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Plant community analysis and effect of environmental factors on the diversity of woody species in the moist Afromontane forest of Wondo Genet, South Central Ethiopia

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Abstract: Floristic diversity and the composition of vascular plants are described for the moist Afromontane forest (MAF) of Wondo Genet, south-central Ethiopia. A total of 75 (20 x 20 m) quadrats were sampled and data on species identity, abundance, elevation, slope and aspect were recorded. Different diversity indices and ordination techniques were used to analyze the data. A total of 240 plant species including seven endemic plant species were found representing 94 families and 210 genera, of which trees constitute 23.8%, shrubs 25%, herbs 35%, lianas 11.3% and ferns 5%. Cluster and indicator species analyses revealed five plant communities described as: *Teclea nobilis-Calpurnia aurea*, *Erythrococca trichogyne-Millettia ferruginea*, *Croton macrostachyus-Vernonia hochstetteri*, *Protea gaguedi-Rhus retinorrhoea* and *Dodonaea angustifolia-Hypericum quartinianum*. Elevation (R^2=0.48, P<0.001), slope (R^2=0.14, P<0.001) and aspect (R^2=0.04, P<0.01) correlated significantly and negatively with species richness, whereas only elevation (R^2=0.30, P<0.001) and slope (R^2=0.13, P<0.001) related significantly and negatively with abundance. Sørensen's similarity coefficient indicates that the forest of Wondo Genet is similar to moist montane forests of southwestern and southeastern Ethiopia. Given the high diversity, coupled with the existence of endemic species, ecosystem conservation and restoration strategies with further research are warranted.

Key words: Ethiopia, plant community, species richness, Afromontane forest

1. Introduction

Ethiopia is endowed with diverse vegetation types ranging from high altitude Afroalpine vegetation in the central highlands to arid lowlands in the East, and rainforests in the West. The altitude of Ethiopia ranges from 125 m b.s.l. to 4533 m a.s.l. and it possesses more land above 2000 m than any other country in Africa (Friis *et al.* 2010). The highlands that host most of the afromontane vegetation are divided into the Western and Eastern highlands by the East African Rift Valley (Friis *et al.* 2010). The country has the fifth largest flora in Africa and tremendous floristic diversity, with an estimated 6,500-7,000 species of higher plants of which about 12% are endemic (Gebre-Egziabher 1991; Vivero *et al*. 2006). According to Friis *et al.* (2010), there are twelve major vegetation types in Ethiopia, some of these divided into subtypes: (1) Desert and semi-desert scrubland (DSS); (2) *Acacia-Commiphora* woodland and bushland (ACB); (3) Wooded grassland of the Western Gambella Region (WG); (4) *Combretum-Terminalia* woodland and wooded grassland (CTW); (5) Dry evergreen Afromontane Forest and grassland complex (DAF); (6) Moist evergreen Afromontane Forest (MAF); (7) Transitional Rain Forest (TRF); (8) Ericaceous Belt (EB); (9) Afro-Alpine belt (AA); (10) Riverine Vegetation (RV); (11) Freshwater Lakes, lakeshores, swamps and floodplains Vegetation (FLV); and (12) Salt-water Lakes, lake shores, salt marshes and pan Vegetation (SLV).

Topographic and altitudinal variation in Ethiopian landscapes has influenced the existence of varied vegetation types and floristic diversity. Several authors have reported that there is a correlation between floristic composition and diversity and environmental gradients, such as elevation, slope and aspect (Smith & Huston 1989; Bale *et al.* 1998; Senbeta & Manfred 2006; Yimer *et al.* 2006; Fontaine *et al.* 2007; Woldemariam Gole *et al.* 2008; Sharman *et al.* 2009). An altitudinal gradient has an effect on diversity of plant species, which creates variation in climatic pattern and soil differentiation (Lomolino 2001). Studies show that elevation, slope, and aspect are determinants for the spatial and temporal distribution of factors such as radiation, precipitation, and temperature that influence species composition (Albert & Christian 2007). Geographic and climatic conditions change sharply with altitude (Kharkwal *et al.* 2005) and vegetation in mountain regions responds to small-scale altitude variation (Bale *et al.* 1998). Similarly, Ovales and Collins (1986) evaluated soil variability across landscapes in two contrasting climatic environments and concluded that topographic position and variation in soil properties were significantly related. In the South-eastern Ethiopian highlands, it has also been studied that in addition to topographic aspect, plant community types are influenced by the physical and chemical properties of the soil (Yimer *et al.* 2006). Topographic aspect has long been known as a potentially significant factor in generating differences in ecosystem characteristics (Bale & Charley 1994; Bale *et al.* 1998). Its impacts are various due to its compound character, potentially encompassing external variables such as solar radiation (Holland & Steyne 1975) and cloud cover (Smith 1977). Primary impacts of aspects are expressed through regulating energy budgets and site moisture relationships.

Wondo Genet forest, where this study was conducted, is classified as Moist evergreen Afromontane Forest (Friis *et al.* 2010). In the 1970s, one of the major areas with remnant high forests was the South-central Rift Valley of Ethiopia, including Shashemene, Wondo Genet, and parts of Sidama (Chaffey 1979). The Wondo Genet forest is an upstream forest within the Hawassa watershed, in which over half a million people live (Dessie & Kleman 2007). Like most other forests in the country, Wondo Genet forest is experiencing a large scale deforestation. This forest is severely threatened by heavy anthropogenic disturbance and has declined from 16% of the catchment land area to 2.8%, within the past three decades alone, mainly driven by the expansion of small-scale agriculture, commercial farms and logging. In the decline of the Wondo Genet forest area, two major modes of change were observed: 1) internal, that is, openings created by small farm plots, grazing lands, and villages; and 2) external, that is, expansion of agriculture frontier from the exterior into the forests (Dessie & Kleman 2007). The valleys and mountain slopes of the Wondo Genet escarpment are very heterogeneous and rendered spatially variable plant communities. Analysis and evaluation of the spatial gradients is, therefore, essential to understand the factors affecting species richness, species abundance and plant community types and their distribution (Tesfaye *et al.* 2008).

