academicJournals

Vol. 8(5), pp. 55-69, April 2016
DOI: 10.5897/JENE2015.0547
Article Number: D08709158233
ISSN 2006-9847

http://www.academicjournals.org/JENE

Journal of Ecology and the Natural Environment

Full Length Research Paper

Floristic composition and plant community types of Agama Forest, an "Afromontane Forest" in Southwest Ethiopia

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Received 27 November, 2015, Accepted 23 February, 2016.

Tropical Afromontane forests are among the most species-rich ecosystems on earth and comprise exceptional species richness and high concentrations of endemic species. The natural forest of Agama, an Afromontane forest, was studied with the objectives of determining its species composition, diversity and community types. Systematic sampling design was used to collect vegetation data. Soil samples were taken from each relevé at a depth of 0 to 30 cm and soil pH, sand, clay and silt were analyzed. The plant communities' classification was performed using the hierarchical cluster analysis. We evaluated species richness, eveness (Pielou J' index) and diversity (Shanon-Wiener index). Sorensens's similarity ratio was used to compare Agama forest with other similar forest in Ethiopia. A total of 162 plant species, 130 genera and 70 families were recorded from which Acanthaceae and Rubiaceae were the richest families. Furthermore nine endemic plant species were identified. In this study, four plant community types were identified and described. Post-hoc comparison of means among the community types showed that altitude was differed significantly between community types, indicating altitude is the most important factor in determining community type. Phytogeographical comparison of Agama Forest with other vegetation using Sorensens's similarity ratio revealed the highest similarity with Masha and Godre forest. In conclusion Agama forest presents high richness, diversity and endemism, with different plant communities according to altitude. Thus conservation of plant biodiversity is highly recommended.

Key words: Diversity, altitude, phytogeography, richness, endemism.

INTRODUCTION

Afromontane vegetation is an archipelago-like centre of endemism and confined in mountains of Africa. The Afromontane region comprises about 4000 plant species, of which about 3000 are endemic to regions (White, 1983). The largest concentrations of Afromontane vegetation found in Ethiopian highlands and very recently

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this region was designated as the “Eastern Afromontane hotspot,” which is one of the 34 regions globally important for biodiversity conservation (Conservation International, 2005). The Ethiopian highlands are the largest mountain complex in Africa and comprise over 50% of the African land area covered by Afromontane vegetation (Tamrat Bekele, 1994;Demel and Tamrat 1995). The Afromontane vegetation of Ethiopian highlands comprises a center of plant biodiversity and endemism (Vivero et al., 2004) due to variation in climate and altitude. Altitudes of the country range from 125 m below sea level in the Dallol depression to 4,620 m above sea level at Ras Dejen. As a result, the country possesses rich biodiversity that occur from the highest mountain to the lowlands. Accordingly, the flora of Ethiopia is estimated to contain between 6,500-7,000 species of higher plants, out of which about 12% are endemic (Tewolde, 1991).

These floral resources found in different vegetation types comprising in forests, woodlands and bush lands and others. The flora of Ethiopia have been investigated by several scholars since the beginning of the 19th C to the mid of the 20th C. Some studies have provided substantial contribution to describe vegetation types of Ethiopia. Pichi-Sermolli (1957); Chaffey (1979); Friis (1992); Sebsebe et al. (1996); Zerihun (1999); Friis and Sebsebe (2001) and Sebsebe et al. (2011).These studies were carried out in different parts of the Ethiopia and contributed in generating valuable botanical information for the Ethiopian flora.

The vegetation composition and structure of forests in southern and southwestern part of the country was also studied Lisane work Negatu L., (1987); Kumlachew and Tamrat (2002); Tadesse (2003); Feyera (2006); Ensermu and Teshome (2008). These studies have described floristic composition and analyzed plant communities and their relation with environmental factors. According to above studies several plant communities were identified, with characteristic plant species of *Ilex mitis*, *Syzygium guineense*, *Pouteria adolfi-friederici*, *Olea welwitschii, Psychotria orophila,* and *Schefflera abyssinica* in southwest Ethiopia*. These species are also reported by (Friis, 1992) as the characteristic species of Afromontane rainforest in southwest Ethiopia*. The vegetation of southwest Ethiopia varies with altitude and affecting the diversity of plant species. The study of variation of modern pollen rain (Bonnefille et al., 1993) along the ecological gradients containing range of vegetation types in southwest Ethiopia. This indicated that the vegetation types vary with altitude and altitudinal variation is an important environmental factor contributing for diversity of vegetation communities. Afromontane forests are the place of origin of the *Coffea arabica* and encompass a variety of commercially valuable spices and honey from wild bee. Furthermore the forests also play a pivotal role in providing water resources for the flow of the Baro-Akobo river system which is an important tributary of the Nile and it accounts for 42% of the water in the White Nile (NTFP, 2006). It is also important for carbon sequestration which has implications for climate change management.

In spite of the ecological and economic role of Ethiopian forests, the forest cover of Ethiopia has declined by human impact. About 35%, of the country’s area was once covered by natural high forests, (EFAP, 1994). By the early 1950s, high forests were reduced to 16% and the country’s forests have declined at fast rate and reached 3.6% by 1980, 2.6% by 1987 (IUCN, 1990), 2.4% in 1992, (Sayer et al., 1992), and were finally reduced to 2.3% in 2003 (Shibru, 2003). Because of this shrinkage of the forest resources, most of the remaining forests of Ethiopia are restricted to the south and southwest parts of Ethiopia, which are less accessible, and less populated (Kumelachew and Tamrat, 2002). These forests are continuously threatened by human activities such as clearing forest for coffee and tea plantation, subsistence farming and periodic movements of immigrants from northern and southern parts of Ethiopia looking for fertile land, resulting in the loss of forest cover in the region.

Recognizing the above mentioned threats to forest biodiversity of afromontane rain forests, the government designed different strategies to conserve the remaining forest resources in the region. Participatory forest management (PFM) was one of the solutions to solve the problem of open access to forest resources and to promote sustainable forest management. For instance farm-Africa introduced the Participatory Forest Management approach in southwest Ethiopia particularly in Bonga and the implementation process has been developed since 1996. Agama forest is part of Bonga forest delineated for PFM since 1996 (Aklilu et al., 2014). Though the forest has been under protection since its demarcation, still it has been continuously exploited for agricultural land expansion, timber harvesting, firewood collection and charcoal production due to lack of awareness on principles of PFM. Botanical assessment such as inventory of floristic composition, providing information on species diversity and community structure is necessary for the forest management and sustainable resource utilization by the community members. Therefore the current study aimed to assess the floristic composition and diversity of an Afromontane forests (Agama forest), to analyze community types of the forest and to evaluate the ecological relationships between plant communities and environmental parameters and to analyze phytogeographical relationship of Agama forests with other similar Afromontane forests types in Ethiopia and finally to recommend conservation action for protecting the forest biodiversity of the region.

