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FLORISTIC COMPOSITION, SPECIES DIVERSITY AND VEGETATION STRUCTURE OF GERA MOIST MONTANE FOREST, JIMMA ZONE OF OROMIA NATIONAL REGIONAL STATE, SOUTHWEST ETHIOPIA

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ABSTRACT: Floristic composition, species diversity and vegetation structure of Gera Moist Montane Forest was conducted in Jimma Zone of Oromia National Regional State, southwest Ethiopia. A total of 132 plant species in 112 genera and 59 families were identified from this forest. Fabaceae was the most dominant family with ten species and nine genera. According to Ensermu Kelbessa and Teshome Soromessa (2008), the dominance of Fabaceae and Asteraceae could be attributed to their efficient and successful dispersal mechanisms and adaptation to a wide range of ecological conditions. Plots of 30 m x 30 m were arranged at a distance of 200 m from each other for sampling woody species. To sample herbaceous plants, five sub-plots each with 1 m x 1 m were laid in the main plot. Shannon-Wiener diversity index was used to compute species richness and evenness between the plant communities. DBH, basal area, and height were computed to describe the structure of the forest. The regeneration status of some woody species of the forest was evaluated based on the number of seedlings and saplings per hectare. Vegetation classification was performed using R-2.11.1 software packages. Plant communities were named after two of the dominant woody species occurring in each group using the relative magnitude of the highest mean cover abundance within the cluster. Future research directions and recommendations are suggested for the sustainable utilization of the vegetation.

Key words/phrases: Endemic species, Gera Forest, Moist evergreen forest, Vegetation structure.

INTRODUCTION

One of the most important reasons behind the rapid deforestation rate in Ethiopia is the increasing of human population growth. This rapid increase in human population is associated with a very high demand for agricultural and grazing lands, forest resources for firewood, charcoal, timber, construction, and many other purposes.

Natural forests in southwestern Ethiopia are disappearing at an alarming rate because of encroachment by agricultural activities and the pressure from

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investors (Taye Bekele *et al*., 2001). The new investment opportunities being undertaken in southwest Ethiopia are converting the few remaining moist montane forests into other land use systems such as coffee and tea plantations (Taye Bekele *et al*., 2001). Loss of forest cover and biodiversity due to human-induced activities is a growing concern in many parts of the world (Feyera Senbeta and Demel Teketay, 2003). In addition, generation of scientific knowledge through the studies of floristic composition and structural analysis could be one of the intervention mechanisms that contribute towards the conservation of vegetation resources and the associated biodiversity. It is, thus, equally important to study and document the remaining vegetation resources for conservation and sustainable utilization based on scientific knowledge. Hence, this study was conducted with the main objective of investigating floristic composition, plant diversity, identification of community types and analysis of vegetation structure in Gera Forest.

MATERIALS AND METHODS

Description of the study area

Gera Forest is situated in Gera District, Jimma Zone of Oromia National Regional State, 380 km southwest of Addis Ababa (Fig. 1). The study forest is located at 7°36'−7°46' N and 36°11'−36°18' E, and altitude between 1600 to 2400 m a.s.l. (GPS reading during fieldwork). Gera Forest has a total area of 80,830.4 ha.

Soil in the forest is dystric nitosol type, which is deep, clay red soil (GDARDO, 2012). The mean annual temperature is about 18.4°C, while mean annual rainfall is 1805 mm year $^{-1}$ (NMSA, 2013).

Methods

Reconnaissance survey and vegetation data collection were carried out between October and November, 2012. Systematic sampling following Kent and Coker (1992) and Mueller-Dombois and Ellenberg (1974) were used in this study.

Sampling sites were arranged along transects in three directions. The first transect, 20 km long, was laid from Chira town to Ifallo kebele. The second transect was laid from Chira town to non-coffee part of Gera Forest while the third transect was laid from Chira to Beshasha town. The second and third transects were 5 and 10 km long, respectively. Each of the three transects contain 16, 21 and 13 plots, respectively. To avoid edge effect, the sampling plots were 50 m far from roads.

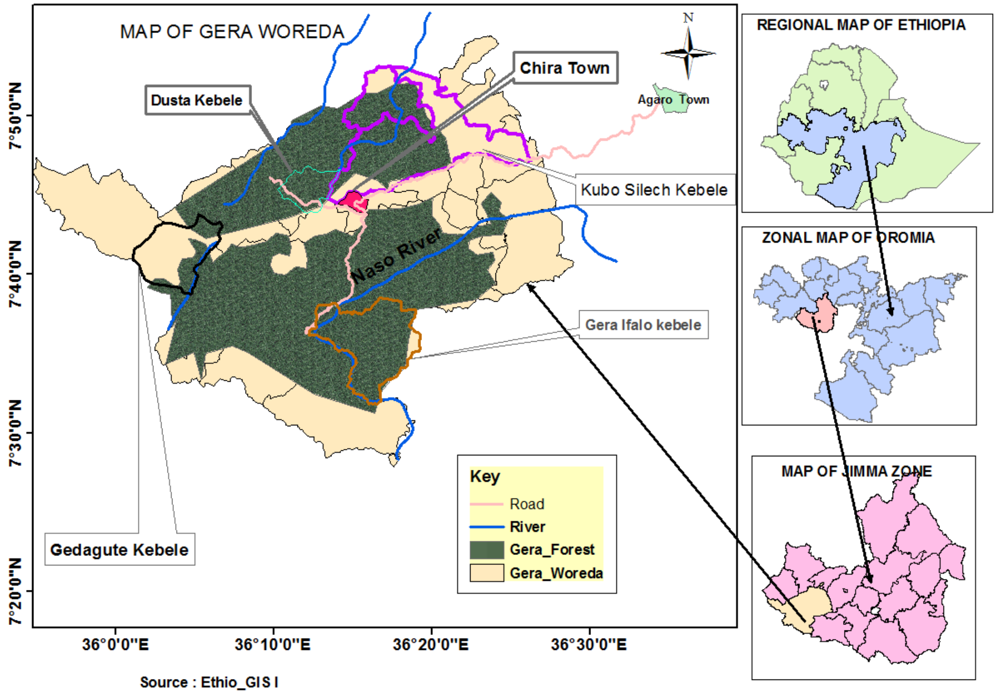

Fig.1. Map of Ethiopia and Jimma Zone showing the location of Gera Forest.

Plots of 30 m x 30 m were arranged at a distance of 200 m from each other for sampling woody species. To sample herbaceous plants, five sub-plots each with 1 m x 1 m were laid in the main plot. For seedlings and saplings, the major plot was partitioned into four, each with 15 m x 15 m.

In this study, seedling refers to young woody species with height ≤ 2 m and DBH less than 2.5 cm, while sapling refers to woody plants with height greater than 2 m and DBH less than 2.5 cm.