Several authors have published the results of Ethiopian plant community investigations (Bekele 1994; Woldemariam Gole *et al.* 2008; Soromessa *et al.* 2004; Aerts *et al.* 2006; Senbeta & Manfred 2006; Lulekal *et al.* 2008; Didita *et al.* 2010) that have shown a connection of plant community distribution with variation in environmental gradients. Understanding of vegetation composition, diversity of species and their habitats, and comparison with similar other habitats (Afromontane forests), may become a tool to estimate the level of adaptation to the environment. Information on floristic composition, diversity and their relationship with their environment is essential in understanding the forest dynamics. Conservation and management of the forest resources also requires data on plant species diversity and the forest communities in order to check out necessary actions for restoring and rehabilitating this forest. In the face of fast rate of deforestation and degradation, there is an urgency to generate information and assist national and regional action towards maintenance of this forest.

The effect of topographic factors and altitude on species richness, abundance and plant community distribution has not been studied in this forest so far. The objectives of the present study are to: (*i*) describe species richness, abundance and plant community types of Wondo Genet Afromontane forest (*ii*) ascertain the pattern of species richness and abundance with elevation, slope and aspect, and (*iii*) carry out floristic similarity (Sørensen's) comparison of the Wondo Genet forest with other Afromontane forests of Ethiopia and Afromontane forests of Mafi in Tanzania and Mt. Elgon in Kenya.

We hypothesize that for the range of altitude and slope studied, floristic diversity increases with altitude, while it decreases with slope steepness, and this is dictated mainly by the moisture gradient.

2. Materials and methods

2.1. Study site

Wondo Genet is situated in the southeastern central highlands of Ethiopia, about 263 km from Addis Ababa, at 7°5'30''N to 7°7'40''N latitude and 38°36'55''E to 38°39'00''E longitude on the eastern slope of the Rift Valley escarpment (Fig. 1). The large-scale physiographic setting is defined by a tectonic depression bounded by steep escarpments. The floor of the depression is covered by lakes, wetlands and alluvial

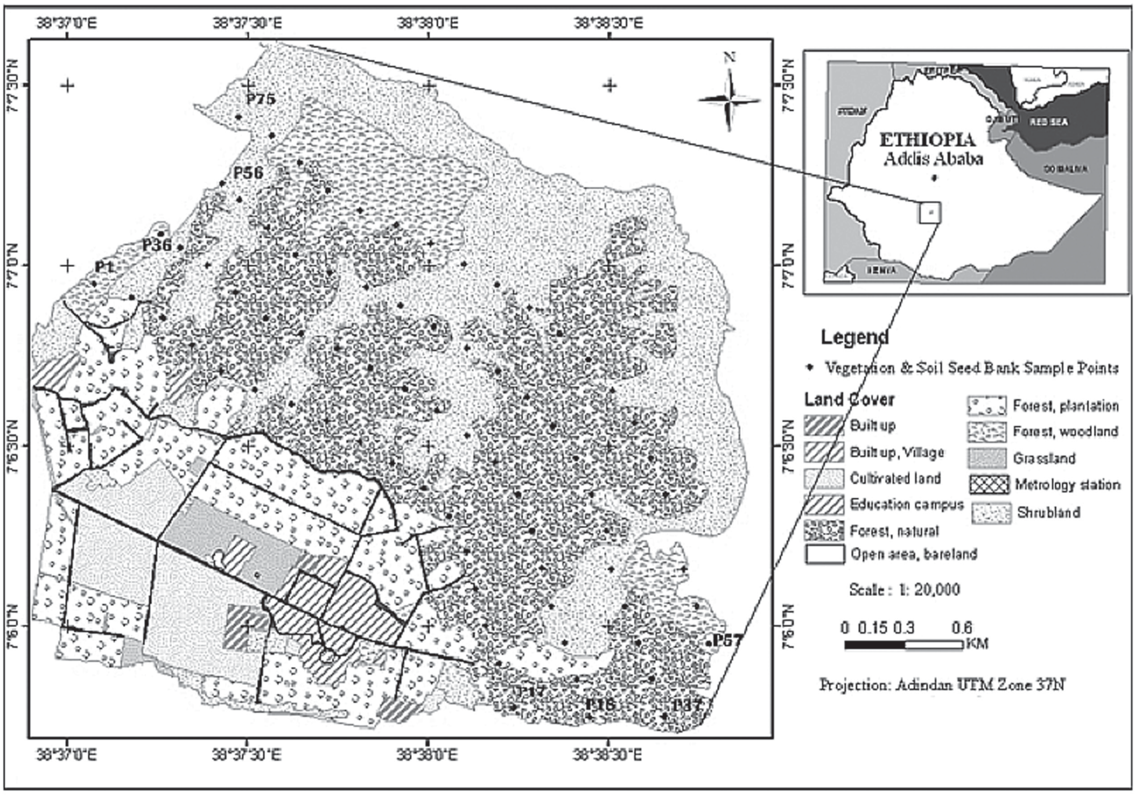

Fig. 1. Location map of the study site and sample quadrats (P) and transects (first transect goes from quadrat P1 to P17, second from P18 to P36, third from P37 to P56 and fourth from P57 to P75)