MATERIALS AND METHODS

Descriptions of the area

The Agama forest is part of eastern African Biodiversity hot spot

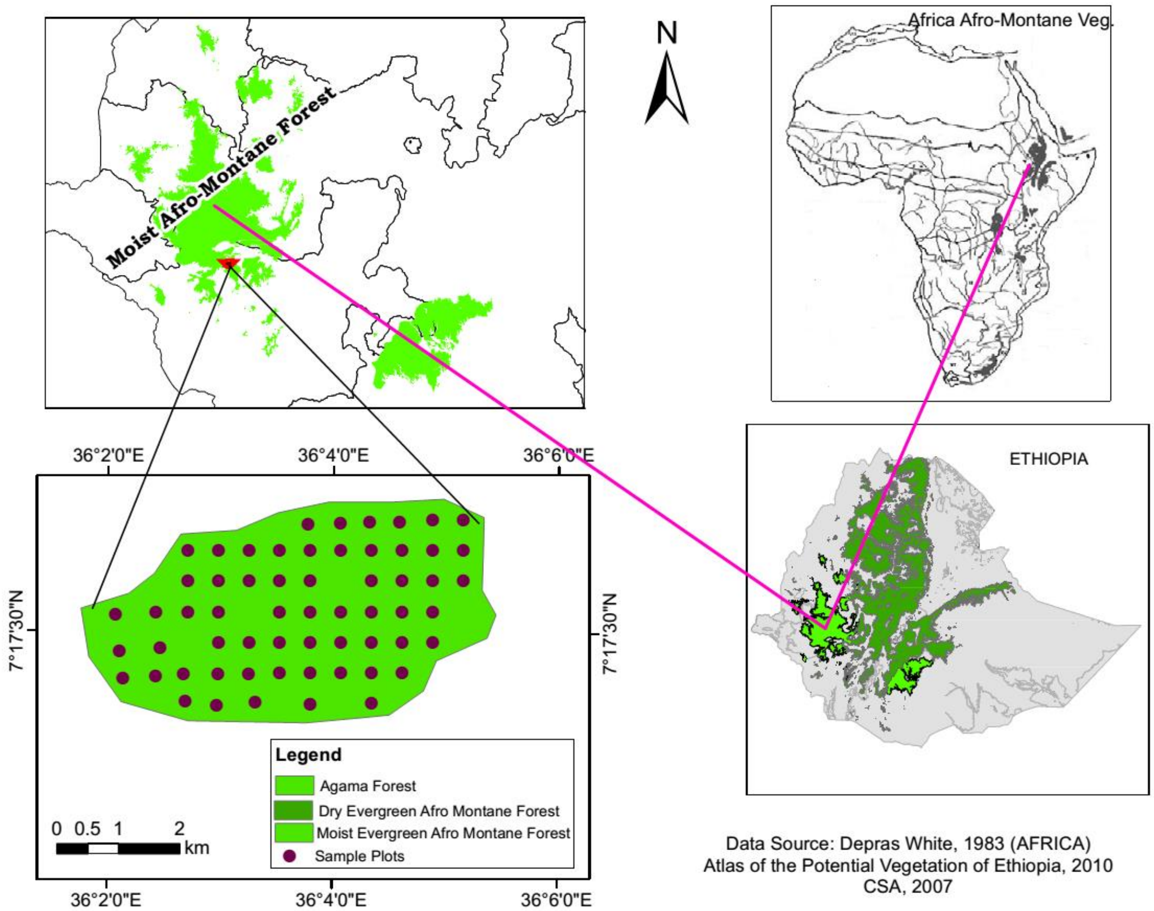

Figure 1. Location Map of Agama forest

and located in east Africa, in southwest Ethiopia (Figure 1) and it has a total area of 1868.5 ha. The area lies at 7°16'N and 36°11' E, and altitude between 1700 m to 2370 m.a.s.l. (Aklilu et al., 2014). The Geology of area belongs to the Precambrian basement complex, the Tertiary Volcanic Rocks from the trap series, and Quaternary Sediments consists of a variety of sedimentary, volcanic and intrusive rocks (Tafesse, 1996). The major soil groups, according to the FAO/UNESCO legend of soil classification, are Nitisols, Acrisols and Vertisols (Anon., 1988).

The vegetation of the area belongs to Afromonatin rain forest and transitional rain forests (Friis et al., 2011).The forest was stratified into four different layers, namely, upper canopy, sub-canopy, shrub layer and the ground layer and *Pouteria adolfi-friederici* occupied emergent trees of the upper canopy. The area receives very high annual rainfall reaching up to 1830 mm in some peak years. The rainfall pattern shows low rainfall in January and February, gradually increasing to the peak period in July and then decreasing in November and December. Maximum and minimum monthly mean temperatures of the area are 26.6 and 9.5°C respectively.

Data collection

A systematic sampling design was used to collect vegetation and environmental data, following Kent and Cooker (1992). Vegetation data were collected using quadrates of 25 m x 25 m (625 m^2), for woody plant species within which a 2 m x 2 m sub-plot was used for recording herbaceous species and soil sample collection. Ten line transect were established and the distance between each transect was 1km.The vegetation was sampled following the transect and located at 1 km apart and were laid systematically at every 500 m. The number of plots per transect is vary depending on length of the transect and accessibility of the sample plots. All level of altitudinal ranges starting from 1700 m up to 2300 m were covered during the sampling. A total of 60 releves were sampled and all vascular plant species found in each relevé were recorded and identified. The cover of all the vascular plant species found in each relevé was estimated and rated according to modified 1-9 Braun Blanquet approach (Vander, 1979). The specimens were collected and identified at the National Herbarium (ETH), Addis Ababa University using the published volumes of Flora Ethiopia and Eritrea by comparing with the authentic specimens in the National Herbarium.

Environmental data and soil analysis

The environmental parameters recorded in this study were altitude, slope, aspect, disturbance, soil pH and soil texture (sand, silt, clay), Altitude was measured by Garmin GPS and slope and aspect were measured using Silva Clinometer and 15T Silva Ranger Compass respectively. Soil analysis was performed in the soil laboratories of

Addis Ababa University, following the procedures, (Sahlemedhin and Taye, 2000). The soil samples were analyzed for texture, using Hydrometer method of mechanical analysis and Sodium hexametaphosphate were used as dispersing agent. The pH measure was taken using Digital pH meter and it was standardized using buffer solutions of pH 4.0 and 9.2. Disturbance was determined on the basis a five point scale following Anderson and Currier (1973). Disturbance scores were based on visible signs of, tree cutting, grazing and presence of beehives. The points of scale were 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).

Phytogeographical comparison

Agama forest was compared with five other afromontane rain forests in Ethiopia for the purpose of investigating forest similarity and differences among the afromontane rainforests of Ethiopia. These included Godre,Gera, Masha, Harenna, Jibbat and Yayu. Godre and Masha forests are close to Agama forest found in Bench Maji and Sheka zones in Southern Ethiopia Nations and Nationalities People's Regional State. Jibbat forest is a transitional forest between dry evergreen afromontane and moist evergreen afromontane forest and found in western Shewa in Oromia region. Harenna Forest is located in the Bale Mountain National Park in south eastern Ethiopia.

