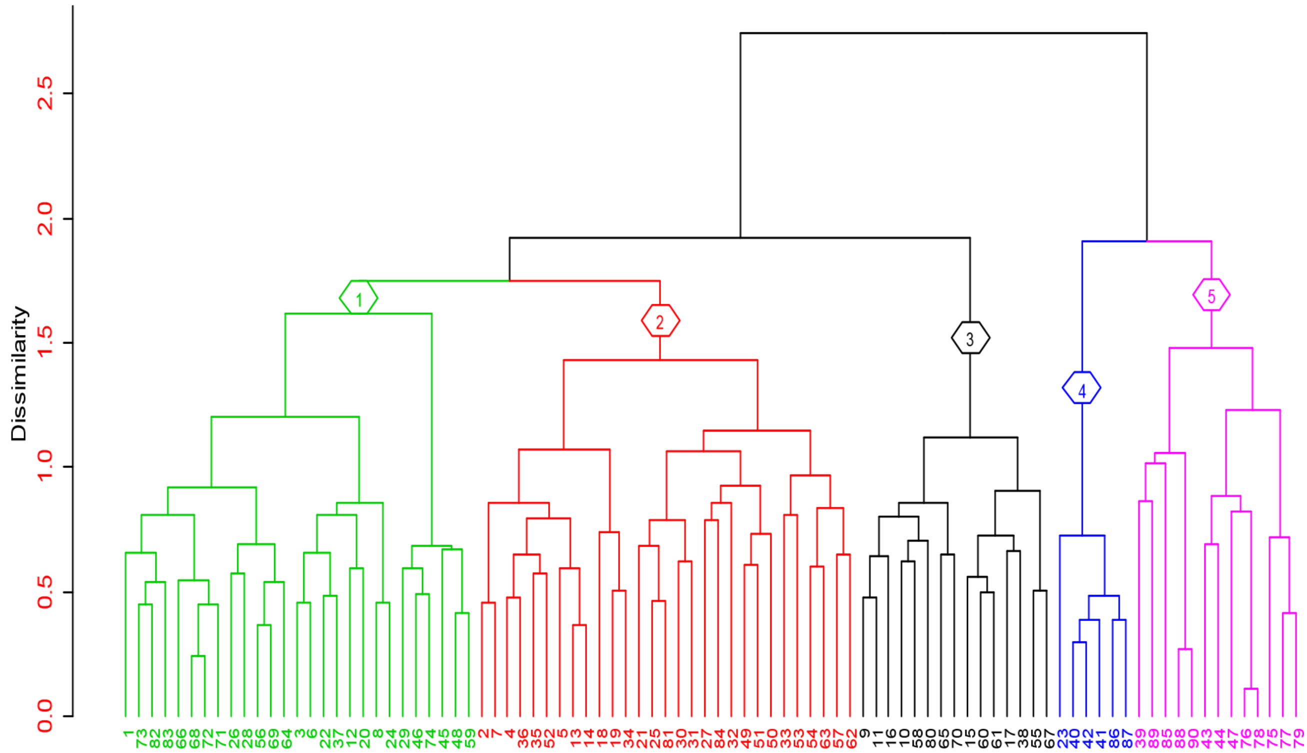

figure 3. Agglomerative hierarchical classification using SR in the Gesha-Sayilem forest

Indicator plant species

Species diversity is an important factor for the stability and proper functioning of ecosystems and plays a critical role in the assessment of human impact on ecological systems (Leitner and Turner 2001; Schläpfer et al. 1999). The analysis of species diversity in five plant communities indicated that the higher number of species per plot has occurred in *Pouteria adolfi-friederici-Schefflera abyssinica* community). The lower number of species per plot was obtained for *Arundinaria alpina* community). The highest species diversity of the communities was attributed due to topographic, climatic, and edaphic differences.

Stability and productivity of community are influenced by various factors. Studies conducted by Cristofoli et al. (2010) and Gong et al. (2008) have also shown that topographic variables (slopes, aspects, and altitude) have an effect on plant diversity. In view of this, those plant communities found in very steep slopes (*Pouteria adolfi-friederici-Schefflera abyssinica* community), on deep gorges, along streams and rivers (*Millettia ferruginea-Sapium ellipticum* community) on gentle slopes (*Ilex mitis-Syzygium guineense* community) have higher plant diversity and species richness since they are located far from human settlement and not exposed to frequent disturbances. On the other hand, the *Arundinaria alpine* community type had the lowest species diversity and richness index due to human disturbances. The variation of species diversity among the plant community's and the influence of altitude on plant community formation support the alternative hypothesis that species diversity and altitude and level of disturbance have strong influence on the community separation.