plains, which together cover half of the watershed. The remaining half consists of uplands and escarpments with slopes varying between 8 and 85 degrees. The altitude ranges from 1800-2500 m a.s.l. The mean annual rainfall is about 1200 mm and it is bimodal. Rain can be expected from March to April and June to August. The period from November to February is relatively dry. The mean monthly temperature ranges from 19°C in August to 25°C in March, April, May and September. The soils are young and of volcanic origin, characterized by well-drained loam or sandy loam, and they are shallow at steep convex slopes, but deeper at lower altitudes (Eriksson & Stern 1987). The valley floor is partly covered by lake deposits rich in plant nutrients. On higher ground the texture is sandy or silty, while clay dominates around the wetlands. The current land use is predominantly smallholder agriculture with an average landholding size of less than one hectare per household. The major crops include enset, khat, sugarcane, maize and potatoes. Wondo Genet is agriculturally fertile, with irrigation farming dominating in the flat and undulating sites. The Wondo Genet forest is the partly fragmented remnant of a formerly larger and more coherent forest covering the eastern rift flank (Dessie & Kleman 2007). It harbors important and rare fauna and flora, and provides watershed, ecosystem, economic, research, and educational services. The population of the Wondo Genet is composed of six main ethnic groups consisting of about half a million people (Dessie & Kleman 2007).

2.2. Data collection

Systematic plot sampling was conducted in May 2010 in four transects and 75 quadrats of 20x20 m. Many researchers have used similar sample sizes and shapes in the different Afromontane forests in Ethiopia (Bekele 1994; Tadesse & Nigatu 1996; Teketay 1997; Senbeta & Teketay 2003; Senbeta & Manfred 2006; Woldemariam Gole *et al.* 2008). The first quadrat was located randomly and, afterwards, the quadrats were established at 100 m intervals along transects. Transects were spaced 350 m apart. In each quadrat, all species with DBH (Diameter at Breast Height) ≥2 cm and height ≥2 m were identified and counted. Diameter was measured using a caliper, and a diameter tape was used, when a tree was larger than what a caliper could measure. A Suunto clinometer was used to measure tree height. The presence of epiphytes, herbs, grasses, sedges and ferns was recorded for a floristic compilation. Vernacular names of species mainly in Oromiffa and Sidama local languages in the Wondo Genet area were provided by the key informants. Plant identification was done in the National Herbarium, Addis Ababa University. Nomenclature followed published guidelines of the Flora of Ethiopia and Eritrea (Hedberg & Edwards 1989, 1995; Edwards *et al.* 1995, 1997, 2000; Hedberg *et al.* 2003). Environmental parameters including slope (using clinometers), elevation (Garmin GPS-72 cross-checked with altimeter), exposition (using Silva compass), and coordinates (using GPS-72) were measured on a plot basis.

2.3. Data analysis

Species diversity, cluster analysis, ordinations and phytogeographic comparison methods have been employed to analyse the data. Each of these methods is described in detail below.

2.3.1. Diversity and cluster analysis

Species diversity was measured using Shannon diversity (H'), H'max, and Shannon evenness (J'), Simpson index (D) and Simpson evenness indices (Magurran 2004).

Hierarchical cluster analysis of the data was done using PC-ORD for Windows version 5 created by McCune and Mefford (2006). Species abundance data was used as input. The Relative Euclidean Distance developed by McCune and Grace (2002) with Ward's method (hierarchical grouping = minimum variance grouping) was used in order to minimize increases in the error sum of squares. The identified groups were tested for the hypothesis of no difference between two or more groups of entities using Multiple Response Permutation Procedure (MRPP) technique. Moreover, species indicator values were calculated following Dufrene and Legendre (1997). Indicator species analysis was used to contrast performance of individual species across two or more groups of samples. Indicator values are measures of faithfulness (closeness) of occurrence of a species in a particular group and ranges from zero (no indication) to 100 (perfect indication). The statistical significance of the indicator values were tested using Monte Carlo technique. The P-value is based on the proportion of randomised trials with indicator value equal to or exceeding the observed indicator value. In the present analysis, a species with a significant indicator value of $P<0.05$ is considered to be an indicator species of a community (group). The community types were named after two of the species that had indicator values of $P<0.05$.

2.3.2. Ordinations

Ordination was also computed using a Nonmetric Multidimensional Scaling (NMDS). The species abundance and environmental matrices containing elevation (meters a.s.l.), slope (%), and aspect were used for the ordination. Aspect was measured in degrees and converted to scales from zero to one, following the formula (1-cos (Ø-45)/2, where Ø is aspect in degrees, East of true North, with zero value indicating the coolest slope (northwest) and one – the warmest slope (southeast). Data analysis was based on Nonmetric Multidimensional Scaling (NMDS) technique using Sørensen distance measure. The main advantages of NMDS are following: (1) it avoids the assumption of linear relationship among variables; (2) its use of ranked distances tends to linearize the relationship between distances measured in species space and distances in environmental space; (3) it allows the use of any distance measure or relativization.

Gradient analyses were done by employing PC-ORD version 5.0 (McCune & Mefford 2006). NMDS was run on the log-transformed abundance data using "Autopilot" mode, relative Euclidean distance measure, six starting dimensions, 50 iterations and instability criterion of 10^{-5}. To test for concordance between environmental variables and the NMDS dimension, Spearman rank correlation coefficients were calculated. Monte Carlo test was performed to evaluate whether NMDS extracts stronger axes than expected by chance. To check for the influence of linear regression of environmental gradient on species richness and abundance, "Tree Diversity Analysis software" R-Software (Kindt & Coe 2005) was used, whilst Pearson's critical value was considered to check the significance level.