Data analysis

An agglomerative Hierarchical Cluster Analysis was performed using Similarity Ratio (S.R), using R software version 2.1.5.2 (Venables et al., 2012). The cut point of the Clusters was decided after visual inspection of the level of aggregation/homogeneity of relevé. Plant community types were further refined in a Synoptic table. The resulting groups were recognized as community types and the species occurrences were summarized by synoptic cover abundance values. The community types were named based on the tree and shrub with high synoptic value.

Ordination was computed using Detrended Correspondence Analysis (DCA) is a technique that is used to display sample plots (sites). In DCA similar samples are plotted close together and dissimilar samples are placed far apart (Hill et al., 1980) (Figure 4).

Richness was calculated and Shannon and Wiener (1949) index was applied to quantify species diversity. Shannon diversity index (H') was based on frequency of species $H = \sum_i^s \text{pilnpi}$ Where, "**H"** = Shannon and Wiener diversity index, S= number of the species Pi=the proportion of individuals or the abundance of species $i^{th} =$ the proportion of total cover in the sample and ln = natural logarithms. The Pielou's (1966) J' evenness index (J) was calculated using the formula: $J = \frac{\text{H}}{\text{In(S)}}$ where J = evenness H' = Shannon–Wiener Diversity Index S= total number of species in the sample and ln = natural logarithms.

A similarity analysis was carried out to evaluate the relationship between forests based on presence of trees, shrubs and herbs. Evaluation was conducted using Sorensen's similarity index. It is described using the following formula (Kent and Coker, 1992). Ss = 2a/ (2a+b+c), Where, Ss = Sorensen's similarity coefficient a = Number of species common to both samples; b= Number of species in sample 1; c = Number of species in sample 2. All the environmental parameters such as altitude, slope, aspect, disturbance and soil data were analyzed as follows: aspect was codified according to Zerihun Woldu et *al*. (1989): N = 0; NE = 1; E = 2; SE = 3; S = 4; SW =3.3, W= 2.5; NW = 1.3; Ridge top = 4. In order to examine the significant differences and similarities between the community types identified, Tukey's multiple tests were performed to detect significant differences between the community types for different environmental parameters (altitude, slope, aspect, and pH and soil texture). Pearson's correlation was calculated to evaluate the relationship between the environmental parameters, anthropogenic disturbances (timber, charcoal and encroachment and grazing).

RESULTS

Floristic composition and endemic plants

A total of 162 plant species (Annex I) belonging to 130 genera and 70 families were recorded and identified in the sample plots in Agama forest (Table 1). Herbs, trees, shrubs, and liana, constituted 50.95, 24.34, 17.19 and 7% of species abundance respectively (Figure 2). Acanthaceae was the richest family representing 8.44% of total floristic composition, followed by Rubiaceae and Asteraceae with 6.49% of species. Euphorbiaceae (4.01%), Roseaceae (3.06%), and Poaceae (3.08%) were also important families in terms of species richness. The remaining families represented less than 3% of species each. Based on the information available on the published Floras of Ethiopia and in Vivero et al. (2005) a total of 9 endemic plant species were recorded (Table 2), comprising more than 5.73% of the recorded species.

Plant community types

A total of 162 clusters were derived from the output at dissimilarity level above 0.80 (Figure 3). These clusters were designated as local plant community types and given names after two dominating woody species, usually a tree and a shrub with higher synoptic value (Table 3). The cluster numbers in the dendrogram correspond to the community types. The description of the plant community types is based on the dominant and characteristic species.

Community I: *Macaranga capensis-Sapium ellipticum* community-This community type is distributed between the altitudinal ranges of 1945-2343 m a.s.l. and the slope gradient vary 30 to 65%. It is dominated by the upper canopy of, *Macaranga capensis,Sapium ellipticum, Allophylus abyssinica*, *Apodytes dimidiata, Ficus sur* and *Croton macrostachyus*. The shrubs and herbs include *Galiniera saxifraga, Flacourtia indica, Buddleja polystachya, Canthium oligocarpum, Aframomum corrorima, Desmodium repandum, Piper capense* and *Aspilinum anisophylum are* the major plant species found in this community. The climbers/lianas of this community are *Tilicora rouplii*,*Culcasia falcifolia* and *Vernonia wollastonii.* Some of the plant species in this community like *Cyathea manniana* and *Phonix relinata* are found along the small streams.

Community II: *Millitia ferruginia–Olea capensis* community-This community is found between 1781-2085

Table 1. Plant Families with their number of genera and species occurred in Agama forest.

Family	Genera	Species number	%	Family	Genera	Species number	% Richness
Acanthaceae	10	14	8.58	Fabaceae	5	6	4.01
Adianthaceae	1	1	0.61	Flacourtiaceae	1	1	0.61
Amaranthaceae	1	1	0.61	Myrtaceae	1	1	0.61
Amaryilidaceae	1	1	0.61	Moraceae	2	4	2.45
Apiaceae	1	1	0.61	Icaccinaceae	1	1	0.61
Apocynaceae	1	1	0.61	Lamiaceae	2	2	1.22
Araceae	1	1	0.61	Lauraceae	1	1	0.61
Araliaceae	2	2	1.22	Oleaceae	2	3	1.94
Asclepiadaceae	1	2	1.22	Orchidaceae	4	4	2.45
Asparagaceae	1	2	1.22	Pittosporaceae	1	1	0.61
Asteraceae	6	10	6.13	Piperaceae	2	2	1.22
Boraginaceae	2	2	1.22	Plantaginaceae	1	1	0.61
Caryophylaceae	1	1	0.61	Polygonaceae	1	1	0.61
Celastraceae	1	1	0.61	Poaceae	4	5	3.08
Combreataceae	1	1	0.61	Primulaceae	1	1	0.61
Commelinaceae	1	1	0.61	Rhamnaceae	1	1	0.61
Cucurbitaceae	2	2	1.22	Ranuaculaceae	2	3	1.94
Cyperaceae	2	3	1.84	Rhizophoraceae	1	1	0.61
Dracenaceae	1	3	1.84				
Euphorbiaceae	6	6	4.01				
Loganiaceae	1	1	0.61	Selaginellaceae	1	1	0.61
Malvaceae	2	2	1.22	Scrophulariaceae	1	1	0.61
Melistostomaceae	1	1	0.61	Spindaceae	1	1	0.61
Melianthaceae	1	1	0.61	Verbenaceae	1	1	0.61
Meliaceae	1	1	0.61	Violaceae	1	1	0.61
Menispermaceae	1	1	1.61	Verbenaceae	1	1	0.61
Rubiaceae	8	10	6.13	Vitaceae	1	1	0.61
Roseaceae	3	5	3.06	Ulmaceae	2	2	1.22
Rutaceae	4	4	2.45	Zingiberaceae	1	1	0.61
Sterculiaceae	1	1	0.61				
Spotaceae	1	1	0.61				

ma.s.l. and its slope gradient vary 15 to 45%. The most characteristic species of this community are *Millettia ferruginea*,*Vepris dainellii,Albizia gummifera,* and *Lepidotrichilia volkensii.* The shrub layer includes *Coffea arabica*, *Dracaena afromontana, Erythrococca trichogyne.* The dominant herbs are *Achyranthes aspera*, *Acanthus eminens, Alecmella abyssinica, Desmodium repandum* and the grass *Oplismenus hirita*. This community is abundant with coffee plants and anthropogenic influences are higher as compared with other communities.