In each plot, species composition was first recorded and then structural attributes such as diameter and height were measured for all woody plants having DBH greater than 2.5 cm. DBH of individuals was measured using a rolling meter. The cover abundance of each species was first estimated visually, and later converted to the Braun-Banquet 1-9 modified scale (Kent and Coker, 1992).

Geographical coordinates of the plots were recorded using Magellan NAV5000 Pro GPS navigation system. A complete list of trees, shrubs, herbs, and climbers were made in each plot. Vernacular names of species were recorded during fieldwork. Plant specimens were collected from the study area, allotted collection numbers, pressed, and dried. Identification of plant species was made at the National Herbarium (ETH), Addis Ababa University.

Data analysis

For this study, agglomerative hierarchical classification using similarity ratio was performed using R for windows version 2.11.1 (Venables *et al*., 2010) to classify the vegetation into plant community types based on abundance data of the species in each plot. Synoptic table of the results of the hierarchical agglomerative cluster analysis was produced using the cluster identifications to compute mean values of the cover abundance of the species in the respective clusters. Synoptic values are the products of species, frequency and average cover abundance values (mean frequency x mean cover-abundance) (van der Maarel *et al*., 1987; cited in Abate Ayalew *et al*., 2006).

Shannon-Wiener diversity index, species richness, and Shannon's evenness were computed to describe species diversity of the plant community types in the vegetation of the study forest.

The structure of Gera Forest was described using frequency distributions of DBH, height and Importance Value Index (IVI) of plant species. Tree or shrub density and basal area values were computed on hectare basis. Importance value index (IVI) was calculated by summing up relative frequency (RF), relative density (RD) and relative dominance (RDO) values to determine species dominance as recommended by Kumar (1981).

RESULTS

Floristic composition

A total of 132 plant species belonging to 112 genera and 59 families were collected, and identified from Gera Forest. Fabaceae was the most dominant family with ten species (8.03%) and nine genera. Asteraceae was the second dominant family with nine species (6.81%) and five genera. The third species-rich family was Euphorbiaceae with eight species (6.06%) and six genera followed by Malvaceae, Lamiaceae and Rubiaceae with six species (4.54%) each. The fifth species-rich family were Acanthaceae with five species (3.78%) followed by Boraginaceae with four species (3.03%) and three genera.

The families, which contributed three species each, were Celastraceae, Moraceae, Oleaceae, Piperaceae, Poaceae, Polypodiaceae, and Rutaceae, while Araliaceae, Aspleniaceae, Dracaenaceae, Lycopodiaceae, Meliaceae, Rhamnaceae, Rosaceae, Sapindaceae, Tiliaceae, Ulmaceae, Urticaceae and Zingiberaceae contributed two species each and the rest 32 families contained only one species each. Fabaceae, Asteraceae, Euphorbiaceae, Malvaceae and Rubiaceae contributed 29.52% of the total plant species and the remaining 54 families contributed 70.48% of the total plant species.

Gera Forest contains a number of flowering plant species that are endemic to Ethiopia. Based on the published Flora volumes and list of species in Gera Forest, the endemic species and the levels of threat on each taxon are given in Table 1 below. Accordingly, 7 (5.30%) endemic species have been recorded from Gera Forest.

Table 1. Endemic species recorded from Gera Forest and their respective family, habit and IUCN category (T = Tree, S = Shrub, H = Herb, NT = Nearly Threatened, LC = Least Concern, VU = Vulnerable, CR = Critically Endangered).

No.	Scientific name	Family	Habit	IUCN category
1	*Aframomum corrorima* (Baker) K. Schum.	Zingiberaceae	H	VU
2	*Erythrina brucei* Schweinf.	Fabaceae	T	LC
3	*Justicia diclipteroides* Lindau subsp. *aethiopica* Hedrèn	Acanthaceae	H	NT
4	*Millettia ferruginea* (Hochst.) Bak.	Fabaceae	T	LC
5	*Satureja paradoxa* (Vatke) Engl.	Lamiaceae	H	NT
6	*Solanecio gigas* (Vatke) C. Jeffrey	Asteraceae	S	LC
7	*Vepris dainellii* (Pichi-serm.) Kokwaro.	Rutaceae	T	LC

Plant community types

Five clusters (Fig. 2) were identified from Gera Forest. Plant community types were named after two of the dominant woody species occurring in each group using the relative magnitude of the highest mean cover abundance within the cluster. A list of the community types along with the synoptic cover-abundance values of the species is given in Table 2.