2.3.3. Phytogeographic comparison

A similarity analysis was carried out to evaluate the relationship between the forests based on the presence of trees and shrubs. Evaluation was conducted using the Sørensen index (Sørensen's similarity coefficient):

$$Ss = 2a/2a+b+c$$

where: *a* – number of species common to both forests, *b* – number of species found only in one forest (here, in Wondo Genet) but absent in the forest under comparison and *c* – number of species present in the other forest but not in Wondo Genet Forest, and *N* – number of species entered for comparison.

Species data where retrieved from the publications: Ethiopia; Jibat, Chilimo, Menagesha and Wofwasha (Bekele 1994), Mena Angetu (Lulekal *et al.* 2008), Yayu (Woldemariam Gole *et al.* 2008); Mafi in Tanzania (Lyaruu *et al.* 2000) and Mt. Elgon in Kenya (Hitimana *et al.* 2004).

3. Results

3.1. Floristic composition

A total of 240 plant species (herbs, lianas, shrubs, and trees) were identified from the studied quadrats in the Afromontane natural forest of Wondo Genet (Appendix 1). The identified species belong to 94 families and 210 genera, including 8 pteridophyte families, one gymnosperm family, 10 monocotyledon and 75 dicotyledon families. The family with the highest species richness was Asteraceae (17 genera, 22 species), followed by Poaceae (15 genera, 16 species), Fabaceae (12 genera, 13 species), Lamiaceae (10 genera, 10 species), Rubiaceae (9 genera, 9 species), Orchidaceae (7 genera, 7 species) and Euphorbiaceae (6 genera, 6 species). The ten families with the highest species richness contributed 41.25% of the total species and 41.9% of the total genera. In comparison, the 20 families with the highest species richness contributed 55.41% of the total species and 55.71% of the total genera. With respect to plant life forms, trees account for 23.75%, shrubs 25%, herbs 35%, lianas 11.25% and ferns 5% of the species recorded. Species like: *Aeollanthus abyssinicus* Hochst. ex Benth*, Droguetia iners subsp. pedunculata* Schweinf*, Millettia ferruginea* Hochst*, Phragmanthera macrosolen* (Steud. ex A. Rich.) M.G. Gilbert*, Solanecio gigas* (Vatke) C. Jeffrey*, Tiliacora troupinii* Cufod.*,* and *Vepris dainellii* (Pic. Serm.) Kokwaro, which are endemic to Ethiopia, were also recorded in this forest and constitute 2.9% of the total species recorded. The IUCN Vulnerable species *Prunus africana* (Hook. f.) Kalkman also inhabits this forest

3.2. Plant community types and the indicator species

Five plant communities (clusters) (Fig. 2) with their indicator species (Table 1) were identified for the forest. The communities identified were: *Ackokanthera schimperi – Calpurnia aurea* community, *Erythrococca trichogyne – Millettia ferruginea*, *Croton macrostachyus – Vernonia hochstetteri*, *Protea gaguedi – Rhus retinorrhoea* and *Dodonaea angustifolia Hypericum quartinianum*. Ten combinations of pair-wise T-test comparisons were conducted and showed a significant difference (P<0.001). From the analyses, the