Comparatively, the Gesha-Sayilem and Masha forest had higher species similarity since they are found in similar climatic zone and topography. Hence, the communities are sharing of species through seed dispersal. On the other hand, the low similarity coefficient between Gesha-Sayilem and Harenna forest is due to the geographical distance which could be explained by historical factors. This is also reported by Bonnefille et al. (1993) vegetation changes due to human impact have a long history in Ethiopia and the destruction of montane forest in southeastern Ethiopia as far back as ca. 2000 years.

Table 3. Indicator species for community types in the moist Afromontane forest

Indicator species	Cluster	Indicator value	P-value
Brillantaisia madagascariensis	1	0.54	0.014 *
Sericostachys scandens	1	0.51	0.006 **
No indicator species	2	-	-
Dracaena fragrans	3	0.57	0.002 **
Olea capensis subsp. *macrocarpa*	3	0.55	0.020 *
Hallea rubrostipulata	3	0.52	0.005 **
Ehretia cymosa	3	0.41	0.035 *
Dombeya torrida	4	0.63	0.004 **
Maesa lanceolata	4	0.56	0.005 **
Cyperus fischerianus	5	0.47	0.040 *
Helichrysum formosissimum	5	0.39	0.020 *
Rumex nepalensis	5	0.39	0.020 *
Schoenoplectus corymbosus	5	0.39	0.026 *

Note: *: Significant at p<0.05, **: Significant at p<0.01, Species diversity, richness and evenness

Table 4. Diversity indices of the vegetation for Gesha-Sayilem forest

Name of communities	Species richness	Shannon`s diversity index (H')	Shannon Evenness (E)
Ilex mitis-*Syzygium guineense* community	89	3.70	0.82
Pouteria adolfi-friederici-*Schefflera abyssinica* community	99	3.90	0.85
Millettia ferriguinea-Sapium ellipticum community	79	3.80	0.87
Arundinaria alpine community type	29	2.96	0.80
Schefflera volkensi-Maesa lanceolate community	60	3.69	0.89

Phytogeographical comparison

The floristic composition of Gesha-Sayilem forest was compared with seven moist Afro-montane forests found in southwest forest. These included Godere, Gera, Masha, Harenna, and Yayu and Settma forest in Jimma Zone (Table 5). From the above forest description, the Gesha-Sayilem forests are closely related to Masha and Godere forest (59% and 53%) respectively. However, the floristic similarity of Gesha-Sayilem forest was found to be less when compared with Harenna Forest.

Community-environment relationship

Our analysis showed that the floristic composition of the plant communities was significantly influenced by only five environmental factors (altitude, disturbance, slope, phosphorus, and electrical conductivity (EC) (Table 5). However, pH, soil texture, CEC, and K had no significant effect on the floristic composition and distribution of the plant community types.

The Gesha-Sayilem Afromontane Rainforest affected by different levels of disturbances such as clearing for coffee plantation, timber extraction, and grazing has affected the diversity, composition, and structure of the forests. Furthermore, traditional beekeeping practices have the potential to influence trees species diversity through construction of traditional hives for honey production. Some of the tree species used for beehive making are *Cordia africana* (Tura 2018), *Polyscias fulva, Croton macrostachyus*, and *Euphorbia abyssinica.* Exploitation of such tree species might have an impact on the population structure of the forest species. The livestock grazing is also one of the challenges in forest conservation of the area. Livestock interferences were observed in the forest. Seedlings and saplings of many plant species are lacking due to either repeated browsing and or trampling on young plants (Feyera 2006).

Vegetation and environmental relationship (CCA)

The analysis of vegetation data using ordination techniques indicated that the pattern of plant species distribution was mainly influenced by environmental factors such as altitude, slope, aspect, disturbance, and soil factors. Among these factors, altitude is an important topographical variable since it affects atmospheric pressure, moisture, and temperature, which govern the growth and distribution of plant. Study conducted by Asmelash et al. (2013) also indicated that the topographic variables, such as altitude, landscape position, soil type, and slope were significantly varied in species composition of at least one of the growth stages. In addition to this, studies conducted by Bonnefille et al. (1993), Kumelachew and Tamrat (2002) noted that the vegetation types in Southwest Ethiopia are mainly delimited by microclimatic conditions associated with altitude. This also supported similar studies conducted in Central Ethiopia by Tadesse et al. (2017) altitudinal gradient is found to be the most complex environmental gradients affecting plant distribution. In addition to altitude, factors like slope and soil characters might have influenced the plant communities (Abreham et al. 2013).