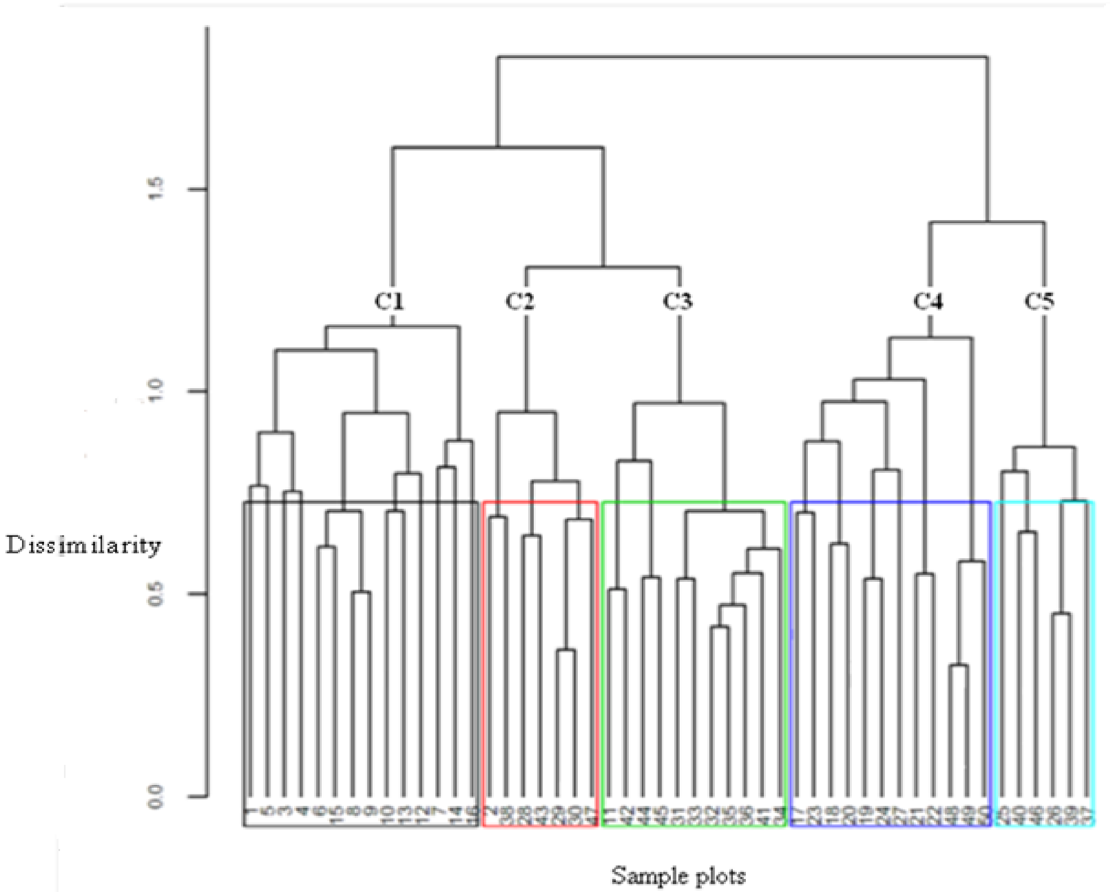

Fig. 2. Dendrogram of the vegetation data obtained from hierarchical cluster analysis of Gera Forest. (C1 = *Vernonia auriculifera-Prunus africana* Community, C2 = *Schefflera abyssinica-Maytenus arbutifolia* Community, C3 = *Coffea arabica-Olea capensis* Community, C4 = *Syzygium guineense-Galiniera saxifraga* Community and C5 = *Croton macrostachyus-Albizia gummifera* Community).

Vernonia auriculifera-Prunus africana community type - This community type extends from 1700 to 2950 m a.s.l. and it is represented by 113 species. The dominant species in the tree layer is *Prunus africana* (Hook.f.) Kalkm. *Vernonia auriculifera* Hiern is the dominant species in the shrub layer of this community. *Millettia ferruginea* (Hochst.) Bak., *Pouteria adolfi-friederici* Rob. & Gilg, *Dracaena steudneri* Engl., *Cordia africana* Lam. and *Allophylus abyssinicus* (Hochst.) Radlkofer are associated tree species in this type. *Tectaria gemmifera* (Fée) Alston, *Achyranthes aspera* L. and

Ageratum conyzoides L. are the dominant species in the herb layer of this community.

Schefflera abyssinica-Maytenus arbutifolia community type - This community type was distributed at altitudes between 1980 and 2160 m a.s.l. *Schefflera abyssinica* (Hochst. ex A. Rich.) Harms is the dominant species in the tree layer. *Maytenus arbutifolia* (A. Rich.) Wilczek is the dominant species in the shrub layer of this type.

Syzygium guineense (Willd.) DC. subsp. *afromontanum* F. white and *Lepidotrichila volkensii* (Gurke) Leroy are associated tree species. *Oplismenus hirtellus* (L.) P. Beauv. and *Pycnstachys eminii* Gurke dominate the field layer of this community type.

Coffea arabica-Olea capensis community type - This community type was distributed at altitudes between 1800 and 2050 m a.s.l. It consists of 58 species. *Coffea arabica* L. is the dominant species in the shrub layer and *Olea capensis* L. is the dominant species in the tree layer of this type. *Syzygium guineense* (Willd.) DC. subsp. *afromontanum* F. white, *Schefflera abyssinica* (Hochst. ex A. Rich.) Harms, *Olea welwitschii* (Knobl.) Gilg & Schellenb and *Albizia gummifera* (J.F. Gmel) C.A.Sim. are the associated tree species. *Olyra latifolia* L. is the dominant species in the herb layer of this community.

Syzygium guineense-Galiniera saxifraga community type - This community type extends from 2140 to 2320 m a.s.l. The community consists of 65 species. *Syzygium guineense* (Willd.) DC. and *Galiniera saxifraga* (Hochst.) Bridson are the dominant species in the tree layer. *Olea welwitschii* (Knobl.) Gilg & Schellenb, *Apodytes dimidiata* E. Mey. ex Arm. and *Maesa lanceolata* Forssk. are the associated tree species in this community type. *Dracaena afromontana* Mildbr., *Clausena anisata* (Willd.) Benth. and *Bersama abyssinica* Fresen. are the dominant species in the shrub layer. *Piper capense* L.f. and *Medicago polymorpha* L. are the dominant species in the herb layer of this community.

Croton macrostachyus-Albizia gummifera community type was distributed at the altitudes ranging from 1970 to 2200 m a.s.l. This community consists of 47 species. *Croton macrostachyus* Del. and *Albizia gummifera* (J.F. Gmel.) C.A.Sim. are the dominant species in the tree layer of this type. *Achyranthes aspera* L., *Tectaria gemmifera* (Fée) Alston and *Pycnstachys eminii* Gurke are the associated species in the herb layer of this community.

Table 2. Synoptic cover-abundance values for species having a value of > 1.0 in at least one community type (Values in bold refer to occurrences as dominant species).

Species	***Vernonia auriculifera-Prunus africana* community**	***Schefflera abyssinica-Maytenus arbutifolia* community**	***Coffea arabica-Olea capensis* community**	***Syzygium guineense-Galiniera saxifraga* community**	***Croton macrostachyus-Albizia gummifera* community**
Vernonia auriculifera Hiern	32.5	0	0	6.7	8.3
Prunus africana (Hook.f.) Kalkm.	28.6	10	17.7	24.6	0
Tectaria gemmifera (Fèe) Alston	27.5	0	8.2	15	2.5
Millettia ferruginea (Hochst.) Bak.	23.6	15	5.5	0.8	14.2
Dracaena steudneri Engl.	18.9	0	0.9	0	0
Pouteria adolfi-friederici Rob. & Gilg	17.1	0	0	0	0
Achyranthes aspera L.	16.4	2.1	7.7	3.3	5
Ageratum conyzoides L.	13.2	0	1.4	0	0
Cordia africana Lam.	12.1	2.9	3.6	2.9	5
Allophylus abyssinicus (Hochst.) Radlkofer	11.8	5.7	0	0	0
Calpurnia aurea (Ait.) Benth.	11.8	11.4	0	0	0
Phoenix reclinata Jacq.	10.4	0	0	0	0
Schefflera abyssinica (Hochst. ex A. Rich.) Harms	36.8	70	61.4	0	25
Maytenus arbutifolia (A. Rich.) Wilczek	11.8	45.7	7.3	17.1	4.2
Polyscias fulva (Hiern) Harms	3.6	45	15.9	15.4	30
Oplismenus hirtellus (L.) P. Beauv.	15.7	32.1	29.1	26.3	0
Lepidotrichila volkensii (Gurke) Leroy	2.1	12.1	0	8.8	0
Pycnstachys eminii Gurke	0	10.7	3.6	2.5	4.2
Coffea arabica L.	43.9	1.4	61.8	0	6.7
Olea capensis L.	11.8	10	16.8	0	0
Olyra latifolia L.	13.2	10.7	14.1	0	3.3
Syzygium guineense (Willd.) DC subsp. *afromontanum* F. White	3.6	17.9	48.6	55	43.3
Galiniera saxifraga (Hochst.) Bridson	11.4	6.4	9.1	37.5	6.7
Piper capense L.f.	9.6	11.4	8.6	29.2	0
Dracaena afromontana Mildbr.	10	0	0	19.6	0