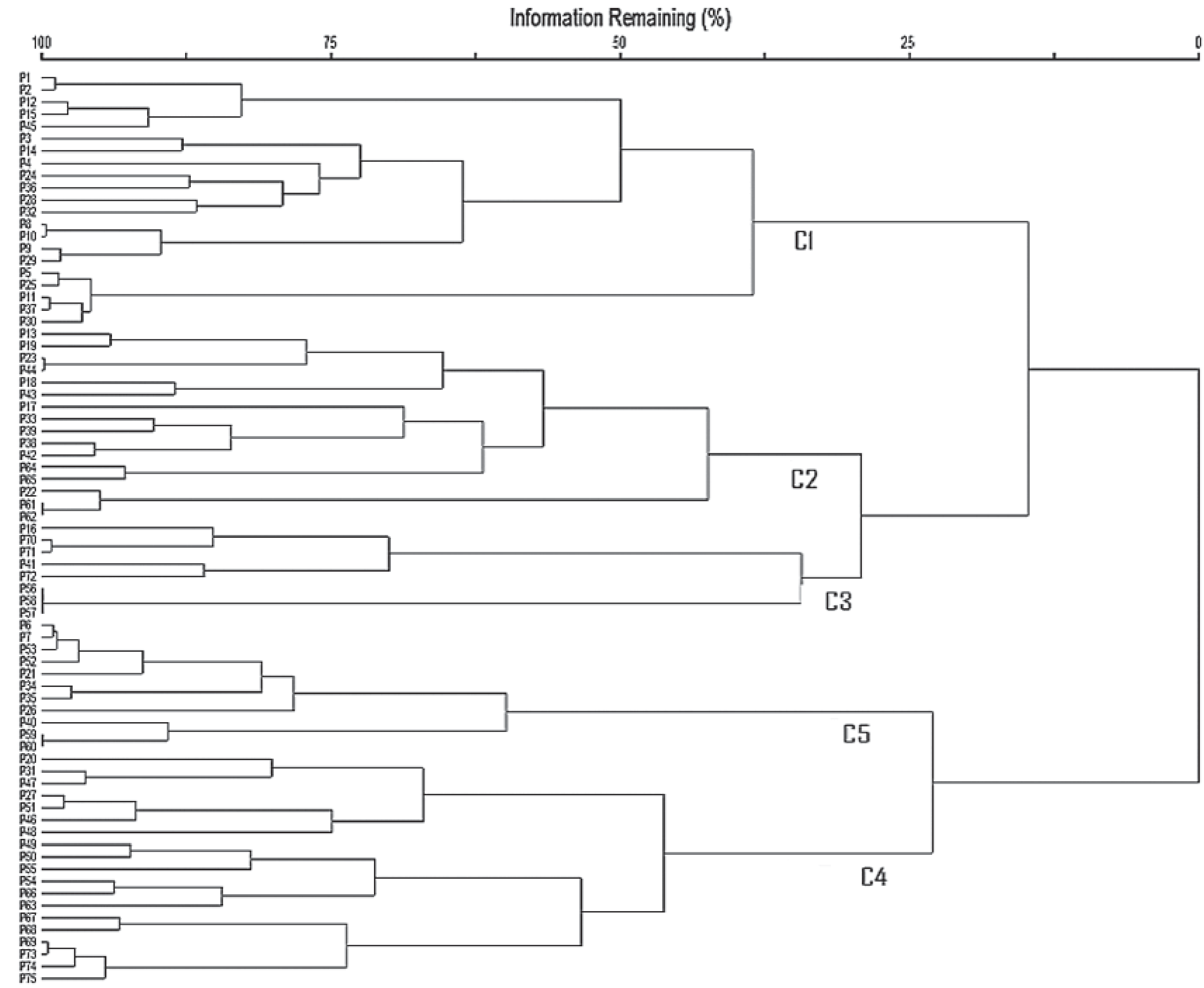

Fig. 2. Dendrogram of the cluster analysis of species abundance of 72 tree and shrub species found in 75 quadrats (plots). The level of grouping was based on 50 to 30% of information remaining (similarity). The quadrat codes and their arrangment along the dendrogram from top to bottom are as follows: **C1**: 1, 2, 12, 15, 45, 3, 14, 4, 24, 36, 28, 32, 8, 10, 9, 29, 5, 25, 11, 37, 30; **C2**: 13, 19, 23, 44, 18, 43, 17, 33, 39, 38, 42, 64, 65, 22, 61, 62; **C3**: 16, 70, 71, 41, 72, 56, 58, 57, 6, 7; **C5**: 53, 52, 21, 34, 35, 26, 40, 59,60; **C4**: 20, 31, 47, 27, 51, 46, 48, 49, 50, 55, 54, 66, 63, 67, 68, 69, 73, 74, 75

Table 1. Results of the indicator species analysis

Species	Probability	1	2	3	4	5
Community I						
Teclea nobilis	0.0002	83	3	0	0	0
Calpurnia aurea	0.0002	82	2	0	1	0
Acokanthera schimperi	0.0002	68	0	1	0	0
Flacourtia indica	0.0002	45	0	0	0	0
Diospyros mespiliformis	0.0002	55	3	2	1	3
Allophylus macrobotrys	0.0002	53	2	1	0	0
Pittosporum viridiflorum	0.0008	40	2	0	0	0
Celtis africana	0.0012	50	19	7	2	0
Cassipourea malosana	0.0024	42	22	0	1	0
Chionanthus mildbraedii	0.0036	41	2	0	0	0
Maytenus arbutifolia	0.0114	40	0	17	8	6
Coffea arabica	0.0134	33	9	1	0	0
Diospyros abyssinica	0.0212	24	2	2	0	0
Afrocarpus falcatus	0.0262	28	1	0	2	20
Grewia ferruginea	0.0336	22	0	1	0	0
Canthium oligocarpum	0.0630	26	1	1	0	10
Acanthus eminens	0.2152	10	0	0	0	0
Prunus africana	0.2523	8	0	3	0	0
Clutia lanceolata	0.2581	10	0	2	1	0
Psydrax schimperiana	0.2831	13	0	7	3	0
Community II						
Erythrococca trichogyne	0.0002	11	58	0	0	0
Millettia ferruginea	0.0002	1	54	1	0	0
Vepris dainellii	0.0004	6	61	0	0	0
Pouteria adolfi-friedericii	0.0010	2	46	0	1	0
Dracaena afromontana	0.0026	0	33	0	0	0
Olea capensis subsp. *welwitschii*	0.0026	18	41	1	0	0
Lepidotrichilia volkensii	0.0122	0	27	1	0	0
Cordia africana	0.0366	0	18	3	0	0
Dracaena steudneri	0.0428	1	23	9	0	0
Fagaropsis angolensis	0.0604	15	24	0	0	0
Ehretia cymosa	0.0830	0	12	0	0	0
Allophylus abyssinicus	0.1120	0	15	1	0	0
Albizia schimperiana	0.1254	17	23	10	0	1
Ficus sur	0.3873	0	7	3	1	0
Oxyanthus speciosus	0.4325	1	12	7	0	0
Ficus vasta	0.4827	0	6	0	0	0
Community III						
Croton macrostachyus	0.0002	1	6	59	0	1
Vernonia hochstetteri	0.0002	0	2	43	0	0
Vernonia auriculifera	0.0008	0	1	48	0	0
Bersama abyssinica	0.0056	1	12	38	0	0
Clerodendrum myricoides	0.0764	4	0	19	1	8
Maesa lanceolata	0.1036	0	0	19	12	3
Carissa spinarum	0.1362	4	0	13	0	3
Maytenus undata	0.2468	0	0	10	0	0
Entada abyssinica	0.2627	0	0	10	0	0
Acacia abyssinica	0.4395	0	0	6	0	4
Oncoba spinosa	0.5073	0	4	8	0	0
Hypericum revolutum	0.6255	5	0	9	2	7
Ekebergia capensis	0.7057	6	0	7	0	1
Polyscias fulva	0.9654	3	3	4	2	0
Community IV						
Protea gaguedi	0.0014	1	0	3	37	1
Rhus retinorrhoea	0.0030	0	0	3	35	5
Myrsine africana	0.0176	2	0	8	34	23
Buddleja polystachya	0.0402	0	0	18	29	27
Abutilon bidentatum	0.1140	0	0	6	16	0
Osyris quadripartita	0.1364	0	0	19	21	10