Table 5. The Monte Carlo test for significance environmental variables influencing vegetation communities in Gesha-Sayilem forest

Variables	df	F value	P-value
Altitude	3	15.90	<0.001 ***
Disturbance	3	1.11	<0.001 ***
Slope	3	0.05	0.521
EC	3	0.75	0.550
P	3	3.43	0.020*
PH	3	4.17	0.004 **
OM	3	0.36	0.830
CEC	3	1.20	0.310
K	3	1.33	0.260

Note: Significant Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1

Table 5. Phytogeographical comparison of Gesha-Sayilem forest with other moist forests

Forest	Altitude	a	b	c	Sc	References
Bibita forest	1750-2200	112	184	82	0.53	Dereje 2007
Masha forest	1700-3000	114	184	16	0.59	Abreham 2009
Yayu forest	1250-1700	89	193	101	0.37	Tadesse 2003
Harenna forest	1300-3000	*72*	266	48	0.31	Feyera 2006
Settma forest	1500-2200	141	158	146	0.5	Dereje 2017
Belete Gera forest	1400-2200	83	216	68	0.36	Kflay and Kitessa 2014

Note: "a" is the number of common species to the forest of both sites, "b" is number of species found in Gesha-Sayilem forest "c" is the number of species found in the vegetation of other sites in comparison with Gesha-Sayilem forest and ''Ss'' is Sorenson's similarity index

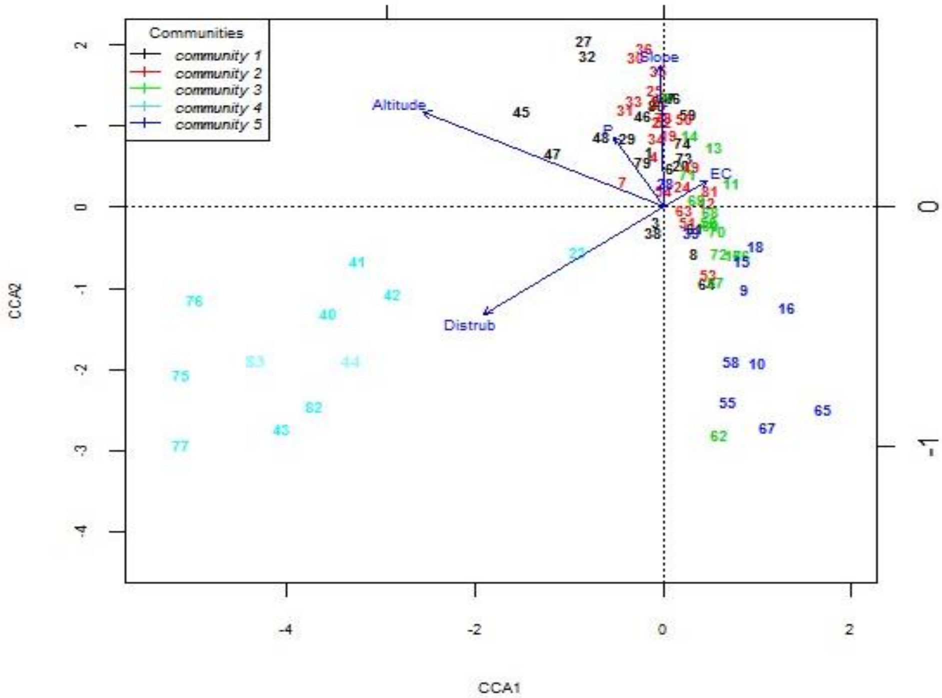

Figure 4. CCA ordination diagram of plots of the Moist Afromontane Forest with vectors of environmental factors

Another equally important factor is disturbance caused by humans. Through personal communication with local elders and field observation, in the area indicated that the forest in the area has been fully covered in the past three decades but this now only restricted to relatively inaccessible areas due to population growth, settlements, overgrazing and expansion of the coffee cultivation. This is in agreement with Tadesse et al. (2008) as the result of the human disturbance, the natural forest of the southwest Ethiopia was fragmented into small isolated forest patches now largely restricted in the gorges and other inaccessible areas. Variation in slope has a strong influence on soil chemical properties since the soil on steeper slopes are influenced by bedrock and tend to be less moist and less acidic (Tewolde Berhane G/Egziabher 1989).