Species	*Vernonia auriculifera-Prunus africana* community	*Schefflera abyssinica-Maytenus arbutifolia* community	*Coffea arabica-Olea capensis* community	*Syzygium guineense-Galiniera saxifraga* community	*Croton macrostachyus-Albizia gummifera* community
Medicago polymorpha L.	0	0	0	17.9	0
Olea welwitschii (Knobl.) Gilg & Schellenb	1.4	0	10.5	17.1	0
Clausena anisata (Willd.) Benth.	11.8	10.7	0	17.1	1.7
Ficus sur Forssk.	12.9	2.1	3.6	16.3	0
Bersama abyssinica Fresen	6.1	9.3	11.4	16.3	6.7
Maesa lanceolata Forssk.	12.1	8.6	0	15.4	5.8
Apodytes dimidiata E. Mey. ex Arm.	2.1	0	3.6	14.6	0
Croton macrostachyus Del.	8.6	7.1	9.1	13.8	48.3
Albizia gummifera (J.F.Gmel.) C.A.Sim.	7.1	7.1	10	12.1	46.7
Vernonia amygdalina Del.	11.4	7.1	2.7	12.1	15
Vepris dainellii (Pichi-serm.) Kokwaro.	7.1	6.4	12.3	7.1	13.3
Rubus niveus Thunb.	6.1	1.4	0	0.8	7.5
Flacourtia indica (Burm. f.) Merr.	0	1.4	0.9	2.5	5.8

Species diversity (richness and evenness) of the plant communities

The highest species richness, evenness and diversity were observed in *Vernonia auriculifera-Prunus africana* (Hook.f.) Kalkm. community (Table 3). This community attained a species evenness index of 0.88 with average altitude of 2325 m a.s.l. showing the highest even distribution of species. *Syzygium guineense-Galiniera saxifraga* Community type exhibited a species evenness index of 0.85 showing the highest even distribution of species next to *Vernonia auriculifera-Prunus africana* community (Table 3). No *Coffea arabica* L. was recorded from *Syzygium guineense-Galiniera saxifraga* Community type.

Schefflera abyssinica-Maytenus arbutifolia community has the least species evenness, but greater than *Coffea arabica-Olea capensis* and *Croton macrostachyus-Albizia gummifera* communities in terms of species richness. *Croton macrostachyus-Albizia gummifera* Community type exhibited the least species richness and diversity (Table 3).

Croton macrostachyus-Albizia gummifera community type is found at an average altitude of 2085 m a.s.l. Generally, the mean evenness of the communities was more or less similar in pattern (Table 3).

Table 3. Shannon-Wiener diversity index.

Community type	**Average altitude (m a.s.l.)**	**Richness**	**Diversity (H')**	**Evenness**
Vernonia auriculifera-Prunus africana	2325	113	4.18	0.88
Schefflera abyssinica-Maytenus arbutifolia	2070	62	3.37	0.81
Coffea arabica-Olea capensis	2085	58	3.38	0.83
Syzygium guineense-Galiniera saxifraga	2230	65	3.55	0.85
Croton macrostachyus-Albizia gummifera	2085	47	3.2	0.84

Community similarity analysis

Sorenson's similarity coefficient was used to determine the similarities among plant communities (Table 4). Accordingly, *Vernonia auriculifera-Prunus africana* and *Croton macrostachyus-Albizia gummifera* communities had the highest similarity ratio of 0.77. Next to *Vernonia auriculifera-Prunus africana* and *Croton macrostachyus-Albizia gummifera* communities, *Vernonia auriculifera-Prunus africana* and *Syzygium guineense-Galiniera saxifraga* communities had higher similarity ratio which is 0.72. The least similarity ratio was exhibited by *Vernonia auriculifera-Prunus africana* and *Coffea arabica-Olea capensis* communities which is 0.49 (Table 4).

Table 4. Sorensen's similarity coefficient among community types.

Community types	***Vernonia auriculifera-Prunus africana***	***Schefflera abyssinica-Maytenus arbutifolia***	***Coffea arabica-Olea capensis***	***Syzygium guineense-Galiniera saxifraga***
Schefflera abyssinica-Maytenus arbutifolia	0.65			
Coffea arabica-Olea capensis	0.493	0.495		
Syzygium guineense-Galiniera saxifraga	0.72	0.71	0.67	
Croton macrostachyus-Albizia gummifera	0.77	0.66	0.64	0.65

Vegetation structure

Tree and shrub density

The ratio of density of individuals with DBH > 10 cm to density of individuals with DBH > 20 cm is taken as a measure of the size class distribution (Grubb *et al*., 1963; cited in Shiferaw Belachew, 2010). Tree and shrub density of Gera Forest, expressed as the number of individuals with DBH greater than 2.5 cm were 1778 individuals/ha. Individuals with DBH between 10 and 20 cm and with DBH greater than 20 cm were 516/ha (29.02%) and 304/ha (17.1%), respectively (Table 5). Accordingly, the ratio of individuals between 10 and 20 cm DBH to DBH > 20 cm was 1.69 for Gera Forest, indicating a prevalence of small sized individuals.

Table 5. Distribution of individuals in different DBH classes.

DBH (cm)	**No. of individuals /ha**	**%**
2.6-10.0	958	53.88
10.1-20.0	516	29.02
>20.0	304	17.1
Total	1778	100

Table 6. Comparisons of tree densities with DBH between 10 and 20 cm (a) and tree densities with DBH > 20 cm (b) of Gera Forest with 10 other forests in Ethiopia.

Forests	**A**	**b**	**(a/b)**	**Sources**
Alata-Bolale	365	219	1.67	Woldeyohannes Enkossa (2008)
Belete	613	323	1.90	Kitessa Hundera and Tsegaye Gadissa (2008)
Bibita (Gura Ferda)	500	263	1.90	Dereje Denu (2006)
Dodola	521	351	1.48	Kitessa Hundera *et al.* (2007)
Donkoro	526	285	1.90	Abate Ayalew *et al*. (2006)
Jibat	565	287	1.96	Tamrat Bekele (1993)
Masha-Andaracha	384.7	160.5	2.40	Kumlachew Yeshitela and Taye Bekele (2003)
Menagesha Suba	484	208	2.33	Tamrat Bekele (1993)
Menna-Angetu	292	139	2.10	Ermias Lulekal *et al*. (2008)
Sese	513.7	412.7	1.24	Shiferaw Belachew (2010)
Gera	516	304	1.69	Present study

Diameter at breast height (DBH)

The diameter at breast height (DBH) class distribution of woody species of Gera Forest is given in Fig. 3. A total of 1778 individuals/ha with DBH > 2.5 cm were counted within the sampled plots. As the DBH class size increases, the number of individuals gradually decreases ranging from 958 stems/ha in the lowest class down to 20 stems/ha in the highest DBH class. This appears to be a regular distribution that resembles the inverted J-shaped distribution of individuals in the different DBH classes (Fig. 3).