Species	Probability	1	2	3	4	5
Premna schimperi	0.7634	7	0	3	8	4
Steganotaenia araliacea	0.9678	0	0	3	4	0
Community V						
Dodonaea angustifolia	0.0004	0	0	7	1	61
Hypericum quartinianum	0.0008	0	0	0	3	35
Syzygium guineense subsp. *guineense*	0.0046	0	0	5	10	36
Rhus vulgaris	0.0064	0	0	10	29	36
Olea europaea subsp. *cuspidata*	0.0066	1	0	5	3	29
Schrebera alata	0.0122	9	0	2	1	31
Erica arborea	0.0174	0	0	0	16	25
Nuxia congesta	0.0226	2	0	4	2	24
Olinia rochetiana	0.0834	0	0	5	0	16
Syzygium guineense subsp. *macrocarpum*	0.1206	0	0	0	0	11
Ficus thonningii	0.2895	0	1	0	0	9
Phoenix reclinata	0.3439	0	6	0	0	9
Combretum molle	0.3507	6	0	7	7	15
Apodytes dimidiata	0.5041	1	0	3	0	6

T-value statistic for the five groups is -27.07 (P<0.001), while the A statistic (chance corrected for within-group agreement) is 0.554. The T-test statistic describes the separation between groups. The A statistics describes within-group homogeneity and falls between 0 and 1. When the items are identical, A=1. In community ecology, values of A are commonly below 0.1. The groups vary in size, ranging from 8 to 21 plots per group. The results of the indicator species analyses determine the degree to which species are associated with the different groups (i.e., communities). Each group has 3-4 indicator species with significant indicator values. In this analysis, a plant species with a significant indicator value at P<0.05 is considered an indicator species of the community. Pair wise comparison of the communities analysed using MRPP indicated T-values ranging from -7 to -20 (P<0.001).

Community I (*Ackokanthera schimperi – Calpurnia aurea*) has twenty species and was found in 21 quadrats (28%). This forest community is the largest, mainly found between the altitudinal ranges of 1880-1990 m a.s.l., mostly, along the natural forest boundary with other land use areas. This community is mainly found along the north-western facing slopes. The slope gradient varies from 18-45%. The community has ten indicator species with significant indicator values (*P<0.001*); namely, *Ackokanthera schimperi* Oliv, *Calpurnia aurea* Benth, *Flacourtia indica* (Burm.f) Merr., *Diospyros mespiliformis* Hochst. *ex A.DC, Teclea nobilis* Delile and *Allophylus macrobotrys* Gilg.

Community II (*Erythrococca trichogyne – Millettia ferruginea*) comprised sixteen species and sixteen quadrats. This forest community is mainly found between the altitudinal ranges of 1990-2050 m a.s.l. and is mostly distributed along the north-western facing slopes. The slope gradient varies from 15-50%. The community has 9 indicator species with significant indicator values. These are: *Erythrococca trichogyne* Prain., *Millettia ferruginea, Vepris dainellii, Pouteria adolfi-friedericii* (Engl.) Baehni, *Dracaena afromontana* Mildbr., *Olea welwitschii* Gilg & Schellenb., *Lepidotrichilia volkensii* (Güerke) J.-F. Leroy, *Cordia africana* Lam., and *Dracaena steudneri* Engl. The tree species that are illegally and selectively logged for their timber, namely, *Cordia africana* and *Pouteria adolfi-friedericii,* and the endemic tree species *Millettia ferruginea* and *Vepris dainellii* are found in this community.

Community III (*Croton macrostachyus – Vernonia hochstetteri*) is represented by fourteen species and ten quadrats. This forest community is mainly found between altitudinal ranges of 1990-2280 m a.s.l., and is mostly distributed along the south-eastern facing slopes. The slope gradient varies from 20-50%. The community has 4 indicator species with significant indicator values, namely, *Croton macrostachyus* Hochst. ex Delile, *Vernonia hochstetteri* Sch. Bip. ex Hochst, *Vernonia auriculifera* Hiern and *Bersama abyssinica* Fresen.

Community IV (*Protea gaguedi – Rhus retinorrhoea*) is represented by eight species and was found in nine quadrats. The community has 4 indicator species with significant indicator values; namely, *Protea gaguedi* J. F. Geml., *Rhus retinorrhoea* Steud. ex Oliv., *Myrsine africana* L. and *Buddleja polystachya* Fresen. This forest community is mainly found between altitudinal ranges of 2200-2400 m a.s.l. and along the south-eastern facing slopes. The slope gradient varies from 50-70%.

Community V (*Dodonaea angustifolia – Hypericum quartinianum*) is the second largest community spread over nineteen quadrats and represented by fourteen species. This community has eight indicator species with significant indicator values. The indicator species are: *Dodonea angustifolia* L. f., *Hypericum quartinianum* A. Rich., *Syzygium guineense* subsp. (Willd.) DC *macrocarpum* Engl. *macrocarpum, Rhus vulgaris* Meikle, *Olea europea* subsp. *cuspidata* (Wall. ex G. Don) Cif., *Schrebera alata* Welw., *Erica arborea* L. and *Nuxia congesta* R. Br.. This forest community is mainly found between the altitudinal ranges of 2050-2150 m a.s.l. and along the south-eastern facing slopes. The slope gradient varies from 35-60%.

3.3. Species diversity, richness and evenness of the woody plant communities

The overall Shannon-Wiener diversity and evenness of the woody species in the studied forest were 3.63± 0.438 and 0.84±0.10, respectively. The overall values indicate that the diversity and evenness of the woody species is relatively high (Table 2). Apparently, communities II, III, and IV had the highest species diversity, while communities I and V – the lowest.