Community III: *Syzygium guineense-Olea welwitschii* community-This community is found between 1810-2230 m a.s.l. and slope gradient vary 12-50%. The indicator species of this community are Olea *welwitschii* and *Syzygium guineense.* The tree species include *Elaeodendron buchananii*, *Ekbergia capensis*, *Olea.capensis* and *Polyscias fulva.* The shrubs are *Bersama abyssinica Cantium oligocarpm*, *Clausena anisata* and *Oxyanthus speciosus.* The herbs are *Alecmella abyssinica*, *Achryanthes aspera*, *Hypoestes triflora*, *Piper capense* and *Oplismenus hirtellus* This community is also dominated with *Piper capense*, one of the spice plant commonly collected by women for income generation.

Community IV*: Vepris dainellii-Schefflera abyssinica*-The community is distributed in the altitude range of 1798–2115m a.s.l. and the slope gradient varies 10 to 50%. The emerging dominant tree species in the community are *Elaeodendron buchananii, Syzygium guineense, Schefflera abyssinica* and *Vepris dainellii*. The shrubs in this community are *Dalbergia lactea,Maytenus gracilipes* and *Dracaena afromontana*. The field layer is dominated by *Desmodium repandum, Pteris pteridioides* and *Asplenium anisophyllum* and *the climbers* include *Clematis hirsuta, Landolphia buchananii, Hippocratea*

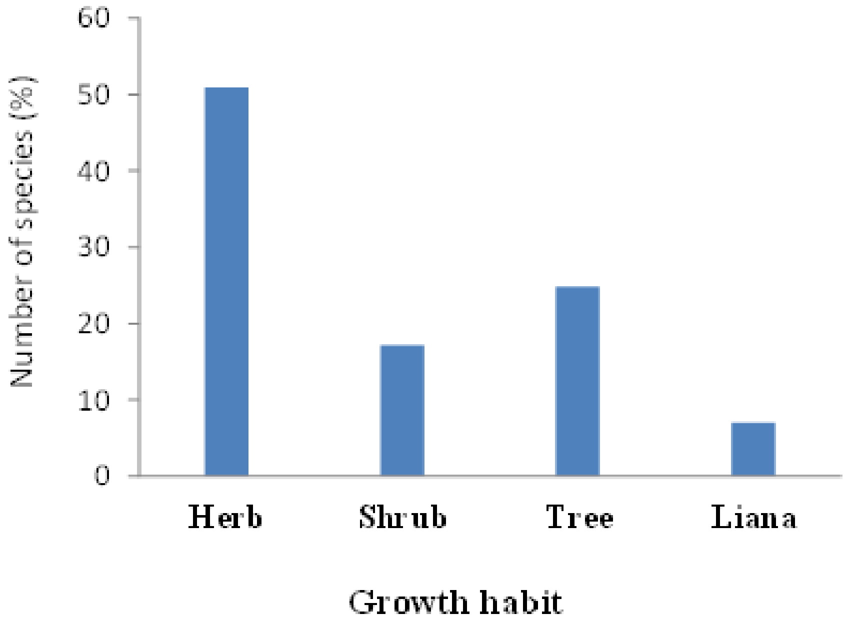

Figure 2. Growth habit of plant species in Agama Forest.

Table 2. Endemic species and their habit in Agama Forest, southwest Ethiopia.

Species	Family	Habit
Aframomum corrorima	Zingeberaceae	Herb
Clematis longicauda	Ranunculaceae	Liana
Millettia ferruginea	Fabaceae	Tree
Pittosporum viridiflorum	Pittosporaceae	shrub
Rinorea friisii	Violaceae	Tree/Shrub
Scadoxus nutans	Amaryllidaceae	Herb
Tiliacora troupinii	Menispermaceae	Climber
Vepris dainellii	Rutaceae	Tree/Shrub
Vernonia filigera	Asteraceae	Shrub

pallens, Jasminum abyssinicum and *Urera hypselodendron.*This community is comprises important honey tree(*Schefflera abyssinica*) known for white honey and contributing for the income of the local communities in the area. which needs conservation attention.

Species diversity, richness and equitability

From analysis of vegetation data using the Shannon-Wiener diversity index, community II had the highest species diversity (4.18), followed by communities IV (4.08) and III (3.96) and I (3.94). Community II had the highest number of species (110) followed by communities III (103) and IV (103), and I (79). Community I had thehighest evenness value (0.902) followed by communities II (0.89), Community IV (0.88) and III (0.85).

Plant community-environment relationship

The community types identified from cluster analysis showed significant difference with respect to altitude, slope, soil texture and number of species (Table 4). Community I was significantly different from the rest of the communities in terms of altitude and slope. All the communities identified in this study occur in slightly acidic soils (pH 4 and 5). There is no significant difference between plant communities for soil pH and sand content. Community types II differed in clay and silt content from community type 1, 3 and 4.

The result of Pearson's correlation of the environmental parameters shows that some of the environmental parameters were correlated (Table 5). Altitude is positively correlated with sand with R^2 = 0.64 and negatively correlated with clay and silt (-0.732 and -0.47)