About 53.88% of individuals have DBH between 2.6 cm and 10 cm. Few individuals of *Pouteria adolfi-friederici* Rob. & Gilg, *Albizia gummifera* (J.F. Gmel.) C.A.Sim., *Olea welwitschii* (Knobl.) Gilg & Schellenb, *Schefflera abyssinica* (Hochst. ex A.Rich.) Harms and *Prunus africana* (Hook. f.) Kalkm. were encountered in the higher DBH classes. The middle DBH classes were also dominated by the above species and, in addition, few individuals of *Allophylus abyssinicus* (Hochst.) Radlkofer, *Dracaena steudneri* Engl., *Polyscias fulva* (Hiern) Harms, *Syzygium guineense* (Willd.) DC. subsp. *afromontanum* F. White, *Millettia ferruginea* (Hochst.) Bak. and *Ficus sur* Forssk.

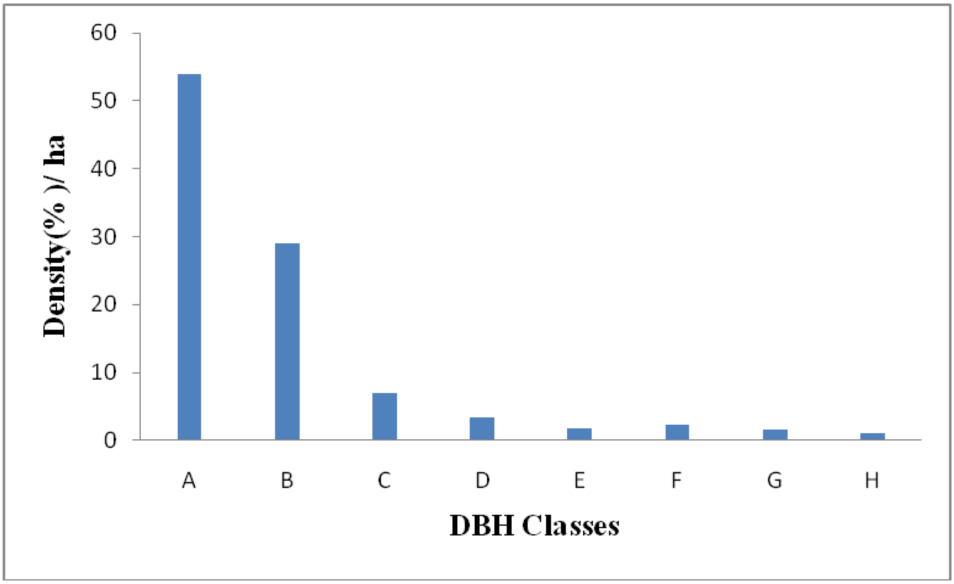

Fig. 3. Density percentage/ha of individuals in DBH classes.

Legend: DBH class A = 2.6 -10.0 cm, B = 10.1-20.0 cm, C = 20.1- 30.0 cm, D = 30.1-40.0 cm, E = 40.1-50.0 cm, F = 50.1- 60.0 cm, G = 60.1-70.0 cm and H >70.0 cm.

Height class distributions

The height class distribution of trees and shrubs in Gera Forest indicated that more than 38% of the individuals had heights less than 9 m (Fig. 4). Species that contribute most to these values in the lower height classes were *Bersama abyssinica*, *Coffea arabica*, *Croton macrostachyus*, *Maesa lanceolata*, *Millettia ferruginea*, *Olea capensis*, *Maytenus arbutifolia*, *Rytigynia neglecta*, *Dracaena afromontana*, *Teclea nobilis* and *Vepris dainellii*. Gera Forest is occupied by species like *Allophylus abyssinicus*, *Polyscias fulva* and *Syzygium guineense* which contribute most to medium height classes. Trees representing the highest height classes (11%), dominating the upper canopy, are *Pouteria adolfi-friederici*, *Prunus africana*, *Olea welwitschii* and *Albizia gummifera*. *Pouteria adolfi-friederici* is the emergent tree and grows above all the canopy trees in Gera Forest. Generally, the highest proportion of species is concentrated in the lower height class followed by the middle and upper height class comprising the vertical structure of Gera Forest.

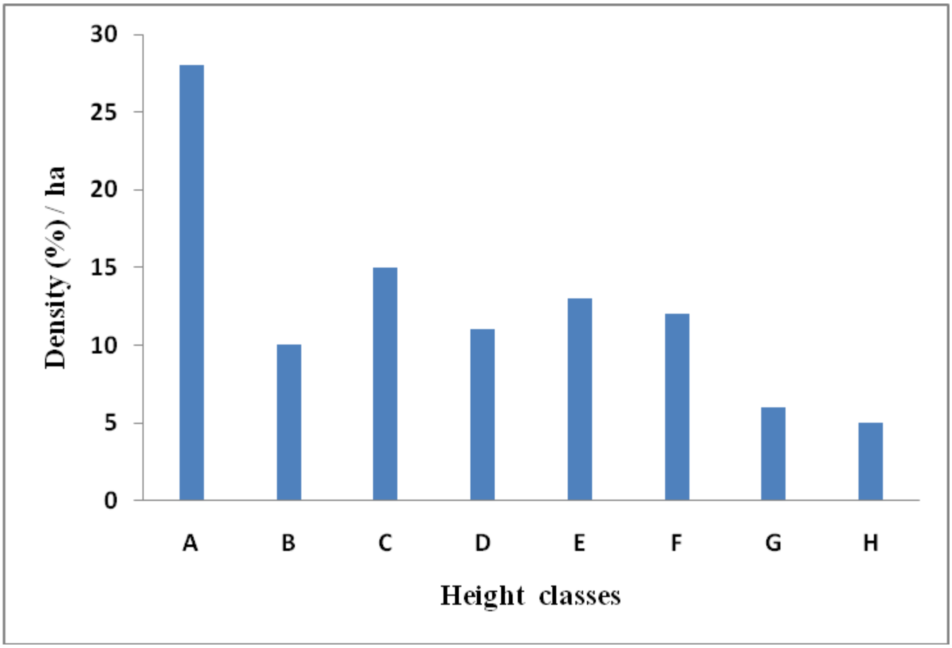

Fig. 4. Distribution of individuals/ha among the height classes.