3.4. Ordination

In the NMDS ordination, the greatest reduction in 'stress' achieved was 14.71 with a three-dimensional solution and final instability of $1x10^{-5}$. The proportions of variance represented by the three axes were 0.288, 0.238 and 0.084, respectively (cumulative r=0.61). Species richness had a significant correlation with AXIS 1 (r=0.229, P<0.05) and AXIS 3 (r=0.567, P<0.01). Species abundance had a significant correlation with AXIS 3 (r=0.400, P<0.01).

Elevation had the strongest significant correlation with AXIS 3 (r=0.768, P < 0.01), AXIS 2 (r=0.332, P<0.01) and AXIS 1 (r=0.281, P<0.05). Slope had significant correlation with AXIS 2 (r=0.354, P<0.01), AXIS 1 (r=0.278,

Table 2. Species richness, diversity indices and evenness of plant community types

Community	Elevation	Species richness	Shannon diversity (H')	H' Max	Evenness (J)	Simpson
I	1800-2000	51 (6.51)	2.890 (0.44)	3.95	0.730 (0.11)	0.900 (0.12)
II	1850-2000	44 (4.19)	3.026 (0.44)	3.78	0.800 (0.10)	0.932 (0.12)
III	1900-2200	61 (7.67)	3.200 (0.42)	4.11	0.778 (0.08)	0.931 (0.07)
IV	2200-2400	45 (3.64)	3.017 (0.39)	3.61	0.793 (0.07)	0.926 (0.09)
V	2050-2150	37 (4.35)	2.836 (0.43)	3.80	0.785 (0.11)	0.897 (0.09)
Over all	1800-2445	72 (6.04)	3.630 (0.43)	4.32	0.840 (0.10)	0.960 (0.10)

Explanation: values in bracket are standard deviations

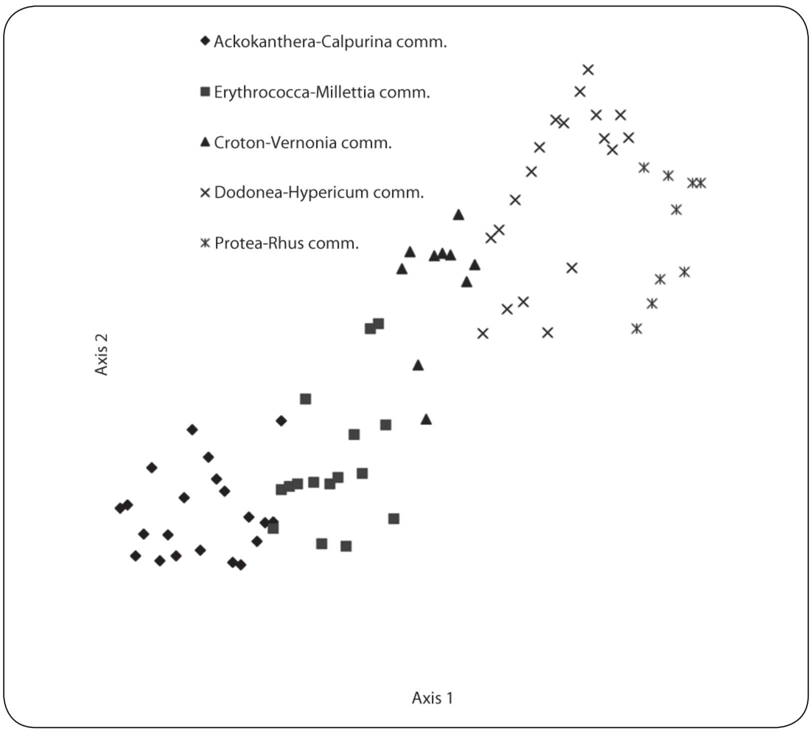

Fig. 3. Ordination based on a Nonmetric Multidimensional Analysis (NMDS) with the abundance of 72 woody species from 75 quadrats

P<0.01), and AXIS 3 (r=0.245, P<0.01). The correlation of aspect with the axes was not significant. Elevation explained 48.16% of the variation in species richness and 30.14% of species abundance. Slope explained 13.69% of the variations in species richness and 12.46% of species abundance. The percent of variation explained by aspect was quite low, 4.33% and 0.79% of the species richness and species abundance, respectively (Fig. 3).

3.5. Linear relationships of environmental variables with species richness and abundance

Both species richness (r^2=0.48, P<0.001) and abundance (r^2=0.30, P<0.001) have shown significantly negative correlation with elevation (Fig. 4a-b). In a similar way, slope was correlated with species richness (r^2=0.14, *P*<0.001) and abundance (r^2=0.13, *P*<0.001) significantly negative (Fig. 4c-d). The correlation of aspect with species richness was negatively significant (r^2=0.04, P<0.01), but its effect on abundance was not significant (Fig. 4e-f).

3.6. Phytogeographical comparison

An attempt was made to compare some Afromontane forests in Ethiopia and Eastern Africa (Tanzania and Kenya) on the basis of similarities in their species composition. Sørensen's similarity coefficient indicates