The result from CCA shows that most of the variation in the pattern of plant distribution was explained by CCA plot. Environmental variables highly correlated with axis one were largely responsible for explaining CCA having higher score of axis. Among these variables, altitude was the one that explained variation in species distribution and the pattern of plant community formation.

In conclusion, Gesha-Sayilem forest is one of the remaining moist Afromontane Forests in southwest Ethiopia and it is rich in plant diversity comprising of 300 species of vascular plants. Asteraceae was the most abundant family followed by Fabaceae, Acanthaceae, Poaceae, Rubiaceae, and Euphorbiaceae. Five plant community types were identified and these were *Ilex mitis-Syzygium guineense*, *Pouteria adolfi-friedericii-Schefflera abyssinica*, *Millettia ferruginea-Sapium ellipticum*, *Arundinaria alpina*, and *Schefflera volkensii-Masea-lanceolata* community types. Among the community types, *Pouteria adolfi-friedericii-Syzygium guineense* community was the most diverse whereas *Arundinaria alpina* community was the least diverse community. This high species diversity is attributed to habitat heterogeneity including topographic, soil, and climatic differences. Among the fourteen environmental factors included altitude, slope, disturbances, Phosphorus and EC were the most important in differentiating plant communities in the area. Conservation practices should be implemented since the forest is under threat due to human influences causing variation in plant diversity. Therefore, management of the forest is important in preserving threatened species like *Schefflera abyssinica*, *Syzygium guineense*, *Pouteria adolfi-friederici* and *Ilex mitis, Croton macrostachyus* and *Olea welwitschii* are the major carbon sink species as well as potential honey source plants in the area.

ACKNOWLEDGEMENTS

We acknowledge the Department of Plant Biology and Biodiversity Management, Addis Ababa University (AAU), Holeta Bee Research Center, and Oromia Agricultural Research Institute for providing required facilities and logistics.

REFERENCES

Abreham A, Sebsebe D, Zerihun W. 2013. Floristic composition, structure and regeneration status of Masha forest, south-west Ethiopia. Afr J Ecol 52: 151-162.

Abreham A. 2009. Floristic Composition and Structure of Masha Forest, Southwest Ethiopia. [Thesis]. University School of Graduate Studies, Addis Ababa.

Admassu A, Teshome S, Ensermu K, Abyot D, Alemayehu K. 2016. Floristic composition and plant community types of Agama Forest, an "Afromontane Forest" in Southwest Ethiopia. Journal of Ecology and the Natural Environment 8 (5): 55-69.

Allen SE, Grimshaw HM, Rowland AP. 1986. Chemical analysis. In: Moore PD, Chapman SE (eds.). Methods in Plant Ecology. Blackwell Scientific, London.

Anderson EW, Currier WF. 1973. Evaluating zones of Utilization. J Range Manag 26 (2): 87-91.

Asmelash B, Ørjan T, Stein RM. 2013. Woody plant assemblages in isolated forest patches in a semiarid agricultural matrix. Biodivers Conserv 22: 2519-2535.

Ayele K. 2011. Delimiting the Interface between Garden Coffee Expansion and Forest Coffee Conservation and its Implication for Protected Area Management: The Case of Kafa Coffee Biosphere Reserve. [Thesis]. University of Klagenfurt, Austria.

Badge B. 2001. Deforestation and land degradation in the Ethiopian highlands: a strategy for physical recovery. Northeast African Stud 8 (1): 7-26.

Bartell SM. 2006. Biomarkers, bioindicators, and ecological risk assessment: a brief review and evaluation. Environ Bioindic 1: 39-52.

Bonnefille R, Buchet G, Friis I, Ensermu K, Mohammed N. 1993. Modern pollen rain on an altitudinal range of forests and woodlands in southwest Ethiopia Opera Bot 121: 71-84.

Brady NC. 1974. The Nature and Properties of Soils. 8th ed., Macmillan, New York.

Cairns Jr, Pratt JR. 1993. A history of biological monitoring using benthic macroinvertebrates. In: Rosenberg DM, Resh VH (eds.), Freshwater Biomon-itoring and Benthic Macroinvertebrates. Chapman & Hall, New York.