Legend: A = 2.6-6.0 m, B = 6.1- 9.0 m, C = 9.1-12.0 m, D = 12.1-15.0 m, E = 15.1-18.0 m, F = 18.1-21.0 m, G = 21.1-24.0 m and H >24.0 m.

Importance value index (IVI)

Analysis of importance value index (IVI) was used for setting conservation priority. Those species with lower IVI values need high conservation efforts while those with higher IVI values need monitoring management.

The importance value index (IVI) of most dominant species of Gera Forest was calculated and presented in Table 7. The results of the analysis show that *Coffea arabica*, *Schefflera abyssinica*, *Syzygium guineense* and *Polyscias fulva* to be the first four most important species with higher IVI values (Table 7).

Analysis of the relative density indicated that *Coffea arabica*, *Schefflera abyssinica*, *Polyscias fulva* and *Syzygium guineense* were the four most abundant species and constituting about 63.64% of the total density (Table 7).

Dominant species of Gera Forest

Based on their IVI values, the most dominant and ecologically significant woody plants in Gera Forest were *Coffea arabica*, *Schefflera abyssinica*, *Syzygium guineense*, *Polyscias fulva*, *Croton macrostachyus*, *Millettia ferruginea*, *Vepris dainellii*, *Prunus africana*, *Galiniera saxifraga* and *Olea welwitschii*.

Table 7. Importance value index (IVI) values of dominant tree species in Gera Forest (RF = Relative Frequency, RD = Relative Density, and RDO = Relative Dominance).

Species	RD %	RDO %	RF %	IVI %
Coffea arabica L.	23.12	7.92	48.89	79.93
Croton macrostachyus Del.	6.49	4.01	7.19	17.69
Galiniera saxifraga (Hochst.) Bridson	5.37	2.12	4.37	11.86
Millettia ferruginea (Hochst.) Bak.	8.03	4.65	4.12	16.8
Olea welwitschii (Knobl.) Gilg & Schellenb	2.53	5.32	3.98	11.83
Polyscias fulva (Hiern) Harms	14.20	2.55	5.19	21.94
Vepris dainellii (Pichi-serm.) Kokwaro.	9.2	1.76	4.69	15.65
Prunus africana (Hook. f.) Kalkm	4.57	6.34	3.62	14.53
Schefflera abyssinica (Hochst. ex A. Rich.) Harms	15.25	34.17	9.97	59.39
Syzygium guineense (Willd.) DC. subsp. *afromontanum* F. White	11.07	30.7	7.90	49.67
Total	99.83	99.54	99.92	299.29

Species population structure

Five generalized patterns of population structure emerge from the analysis of the population structure of 15 selected dominant species in Gera Forest

(Fig. 5). The first pattern was formed by species with positively skewed distribution (inverted J-curve). These species had the highest density in the lower DBH classes with gradual decrease in density towards the higher DBH classes, which suggested good reproduction and recruitment potential in the forest. *Maesa lanceolata*, *Galiniera saxifraga*, *Podocarpus falcatus*, *Teclea nobilis* and *Vepris dainellii* had inverted J-curve structure.

The second pattern was bell-shaped distribution formed by species with high number of individuals in the middle DBH classes. Species such as *Albizia gummifera*, *Dracaena steudneri*, *Polyscias fulva* and *Millettia ferruginea* were characterized by this distribution pattern.

The third pattern was formed by species having irregular distribution over diameter classes. Some diameter classes were poorly represented indicating selective removal of medium-sized individuals while other diameter classes are well represented. Species like *Prunus africana*, *Olea welwitschii* and *Macaranga capensis* had this type of population pattern.

The fourth pattern was exhibited by species with individuals well represented in the lower DBH classes but absent in the higher DBH classes, representing species with good reproduction but bad recruitment. Species like *Croton macrostachyus* were characterized by this distribution pattern. The fifth pattern showed poor reproduction and complete absence of individuals in lower and intermediate DBH classes. Species like *Pouteria adolfi-friederici* and *Schefflera abyssinica* were characterized by this distribution pattern.

Regeneration status of the study forest

The composition, distribution and density of seedlings and saplings are indicators of the future regeneration status of any forest (Fekadu Gurmessa, 2010). The total seedlings and saplings of dominant woody species in the study area were about 4,838 and 1,331 individuals per hectare, respectively. The ratio of seedlings to saplings was 3.63. In this study, different species have different densities of seedlings and saplings.

The highest density of seedlings and saplings were recorded for *Millettia ferruginea*, *Croton macrostachyus*, *Cordia africana*, *Syzygium guineense*, *Vernonia amygdalina*, *Vernonia auriculifera*, *Coffea arabica* and *Grewia ferruginea*. Species like *Podocarpus falcatus*, *Schefflera abyssinica*, *Teclea nobilis* and *Olea capensis* showed the lowest seedling and sapling densities. On the other hand, some woody species like *Polyscias fulva*, lacked both seedlings and saplings in Gera Forest.