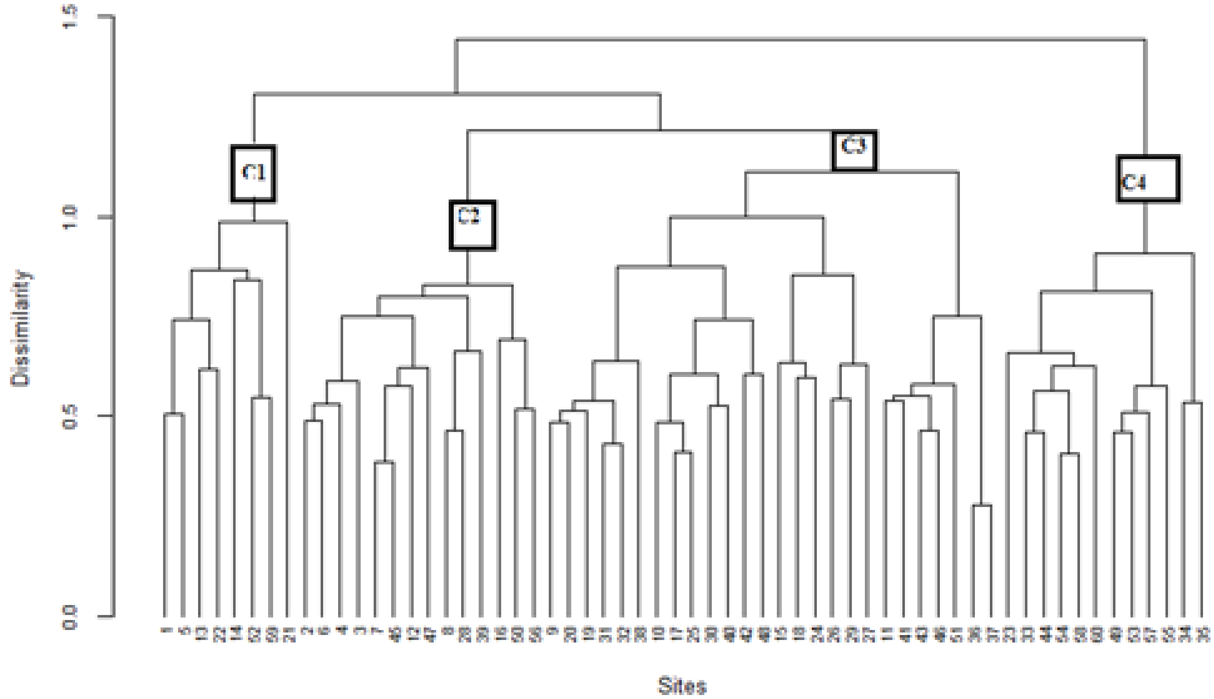

Figure 3. Dendrogram of the cluster analysis results of species abundance found in 60 plots. The plot code and the arrangement of the plots along the dendrogram from left to right are as follows:(C1= *Macarnga capensis-Sapium ellipticum*,C2= *Millitia ferruginia–Olea capensis community*,C3= *Syzygium guineense -Olea welwitschii* community and C4= *Schefflera abyssinica –Vepris dainellii*).

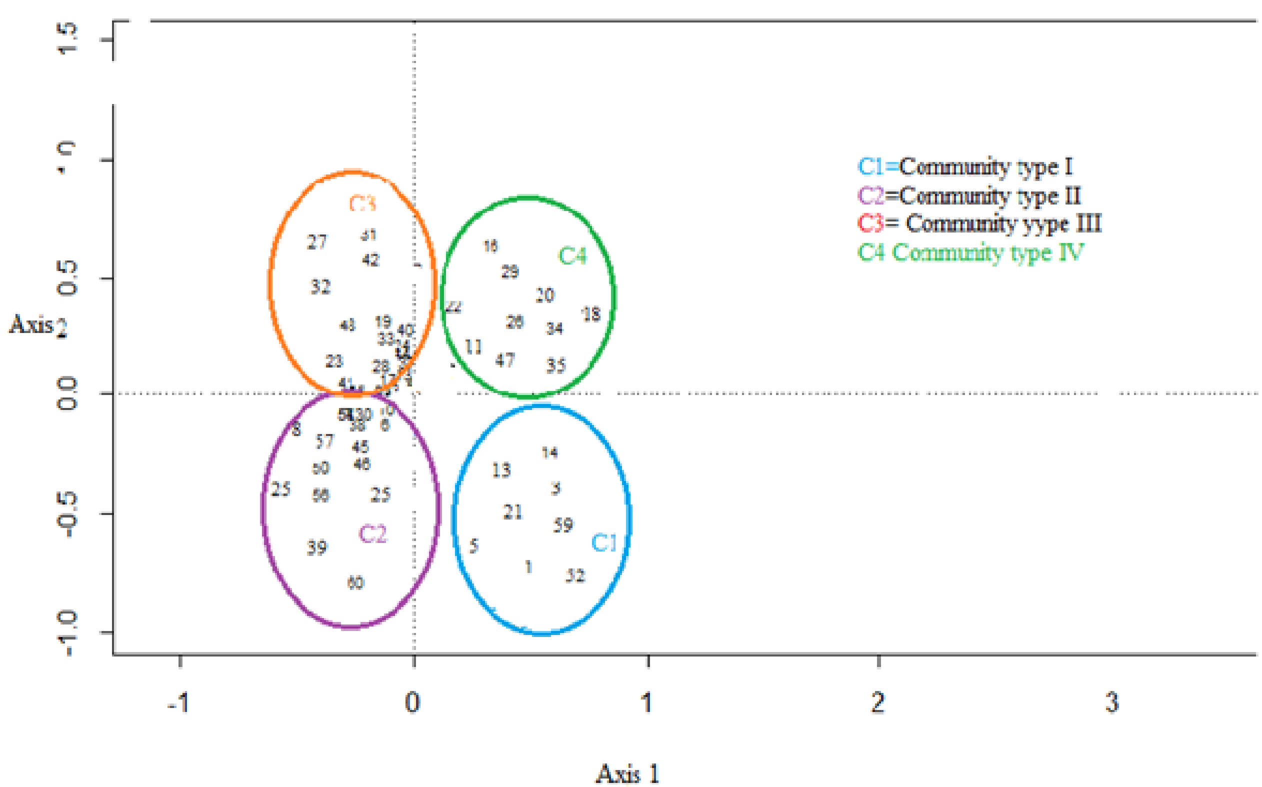

Figure 4. Distribution of relevés on the first and second axis of Detrended correspondence analysis.

Table 3. Synoptic cover value of plant for species reaching ≥ 1% in at least one community.

Community type	**I**	**II**	**III**	**IV**
Plot size	10	23	19	8
Macaranga capensis	**5.83**	1.65	1.30	0.00
Sapium ellipticum	**5.66**	3.13	0.80	2.5
Cyathea manniana	**4.66**	0.21	0.00	0.00
Desmodium repandum	**4.50**	3.47	4.00	3.00
Galiniera saxifrage	**4.02**	2.84	2.00	2.83
Canthium oligocarpum	**4.08**	2.57	2.80	1.83
Phonix reclinata	**4.01**	3.23	0.30	4
Ficus sur	**3.66**	2.26	0.20	0.66
Allophyllus abyssinicus	**3.16**	1.52	0.30	0.00
Ilex mitis	**3.54**	1.42	2.90	1.33
Millettia ferruginea	2.5	**6.84**	0.70	3.50
Olea capensis	4.00	**6.39**	5.20	6.66
Coffea arabica	2.5	**4.02**	0.90	2.33
Dracaena afromontana	2.16	3.55	**3.50**	3.51
Syzygium guineense	5.83	4.47	**8.1**	5.33
Olea welwitschii	2.83	3.23	**7. 90**	6.83
Bersama abyssinica	2.5	3.39	**4.60**	1.83
Vepris dainellii	3.66	4.21	5.70	**8.16**
Schefflera abyssinica	3.66	3.31	0.50	**7.5**
Oxyanthus speciosus	0.83	4.28	5.10	**6**
Landolphia buchananii	1.5	2.86	1.80	**5.16**
Maytenus gracilipes	0.83	2.07	3.60	**4**
Dalbergia lactea	2.33	0.92	0.90	**3.83**

respectively.

Phytogeographical comparison

The Agama forests in southwestern Ethiopia are floristically related more to the Masha and Godre forest since they are situated in the same climatic region and geographical location. Accordingly Masha and Godere forests share similar Sorensen similarity Index of (0.59) and (0.46) respectively (Table 6). Furthermore Harenna and Jibbat forests are less similar with lower similarity index (0.38 and 0.32) respectively.