Cristofoli S, Monty A, Mahy G. 2010. Historical landscape structure affects plant species richness in wet heathlands with complex landscape dynamics. Landscape Urban Plann 98: 92-98.

Demel T. 2001. Deforestation, Wood famine and Environmental Degradation in Ethiopia's Highlands Ecosystems: Urgent needs for Action. Northeast African Studies 8 (1): 53-76.

Dereje D. 2007. Floristic Composition and Ecological Study of Bibita Forest, Southwest Ethiopia. [Thesis]. Addis Ababa University, Addis Ababa.

Dereje D. 2017. Impact of climate and land use on plant diversity, carbon storage and leaf area index in the Jimma Highlands, Southwest Ethiopia. [Dissertation]. Addis Ababa University, Addis Ababa.

EFAP. 1994. The Challenges for Development, Volume 2. Ministry of Natural Resources Development and Environmental Protection EFAP Secretariat, Addis Ababa.

Ensermu K, Sebsebe D. 2014. Diversity of vascular plant taxa of the Flora of Ethiopia and Eritrea. Ethiop J Biol Sci 2014: 37-45.

Ensermu K, Teshome S. 2008. Interfaces of Regeneration, structure, Diversity and uses of some plants species in Bonga Forest. A Reservoir for wild Coffee Gene Pool. SINET, Ethiopia J Sci 31: 121-134.

Ermias L. 2014. Plant diversity and ethnobotanical study of medicinal plants in Ankober District, North Shewa Zone of Amhara Region, Ethiopia. [Dissertation]. Addis Ababa University, Addis Ababa

Fekadu G. 2012. Floristic composition and community analysis of Komto Afromontane moist forest, East Wollega Zone, West Ethiopia. Sci Technol Arts Res J 2 (2): 58-69.

Feyera S. 2006. Biodiversity and Ecology of Afromontane Rain Forest with Wild *Coffea arabica* L. Populations in Ethiopia. Dench M, Martius C, Rodgers C (eds.). Ecology Development Series No 38. Cuvillier Verlag, Göttingen, Germany.

Friis Ib. 1992. Forest and forest trees of north-east Tropical Africa. Kew Bull. Additional Ser. 15 (i–iv): 1-396.

Friis Ib. 2011. Atlas of the Potential Vegetation of Ethiopia. Addis Ababa University Press, Addis Ababa.

Gebrehiwot K, Hundera K. 2014.Species composition, Plant Community structure and Natural regeneration status of Belete Moist Evergreen Montane Forest, Oromia Regional State, Southwestern Ethiopia. Momona Ethiopian J Sci 6 (1): 97-101.

Gonga XY. 2008. Slope aspect has effects on productivity and species composition of hilly grassland in the Xilin River Basin, InnerMongolia, China J Arid Environ 72 (4): 483-493

Haile Y, Ensermu K, Tamirat B, Ermias L. 2008.Floristic Composition and structure of the Dry Afromontane forest at Bale Mountain National Park, Ethiopia. [Thesis]. Addis Ababa University, Addis Ababa.

Hedberg I, Friis I, Persson S. 2009. Flora of Ethiopia, Vol.1, Lycopodiaceae to Pinaceae.Appendix-Additional and amendment to Vols. 2-7. The National Herbarium, Addis Ababa, Ethiopia; Uppsala, Sweden.

Indra PT, Arvind PD. 2015. Heavy metal analysis of soil samples collected from in and around Satna. Intl J Inf Res Rev 2 (3): 516-520.

Kent M, Coker R. 1992.Vegetation description and analysis: A practical approach. CRC Press, Inc., London.

Kflay G, Kitessa H. 2014. Species composition, Plant Community structure and Naturalregeneration status of Belete Moist Evergreen Montane Forest, Oromia Regional State, Southwestern Ethiopia. Momona Ethiopian J Sci 6 (1): 97-101.

Kumelachew Y. Tamrat B.2002. Plant community analysis and ecology of Afromontane and transitional rainforest vegetation of southwestern Ethiopia. SENET. Ethiop J Sci 25 (2): 155-175.

Lal R. 2012. Carbon sequestration in Urban Ecosystem. Phil Trans R Soc B 363: 815-830.

Leitner W, Turner R. 2001. Measurement and analysis of biodiversity. In: Levin SA (ed.) Encyclopedia of Biodiversity. Vol. 4. Academic Press, Princeton, NJ.

McCune B, Grace JB. 2002. Analysis of Ecological Communities. Version 5.0 MM Software Design, USA.