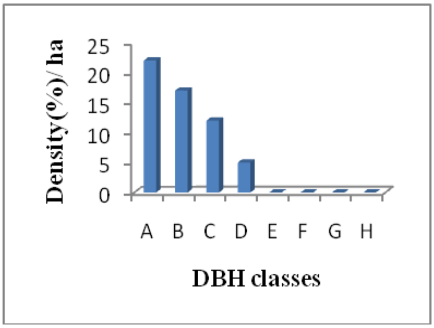

Fig. 5A- *Maesa lanceolata*

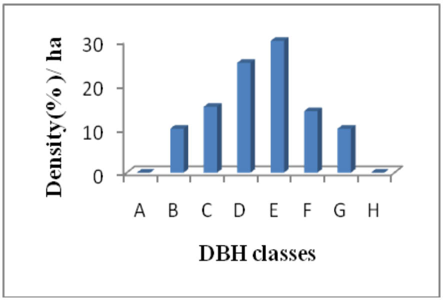

Fig. 5B- *Polyscias fulva*

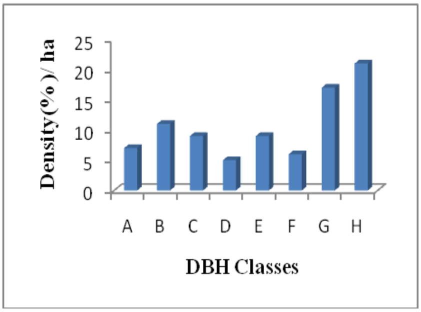

Fig. 5C- *Prunus africana*

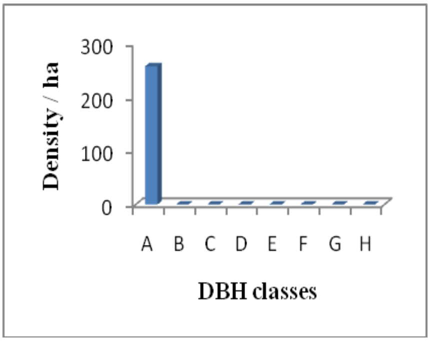

Fig. 5D- *Coffea arabica*

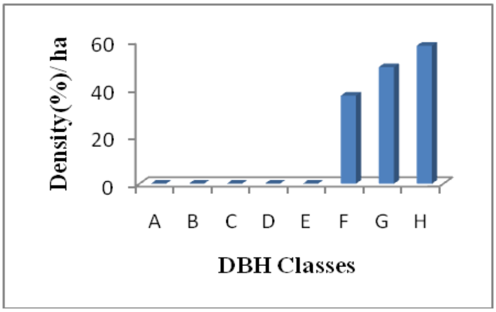

Fig. 5E- *Schefflera abyssinica*

Fig. 5. Population structure of some selected tree species. Legend: DBH class A = 2.6-10.0 cm, B = 10.1-20.0 cm, C = 20.1- 30.0 cm, D =30.1-40.0 cm, E = 40.1- 50.0 cm, F = 50.1- 60.0 cm, G = 60.1-70.0 cm and H >70.0.

DISCUSSION

Floristic description

Fabaceae and Asteraceae have been reported as dominant families in the Afromontane Flora of Ethiopia (Negusse Tadesse, 2006; Getachew Tena *et al*., 2008). The dominance of Fabaceae and Asteraceae could be attributed to their efficient and successful dispersal mechanisms and adaptation to a wide range of ecological conditions (Ensermu Kelbessa and Teshome Soromessa, 2008).

Fabaceae is the largest family in the Flora of Ethiopia and Eritrea followed by Poaceae and Asteraceae. In Gera Forest, however, Poaceae was not recorded as a dominant family because it was represented by only three species. Dominance of families may vary in different forests of Ethiopia. For example, Kumlachew Yeshitela and Tamrat Bekele (2002) reported the dominance of Euphorbiaceae and Moraceae from Afromontane and transitional rainforest vegetation of southwestern Ethiopia.

Out of the 132 plant species identified in the present study, only seven (5.3%) are endemic to Ethiopia. Feyera Senbeta *et al*. (2007) also reported low number of endemic plants (only 3%) from Sheko Forest, southwest Ethiopia. Ensermu Kelbessa *et al*. (1992) and Vivero *et al*. (2005) have published information on endemic flowering plant species of Ethiopia and the levels of threat to them. Coetzee (1978), White (1978) and Friis *et al*. (2001) reported low endemicity in the Afromontane rainforests of Ethiopia. Endemism may arise due to geographical and ecological isolations (Kruckeberg and Rabinowitz, 1985).

Community types

Vernonia auriculifera-Prunus africana community was found to have the highest species richness, evenness and diversity (Table 3). This community is found in specialized habitats including river courses (Naso River). Wild population of *Coffea arabica* L. is found abundantly in this community. According to the local informants, coffee plantation and deforestation is highly prohibited in this community type. This is a good practice for biodiversity conservation. The presence of Naso River and less anthropogenic influences might have contributed to highest species richness, evenness and diversity of this community.

High evenness in a community indicates little dominance by any single species but repeated coexistence of species over all plots of the community (Anteneh Belayneh *et al*., 2011). The prevalence of abundant seedlings and saplings of *Coffea arabica*, *Millettia ferruginea* and *Vernonia auriculifera* in this community indicates, the community is regenerating and may persist in the future. Fekadu Gurmessa (2010) noted that the composition, distribution and density of seedlings and saplings are indicators of the regeneration status of any forest.

Coffea arabica-Olea capensis community was highly dominated by *Coffea arabica*. In this community, some trees, shrubs and herbs were cleared for coffee plantation. This community is less species rich than *Vernonia auriculifera-Prunus africana*, *Schefflera abyssinica-Maytenus arbutifolia*, and *Syzygium guineense-Galiniera saxifraga* community types. This could be due to expansion of coffee plantation by the local farmers and investors. Feyera Senbeta *et al*. (2007) pointed that high dominance of *Coffea arabica* in Sheko Forest was an indication of human influence through selective removal of other associated plant species in order to promote coffee development.

More seedlings and saplings of *Coffea arabica* showed good regeneration potential of the future coffee forest. Some plant species may have a wide range of dispersal mechanisms or rapid reproduction strategies. Species able to survive and flourish after disturbance tend to be those that reproduce rapidly and abundantly (McKinney, 1997).

In *Syzygium guineense-Galiniera saxifraga* community type, regenerating species of *Piper capense* and *Bersama abyssinica* were abundant under the canopy layer. The dominance of *Syzygium guineense* in the community may be due to its low demand for timber and construction purposes by the local people and also its seeds germinate rapidly and easily. Kitessa Hundera and Tsegaye Gadissa (2008) reported similar results from Belete Forest of southwest Ethiopia. *Coffea arabica* was not recorded from this community type, indicating no coffee plantation and relatively low human interference. According to the local informants, agricultural practice is done few kilometers away from the forest area where this community was found. This practice might have contributed to high species richness, diversity and evenness of this community, as moderate disturbance is known to increase species diversity.

Croton macrostachyus-Albizia gummifera community is dominated by low sized *Croton macrostachyus* that has more seedlings and saplings and good regeneration potential. This community exhibited the least species richness and diversity that are 47 and 3.2, respectively (Table 3). As this community was easily accessible, it experienced human interference in the form of selective cutting of economically important trees and firewood collection. Cattle interferences were also observed in some of its stands. These factors could have contributed to low species richness and diversity of this community. Fekadu Gurmessa (2010) also reported similar results from Komto Forest.

Structural description

The forest pattern was exemplified by the species structure with reversed J-shape in DBH class distribution suggesting good reproduction and recruitment potential of the forest. This relationship was also observed in Sese Forest by Shiferaw Belachew (2010), Chilimo and Menagesha forests (Tamrat Bekele, 1993), Masha-Andracha Forest (Kumlachew Yeshitela and Taye Bekele, 2003), and Alata-Bolale Forest (Woldeyohannes Enkossa, 2008) (Table 6).

High proportion of DBH was contributed by *Olea capensis*, *Macaranga capensis*, *Cordia africana*, *Croton macrostachyus*, *Maesa lanceolata* and *Galiniera saxifraga*. This could be due to the use of plants by local people for different purposes like construction, timber, farm implements and firewood. For example, *Olea capensis* and *Olea welwitschii* are widely used by the local people for farm implements, beehive making, and the use of bark for smoking houses. Kitessa Hundera and Tsegaye Gadissa (2008) reported similar results from Belete Forest of southwest Ethiopia.