DISCUSSIONS

Agama forest is one of the moist Afromontane rainforest and rich in plant biodiversity. It comprises an economically important plants used for coffee, spices and honey. These plant species are *Coffee arabica*, *Aframomum corrorima*, *Piper capense* and *Schefflera abyssinica* are the most frequent species in almost in all sample plots. Even though the size of the study area was limited; it had high number of plant species which is more or less comparable with that reported for the Afromontane and transitional rainforest vegetation in southwestern Ethiopia (Kumelachew and Tamrat, 2002) and Gara Ades forest in southeastern Ethiopia (Uhligsit and Uhlig, 1990). Agama forest contains a number of flowering plant species that are endemic to Ethiopia. The endemic plant species identified (9 species) in this study is in agreement with similar studies with Abreham (2009) for Masha Andracha Forest, Derje (2002) for Gura Ferdea forest and Ensermu and Teshome (2008) for Bonga forest. Some of this species are in the IUCN Red Data list, were identified in Agama Forest. The number of endemic plant species recorded for the study area is small compared to dry afromontane forests, since the southwest moist montane forests are poor in trees/shrubs endemicity (Kumelachew and Simon, 2002).

Species diversity and evenness are used to interpret the relative variation among the communities. Lower evenness in Community III indicates the dominance of a few species such as *Pouteria adolfi-friedericii* (Engl.) Baehni, *Schefflera abyssinica* (Hochst. ex A. Rich.) Harms, *Vepris dainellii* (Pichi-serm.) Kokwaro, *Dracaena afromontana* Mildbr, and *Acanthopale aethiogermanica* Ensermu in the community and similar observation was reported by Abraham (2009) for Masha forest. On the other hand, high evenness in community I, II and IV indicates little dominance by any single species but

Table 4. Post-hoc comparison of means between environmental variables and plant community.

Environmental variables	Plant Community Types			
	I	II	III	IV
Altitude (m)	2193±41.37^{b}	1905±21.62^{a}	1960±25.2^{a}	1913±38.95^{a}
Slope (%)	33.6±5.3^{b}	16.3±2.8^{a}	14.7±4.6^{a}	25±3.5^{a}
Aspect	1.99±.42 ^{a}	2.29±0.32 ^{a}	2.46±0.43 ^{a}	1.3±0.21 ^{a}
Disturbance	2.35±1.88 ^{a}	2.36±.20^{a}	2.66±.21^{a}	2.15±.24^{a}
pH	4.8±0.12 ^{a}	5.06±0.106 ^{a}	5.22±0.09 ^{a}	4.76±0.15 ^{a}
Sand (%)	66.9±2.15^{b}	51.0±1.8^{a}	54.4±2.3^{a}	48.9±5.4^{a}
Clay (%)	18.36±1.26^{a}	29.4±0.85^{b}	24.9±1.73^{ab}	31.4±3.92^{b}
Silt (%)	14.65±1.37^{a}	21.16±1.05^{b}	19.10±1.18^{ab}	19.60±2.02^{ab}

Table 5. Pearson's correlation between environmental variables measured in Agama forest.

Variables	Altitude	Slope	Aspect	Disturbance	PH	Sand	Clay	Silt
Altitude	-							
Slope	0.166	-						
Aspect	-.005	0.043	-					
Disturbance	0.135	0.396	-0.003	-				
PH	-.095	0.037	0.012	-0.096	-			
Sand	0. 640**	-0.115	-0.219	0.67**	0.013	-		
Clay	-0.73**	-0.215	0.143	0.993**	0.114	0.775**	-	
Silt	-0.479	0.048	0.02	-0.583**	0.109	0.882	0.549	-

Table 6. Phytogeographical Comparison of Agama forest with other forests in Ethiopia, according to Sorensen similarity Index.

Forests	Sorensen index	Dissimilarity	References
Godre	0.46	0.54	Dereje Denu,2006
Masha	0.59	0.41	Abreham Assefa, 2009
Yayu	0.40	0.60	Tadesse Woldmariam,2004
Harenna	0.38	0.62	Lisanework Nigatu,1987
Jibat	0.32	0.78	Tamart Bekele, 2002

Values in a row with different letters are significantly different (P<0.05).

repeated coexistence of species over all plots in a community *(Vepris dainellii*). The highest species richness and diversity were observed in community II. The possible reason may be the altitude since it is found at mid altitudes which provides with optimal conditions of environmental factors that favor vegetation growth (Rosenzwieg, 1995). Some species may exclusive to live in mid, low and high altitudes depending on their physiological need and adaption (Austrheim, 2002). Community type **I** showed the lowest species richness and diversity. This difference is the result of differences in site productivity, habitat heterogeneity and anthropogenic influences such as selective removal of economically important trees and grazing by livestock. Local people reported that this community was used as settlement area for indigenous people before introduction of PFM. The altitude was relatively the important environmental factor that separates the four plant communities studied. Community I was significantly different from the rest of the communities since it is found at higher altitude (2343 m) and the communities II, III and IV are found at intermediate altitudes. This study is in agreement with Bonnefille et al. (1993) reported that the presence of altitudinal Zonation is delimiting vegetation types in southwestern Ethiopia and affecting atmospheric pressure, moisture and temperature which have again a strong influence on the growth and development of plants and the distribution of vegetation. Studies by Herdberg in 1951 also confirmed the altitude effect on vegetation in eastern African mountain.

The acidity of the soil in southwest Ethiopia is relatively higher as compare to other parts of the country due to intense breakdown of organic matter and leaching of the soil by heavy rainfall. This results in leaching of appreciable amounts of exchangeable basic ions like calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) from the surface of soil (Achalu et al., 2012). The soil pH decreases with increasing altitude and this could affect the chemical reaction between plant roots and nutrients, the availability of nutrients in the soil for plant use and microbial activity (Donahue et al., 1983). These could be the possible reasons for the decline of species richness and diversity with altitude. The differences in soil texture among the communities are not strongly significant due to limited size of the study area and the altitude ranges are not strongly significant to show variation among the plant communities.

The Agama forest was more floristically related to the Masha and Godre forests due to geographical proximity and located in similar climatic zone. Proximity of the areas favors seed dispersal and migration which result in a high floristic similarity. On the other Jibbat and Harenna forests are found in south eastern parts of the country and it has low floristic similarity due to variation in altitude soil, and climatic factors (rainfall, temperature). On top of this human influence on the forest resource also causes variation in floristic diversity. Bonnefille and Hamilton (1986), reported that the destruction of montane forest in southeastern Ethiopia as far back as ca. 2000 years and these historical factors may have led to the variation in floristic diversity between the southwest (Agama) and southeastern (Harenna).

CONCLUSION AND RECOMMENDATION

The Agama forest, in southwest Ethiopia, has high floristic richness and diversity. Four community types were identified at an altitude between 1800 and 2371 m. The communities at the bottom and middle of the altitudinal gradient were richest while the community restricted to the top had less species. The Soil of Agama forest is acidic (with low pH) caused by excessive rainfall. The Agama forest is rich in plant biodiversity as compare to its limited size thus conservation of forest through, strengthening of existing PFM and provision of environmental education for forest user groups are highly recommended.

Conflict of interests

The authors have not declared any conflict of interests.