Mesfin T. 2004. Asteraceae (Compositae). In: Hedberg I, Friis IB, Edwards S (eds.). Flora of Ethiopia and Eritrea Volume 4, part 2. The National Herbarium, Addis Ababa University, Ethiopia, Uppsala, Sweden.

Muhammad I, Amin-Ul-Haq K, Aziz-Ul-H, Farah K, Mitu L, Muhammad A, Muhammad AI. 2010. Evaluation of physicochemical characteristics of soil samples collected from Harrapa-Sahiwal (Pakistan). Asian J Chem 22 (6): 4823-4830.

Schläpfer F, Schmid B, Seid I. 1999. Expert estimates about effects of biodiversity on ecosystem processes and services. Oikos 84 (2): 346-352.

Silvertown J. 2004. Plant coexistence and the niche.Trends Ecol Evol 19 (11): 605-611.

Sisay N. 2008.Flora Biodiversity Assessment in Bonga, Boginda and Mankira Forest, Kafa, Ethiopia. [Thesis]. Addis Ababa University, Addis Ababa.

Tadesse W, Borsch T, Denich M, Demel T. 2008. Floristic Composition and environmental factors characterizing coffee forests in southwest Ethiopia For Ecol Manag 255 (2). 2138-2150.

Tadesse W. 2003. Vegetation of the Yayu Forest in Southwest Ethiopia: Impacts of human use and implications for in situ conservation of wild *Coffea arabica* L. populations. Ecology and Development Series No. 10. Cuvillier Verlag, Göttingen, Germany.

Tadesse Z, Kelbessa E, Bekele T. 2017. Floristic composition and plant community analysis of vegetation in Ilu Gelan district, West Shewa Zone of Oromia region, Central Ethiopia. Trop Plant Res 4 (2): 335-350.

ter Braak CJ, Prentice F. 1988. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67: 1167-1179.

Tewolde GE. 1991. Diversity of Ethiopian flora. In*:* Engels JMM, Hawkes JG, Melaku W (eds.) Plant Genetic Resources of Ethiopia. Cambridge University Press, UK.

Tura B, Admassu A. 2018. Honeybee flora resources of Guji Zone, Ethiopia. J Biol Agric Healthcare 8 (21): 1-9.

Tura B, Admassu A. 2019. Pollen Analysis of Honey from Borana Zone of Southern Ethiopia. J Apic Sci 63 (2): 233-242.

Tura B. 2018. Lowland semi-evergreen forest of Ethiopia. Forest Res Eng Intl J 2 (5): 244–248.

Tura TT, Soromessa T, Leta S, Argaw M. 2017. Plant community composition and structure of Asabot Dry Afromontane Forest, West Harare Zone, Ethiopia. J Biodivers Endanger Species 5 (4): 1-12.

Vetaas OR, Grytnes JA. 2002. Distribution of vascular plant species richness and endemic richness along the Himalayan elevation gradient in Nepal. Global Ecol Biogeogr 11: 291-301.

Vivero JL, Ensermu K, Sebsebe D. 2005. The Red List of Endemic Trees and Shrubs of Ethiopia and Eritrea. Fauna and Flora International, Cambridge, UK.

WCMC.1994. Biodiversity Data Sourcebook.World Conservation Monitoring Centre, World Conservation Press, Cambridge, UK.

Westhoff V, van der Maarel E. 1978. The Braun-Blanquet approach. In: Whittaker RH. (ed.) Classification of Plant Communities. Junk, The Hague.
Yirga F, Marie M, Kassa S, Haile M. 2019. Impact of altitude and anthropogenic disturbance on plant species composition, diversity, and structure at the Wof-Washa highlands of Ethiopia. Heliyon 5: 1-13.
Zerihun W, Feoli E, Lisanework N. 1989. Partitioning an elevational gradient of vegetation from Southeastern Ethiopia by probabilistic methods. Vegetation 81: 189-198.
Zerihun W. 1999. Forest vegetation types of Ethiopia and their status in the geographical context. In: Edwards S, Abebe D, Taye B, Gunther, H. (eds.). Proceedings of the National ForestGenetic Resources Conservation Strategy Development Workshop. June 21-22, Addis Ababa, Ethiopia.
Zerihun W. 2017. Comprehensive Analysis of Vegetation and Ecological Data-Basic, Concepts, Methods. Addis Ababa University Press, Addis Ababa.