As the DBH of *Coffea arabica* falls between the range of 2.6 to 10 cm, it contributes mostly to the first DBH class (Fig. 4D). Density distribution at different height classes in the study area showed that more than 53% of the individuals had heights less than 12 m and 36% of individuals fall between 12.1-21.0 m range. Individuals ≥ 21.1 m in height made up 11%.

Density distribution at different height classes also showed similar trend to that of DBH classes. The highest proportion of species is concentrated in the lower height classes followed by the middle and upper height classes of the vertical structure of the forest. Thus, this study confirms that the number of individuals decreased as the height of the individuals increased suggesting the dominance of low stature individuals in the forest. This could be due to a long history of disturbance in the forest. This result is in line with the results observed in Chilimo Forest by Tamrat Bekele (1993), Denkoro Forest by Abate Ayalew *et al*. (2006), and Bonga Forest by Ensermu Kelbessa and Teshome Soromessa (2008). As the height of *Coffea arabica* falls between 2.6-9 m, it contributed most for the first and second height classes as indicated in Fig. 4. Trees representing the highest height classes (11%) dominating the upper canopy are *Pouteria adolfi-friederici*, *Prunus africana, Olea welwitschii* and *Albizia gummifera*.

Two major groups of woody species can be recognized based on the five patterns of species population structure. The first group consists of species that are capable of regenerating in the forest under-story. These species are *Millettia ferruginea*, *Podocarpus falcatus*, *Maesa lanceolata*, *Grewia ferruginea*, *Cordia africana*, *Syzygium guineense*, *Vernonia amygdalina* and *Vernonia auriculifera*.

The second group includes those species that are old and large sized but not well represented by their seedlings and saplings showing poor regeneration in the forest. These species are *Polyscias fulva*, *Pouteria adolfi-friederici* and *Schefflera abyssinica*. This could be due to the inability of seeds to germinate readily under the parent plants. Such similar species population pattern depicting poor reproduction and complete absence of individuals in intermediate classes was also observed in Denkoro Forest by Abate Ayalew *et al*. (2006).

Nichols (2005) reported that the seeds of *Schefflera abyssinica* do not germinate readily. Birds and monkeys probably eat the seeds, performing the task of preparing the seeds for germination.

Schefflera abyssinica is also found as an epiphyte on other trees. The seeds are lodged in tree forks and other places that are rich in plant detritus and where water can easily reach the seeds. Young species of *Schefflera abyssinica* prefer growth on other plants. As a result, the seedlings were not observed on the ground (Ensermu Kelbessa and Teshome Soromessa, 2008). Most of the species with irregular distributions are tree species that are hunted by the local people selectively for house construction, firewood and timber production or overgrazing which affects the seedlings under the mother trees. The complete absence of individuals in some diameter classes indicates that the regeneration of species was hampered during one or several phases of their life cycle. These might be caused by trampling by livestock, selective cutting for construction, timber or firewood purposes (Fekadu Gurmessa, 2010).

The importance value index of most dominant species was calculated and presented in Table 7. This shows that *Coffea arabica*, *Schefflera abyssinica* and *Syzygium guineense* were the first three most important species with higher IVI values indicating their good distribution throughout the forest.

High dominance and density of *Schefflera abyssinica* and *Syzygium guineense* might be due to their low demand by the local people for timber and other construction purposes.

The highest composition, distribution and density of seedlings and saplings of *Millettia ferruginea*, *Croton macrostachyus*, *Cordia africana*, *Syzygium guineense*, *Vernonia amygdalina*, *Vernonia auriculifera*, *Coffea arabica* and *Grewia ferruginea* are indicators of the regeneration status of Gera Forest. Generally, the presence of more seedlings and saplings indicate that Gera Forest is under regeneration.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The study has resulted in the documentation of 132 vascular plant species representing 112 genera and 59 families. Fabaceae and Asteraceae were found to be the most dominant families followed by Euphorbiaceae, Malvaceae and Rubiaceae. The study forest was also an important reservoir of endemic plants. About seven endemic plant species, some of which are in the IUCN Red Data List, were identified. Hence, Gera Forest could serve for the purpose of biodiversity conservation. It also has agronomical significance due to its high wild coffee (*Coffea arabica*) gene pool.

The variation in species composition and diversity among communities could be associated with different factors, such as altitude, anthropogenic impacts and soil properties. The presence of relatively higher percentage of lower diameter size in the forest indicated that Gera Forest is at a stage of secondary regeneration. In addition, the density of woody species in Gera Forest decreased with increasing DBH and height classes implying good recruitment. Analysis of population structure of most common species of trees and shrubs revealed different patterns of population structure, indicating a high variation among species population dynamics of Gera Forest. Accordingly, five population patterns were observed in Gera Forest. Analysis of regeneration of some selected woody species revealed that some tree species have lower seedling and sapling stages while others are represented by more seedling, sapling and mature stages in the forest.

Recommendations

Gera Forest is one of the remaining forests harbouring a unique gene reserve of wild coffee and several associated economic plant species. This forest is ecologically, socially and economically very important for the inhabitants residing nearby who are mostly dependent on forest products to make their living. The major threats observed in the study forest were encroachment, coffee production and agricultural expansion. Loss of such a forest and the various threatened species would have great implications for the environment, biodiversity and socio-economic setup of the communities. The concerned bodies have to take due consideration for conservation and sustainable utilization of this forest resource. For effective management and monitoring of Gera Forest on a sustainable basis, the following points are forwarded as recommendations:

- The management strategy should focus on multiple-use conservation approach. For example, undisturbed areas of the forest can be designated for strict conservation so that they may act as repositories of biodiversity and possibly as a source of forest genetic resources while the peripheral areas could be utilized on a sustainable basis;
- Assist in propagation and distribution of seedlings of *Schefflera abyssinica*, *Polyscias fulva*, *Olea capensis*, *Olea welwitschii* and *Prunus africana* whose uses are already widespread in the study area;
- Introduce modern beehive so as to reduce the pressure on selectively utilized species for the purposes of hive construction in particular, *Olea welwitshii*, *Polyscias fulva* and *Croton macrostachyus*;
- Initiate enrichment plantation of those species that have been over utilized for various purposes such as *Prunus africana*, *Olea capensis, O. welwitschii, Macaranga capensis, Podocarpus falcatus*, *Pouteria adolfi-friedrici* and *Polyscias fulva*;
- Natural regeneration of species in the forest can be facilitated through reduced grazing pressure; and
- More basic and applied researches should be encouraged to assist the planning and management of the forest.

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