ACKNOWLEDGMENT

The authors highly acknowledged for the financialsupport provided by thematic research division of Addis Ababa University and Biovision foundation. We also thank the National Herbarium, Addis Ababa University, for letting to utilize the available facilities including flora books and specimens for plant identification.

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Appendix I. checklist of plant species identified from Agama Forest.

S/N.	Plant species	Family	Growth form
1	*Acanthopale ethio-germanica* Ensermu	Acanthaceae	Shrub
2	Acanthopale pubescens (Lindau ex Engl.0.46) C.B. Clarice	Acanthaceae	Herb
3	*Acanthus eminens* C.B.Clarke	Acanthaceae	Shrub
4	Achyrospermum schimperi (Hochst. ex Briq.) Perkins,	Lamiaceae	Herb
5	*Achyranthes aspera* L.	Amaranthaceae	Herb
6	*Adianthum thalictroides schltd*	Adianthaceae	Herb
7	*Aerangis brachycarpa (luch.) Th. Dur.&Schinz,*	Orchidaceae	Herb
8	*Aframomum corrorima* (Braun) Jansen	Zingiberaceae	Herb
9	*Ajuga alba* (Guerke) Robyns	Lamiaceae	Herb
10	*Albizia gummifera* (Gmel.) C.A. Sm.	Fabaceae	Tree
11	*Alblzia schimperiana Oliv.*	Fabaceae	Tree
12	*Alecmella fischeri Engl*	Roseaceae	Herb
13	*Alecmella abyssinica* Fresen	Roseaceae	Herb
14	*Alectra vogelii* Benth.	Scrophulariaceae	Herb
15	*Allophyllus abyssinicus (Hochst)Radlk*	Spindaceae	Tree
16	*Ammocharis tinneana* (Kotschy &Peyr.)Milne-Redh.	Orchidaceae	Herb
17	*Apodytes dimidiata* E. Mey. ex Arn	Icaccinaceae	Tree
18	*Asparagus africanus* Lam.	Asparagaceae	Herb
19	*Asparagus setaceus (Kunth)* Jessop	Asparagaceae	Herb
20	*Aspilia mossambicensis (Oliv.)* Wild	Asteraceae	Herb
21	*Asplenium aethopicum (Brum.f.)* bech	Aspleniaceae	Herb
22	*Asplenium anisophyllum* Kunze	Aspleniaceae	Herb
23	*Asplenium bugoiense* Hieron	Aspleniaceae	Herb
24	*Asplenium erectum* Willd.	Aspleniaceae	Herb
25	*Asplenium friesiorum* C.Chr.	Aspleniaceae	Herb
26	*Asplenium sandersonii* Hook	Aspleniaceae	Herb
27	*Asystasia gangetica (L.) T.* Andders. Subsp*. Micrantha (Nees).* Ensermu	Acanthaceae	Herb
28	*Bersama abyssinica* Fresen.	Melianthaceae	Tree/Shrub
29	*Bothriocline schimperi* Olivo & Hiern ex Benth.	Asteraceae	Herb
30	*Brillantaisia madagascariensis* T. Anders.	Acanthaceae	Shrub
31	*Buddleja polystachya* Fresen.	Loganiaceae	Tree/shrub
32	*Bulbophyllum josephii (Kuntze)* Summerh.,	Orchidaceae	Herb
33	*Canthium oligocarpum* Hiern	Rubiaceae	Tree
34	*Cassipourea malosona* (Baker) Alston	Rhizophoraceae	Tree
35	*Carex chlorosaccus* C.B. Clarke	Cyperaceae	Herb
36	*Carex spicato-paniculata Bock.* ex *C.B. Clarke*	Cyperaceae	Herb
37	*Cayratia gracilis (Guill.* & *Perr.]* Suesseng*.*	Vitaceae	Herb
38	*Celtis africana* Burm.	Ulmaceae	Tree
39	*Chamaecrista mimosoides (L.)* Green	Mimosoideae	Liana
40	*Clausena anisata* (Wild.) Benth.	Rutaceae	Shrub/Tree
41	*Clematis longicauda* Steud. ex A. Rich	Ranuaculaceae	Liana
42	*Clematis simensis* Fresen.	Ranuaculaceae	Liana
43	*Coffea arabica* L.	Rubiaceae	Shrub/Tree
44	*Cordia africana* Lam.	Boraginaceae	Tree
45	*Combretum paniculatum* Vent.	Combreataceae	Liana
46	*Commelina diffusa* Burm.f.	Commelinaceae	Herb
47	*Coniogramme africana* Hieron	Hemionitidaceae	Herb
48	*Crassocephalum crepidioides (*Benth.) S. Moore	Asteraceae	Herb
49	*Croton macrostachys* Del.	Euphorbiaceae	Tree
50	*Cryptotaenia africana (Hookf)* Drude	Apiaceae	Herb

Appendix I. Contd.

51	*Cucumis dipsaceus Ehrenb.* ex Spach	Cucurbitaceae	Herb
52	*Culcasia falcifolia* Engl.	Araceae	Herb
53	*Cyathea manniana* Hook.	Cyatheaceae	Tree
54	*Cyperus fischeria* A.Rich.	Cyperaceae	Herb
55	*Dalbergia lactea* Vatke	Fabaceae	Shrub
56	*Desmodium repandum* Vahl	Fabaceae	Herb
57	*Dicliptera maculata* Nees,	Acanthaceae	Herb
58	*Didymochlaena truncatula* (Sw.) J. Sm	Aspidiaceae	Herb
59	*Dissotis canescens* (Graham) Hook.f.	Melistostomaceae	Herb
60	*Dombeya torrida* (J.F.Gmel.) Bamps	Sterculiaceae	Tree
61	*Dracaena afromontana* Mildbr.	Dracenaceae	Shrub
62	*Dracaena fragrans* (L.) Ker-Gawl.	Dracenaceae	Shrub
63	*Dracaena steudneri* Scw.ex Engl.	Dracenaceae	Tree
64	*Drynaria volkensii* Hieron	Polypodiaceae	Herb
65	Dryopteris concolor (langsd.&Fisch.) Kuhn in Vonder Decken	Dryopteridaceae	Herb
66	*Ehretia cymosa* Thonn.	Boraginaceae	Tree
67	*Ekebergia capensis* Sparrm.	Meliaceae	Tree
68	*Elaeodendron buchananii*	Celastraceae	Tree
69	*Elatostemma monticolum* Hook. f.	Urticaceae	Herb
70	*Embelia schimperi* Vatke	Myrsinaceae	Liana
71	*Erythrococca trichogyne* (Muell. Arg.) Prain	Euphorbiaceae	Shrub/Tree
72	*Euphorbia ampiphyla Pax.*	Euphorbiaceae	Tree
73	*Ficus sur* Forssk.	Moraceae	Tree
74	*Ficus ovata* Vahl	Moraceae	Tree
75	*Ficus thonningii* Blume	Moraceae	Tree
76	*Fagaropsis angolensis*	Rutaceae	Tree
77	*Flacourtia indica* (Burm.f.) Merrill	Flacourtiaceae	Tree
78	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	Tree
79	*Tacazzea conferta* N.E. Br.	Asclpidaceae	liana
80	*Tacazzea apiculata* Oliv	Asclpidaceae	liana
81	*Habenaria quartiniana* A. &ch.,	Orchidaceae	Herb
82	*Helicbrysum stenoptel1lm* DC.	Asteraceae	Herb
83	*Hippocratea pallens* Oliv.	Celastraceae	shrub
84	*Holothrix praecox* Rchbf.	Orchidaceae	Herb
85	*Hyparrhenia hirta (L.) Stapf,* var. *brachypoda* Chiov.	Poaceae	Herb
86	*Hypoestes forskaolii* Roem. & Schult.	Acanthaceae	Herb
87	*Hypoestes triflora* (Forssk.) Soland.ex Roem. & Schult.	Acanthaceae	Herb
88	*Ilex mitis* (L.) Radlk.	Aquifoliaceae	Tree
89	*Indigofera mimosoides* Bak.	Fabaceae	Shrub
90	*Isoglossa laxa* Oliv.	Acanthaceae	Herb
91	*Isoglossa somalensis* Lindau	Acanthaceae	Herb
92	*Jasminum abyssinicum* DC.	Oleaceae	Liana
93	*Landolphia buchananii* Stapf.	Apocynaceae	Liana
94	*Lepidotrichilia volkensii* (Gurke) Leory	Meliaceae	Tree
95	*Loxogramme lanceolata* auct,non(sw.) presl	polypodiaceae	Herb
96	*Lycopodium dacrydioides* Bak	Lycopodiaceae	Herb
97	*Lysimachia ruhmeriana* Vatke	Primulaceae	Herb
98	*Macaranga capensis* (Baill.) Sim	Euphorbiaceae	Tree
99	*Maesa lanceolata* Forssk.	Myrsinaceae	Shrub /Tree
100	*Maytenus gracilipes* (Welw.ex Oliv.) Exell	Celastraceae	Shrub
101	*Mikaniopsis c1ematoides* (.S'ch. *Bip.* ex *A. Rich.) Milne-Redh.*	Asteraceae	Herb
102	*Millettia ferruginea* (Hochst.) Baker	Fabaceae	Tree

Appendix I. Contd.

103	*Monothecium glandulosum* Hochst.,	Acanthaceae	Herb
104	*Ocotea kenyensis* (Chiov.) Robyns & Wilcz	Lauraceae	Tree
105	*Olea capensis* subsp. *macrocarpa* (C. A. Wright) Verdc.	Oleaceae	Tree
106	*Olea welwitschii* (Knobl.) Gilg & Schellenb.	Oleaceae	Tree
107	*Oplismenus hirtellus* (L.) P. Beauv.	Poaceae	Herb
108	*Oxyanthus speciosus* DC.	Rubiaceae	Shrub
109	*Panicum monticola* Hook. f.	Poaceae	Herb
110	*Pavonia* urens *Cav.*	Malvaceae	Shrub
111	*Pavetta abyssinica* Fresen. var. abyssinica	Rubiaceae	Shrub
113	*Pentas lanceolata* (Forssk.) Defl.	Rubiaceae	shrub
114	*Pentas schimperiana(A.Rich)vatke*	Rubiaceae	Herb
115	*Peponium vogelii* (Hook.f.) Engl.	Cucurbitaceae	Herb
116	*Peperomia tetraphylla* (Forster.) Hook. & Arn.	Piperaceae	Herb
117	*Phaulopsis imbricata* (Forssk.) Sweet	Acanthaceae	Herb
118	*Pittosporum viridiflorum* Sims	Pittosporaceae	Shrub
119	*Phonix reclinata* Jacq.	Araceae	Tree
120	*Phyllanthus ovalifolius* Forssk.	Euphorbiaceae	Herb
121	*Pilea rivularis* Wedd.	Urticaceae	Herb
122	*Piper capense* L.f.	Piperaceae	Herb
123	*Plantago palmata* Hook.f.	Plantaginaceae	Herb
124	*Poecilostachys oplismenoides (Hack.)* W. D*. Clayton*	Poaceae	Herb
125	*Polygonum nepalense* Meisn.	Polygonaceae	Herb
126	*Polyscias fulva* (Hiern) Harms	Araliaceae	Tree
127	*Pouteria adolfi-friederici* (Engl.) Baehni	Sapotaceae	Tree
128	*Premna schimperi* Engl.	Verbenaceae	Shrub
129	*Prunus africana (Hook. f.)* Kalkm*.*	Roseaceae	Tree
130	*Psychotria orophila* Petit	Rubiaceae	Shrub
131	*Pteris pteridioides* (Hook.) ballard	Pteridaceae	Herb
132	Pycnostachys eminii Gurke,	Lamiaceae	Shrub
133	*Rhamnus prinoides* L'Herit.	Rhamnaceae	Shrub/Tree
134	*Rinorea friisii M. Gilbert*	Violaceae	Tree
135	*Rothmannia urcelliformis* (Hiern) Robyns	Rubiaceae	Tree
136	*Rubus apetalus* Poir.	Roseaceae	Shrub
137	*Rubus steudneri* Schweinf.	Roseaceae	Liana
138	*Rytignia neglecta* (Hiern) Robyns	Rubiaceae	Shrub
139	*Scadoxus multiflorus (Martyn) Raf'*	Amarylidaceae	Herb
140	*Sapium ellipticum* (Krauss) Pax.	Euphorbiaceae	Tree
141	*Schefflera abyssinica* Harms	Araliaceae	Tree
142	*Selaginella kalbreyeri* Bak.`	Selaginellaceae	Herb
143	*Setaria megapbylla (Steud.) Th. Dur. &* Schinz	Poaceae	Herb
144	*Sida collina Schlechtend.*	Malvaceae	Herb
145	*Stellaria mannii Boolc.,*	Caryophylaceae	Herb
146	*Stephania abyssinica* (Dill & A. Rich.) Walp	Menispermaceae	Herb
147	*Syzygium guineense* (Willd.) DC.	Myrtaceae	Tree
148	*Teclea nobilis* Del.	Rutaceae	Shrub/Tree
149	*Thalictrum rhynchocarpum* Dill. & A. Rich	Ranunculaceae	Herb
150	*Tiliacora troupinii* Cuf.	Menispermaceae	Liana
151	*Trema orientalls (L) Blo,*	Ulmaceae	Tree
152	*Trilepisium madagascariense* DC.	Moraceae	Tree
153	*Tristemma mauritianum* J. F. Gmel	Melistostomaceae	Herb
154	*Urera hypselodendron (A. Rich.) Wedd.,G*	Urticaceae	Herb
155	*Vepris dainellii* (Pich.-Serm.) Kokwaro	Rutaceae	liana

Appendix I. Contd.

156	*Vernonia amygdalina* Del.	Asteraceae	Tree
157	*Vernonia auriulifera* Hiern	Asteraceae	Shrub/Tree
158	*Vernonia hochstetteri Sch*. Bip. ex Walp	Asteraceae	Shrub/Tree
159	*Vernonia filigera* Oliv. & Hiern	Asteracea	Herb
160	*Vittaria guineensis* Desv	Vittariaceae	Herb