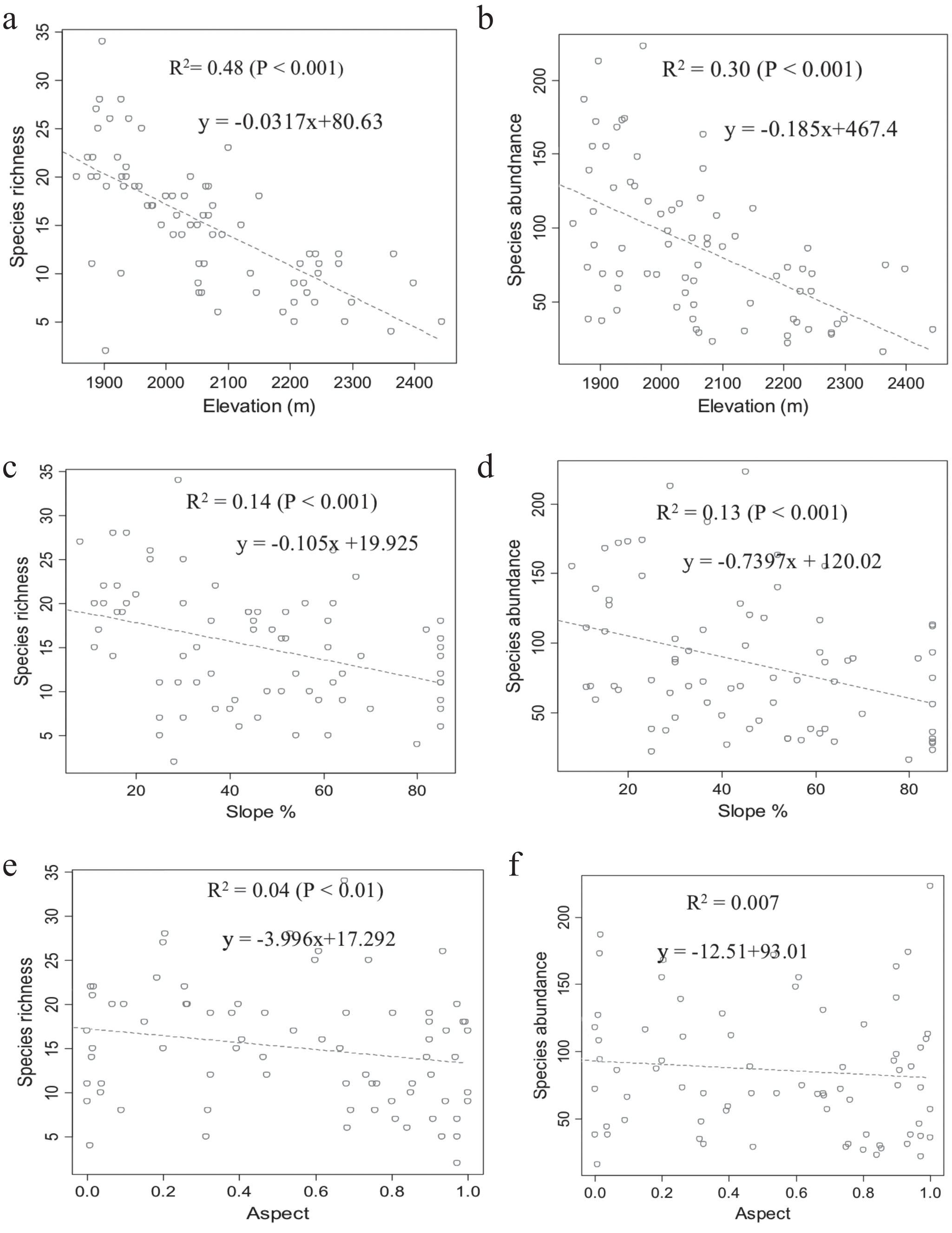

Fig. 4. Relationship between elevation (a-b), slope (c-d) and aspect (e-f) and species richness and abundance in the Wondo Genet Forest, south-central Ethiopia

Table 3. Comparison of the Wondo Genet Forest with five other Ethiopian and two Eastern African montane forests

Forest	N	a	b	c	Ss	Source
Jibat	51	35	37	16	0.56	Bekele 1994
Chilimo	31	19	53	12	0.36	Bekele 1994
Menagesha	31	16	56	15	0.31	Bekele 1994
Wof-washa	30	19	53	11	0.37	Bekele 1994
Yayu	87	33	39	39	0.45	Wodemariam Gole *et al*. 2008
Mena Angetu	117	34	38	35	0.47	Lulekal *et al.* 2008
Mafi (Tanzania)	61	13	59	48	0.19	Lyaruu *et al*. 2000
Mt. Elgon (Kenya)	51	23	49	28	0.37	Hitimana *et al*. 2004

that the studied forest is similar to moist montane forests of southwestern and southeastern Ethiopia (Table 3).

4. Discussion

The inventory presented in this study shows that the Wondo Genet forest is one of the most diverse forests in Ethiopia with respect to plant species richness. Afromontane forests of Ethiopia has been studied by several authors (Bekele 1994; Teketay 1995; Teketay & Bekele 1995; Woldemariam Gole *et al.* 2000; Friis *et al.* 1982; Friis 1992; Senbeta & Manfred 2006; Woldemariam Gole *et al.* 2008). Comparisons of the recorded species richness of the Wondo Genet forest in this study with other published studies of species richness of Afromontane forests, reveal that the level of the diversity in the studied forest is high. With about 240 species, the Wondo Genet Afromontane forest has higher species richness, than, for instance, Jibat forest with 58 species (Bekele 1994), Chilimo forest with 90 (Woldemariam Gole *et al*. 2000), Dakata forest with 202 (Teketay 1995), Bonga forest with 154 (Friis *et al.* 1982), the Harrena forest with 128 (Tadesse & Nigatu 1996) and Yayu with 220 (Woldemariam Gole *et al* 2008). However, Wofwasha forest was reported to have more than 250 species (Teketay & Bekele 1995), so presents an exceptional species richness.

With a record of seven endemic species to Ethiopia, Wondo Genet has a relatively high number compared to, for example, Yayu forest with three endemic species (Woldemariam Gole *et al.* 2008), but lower than Wofwasha, which has 29 species (Teketay & Bekele 1995). Sidamo floristic region, where this forest is located, is among the richest centers of endemism in Ethiopia (Friis *et al.* 2001). It was noted that endemic plant species account for 11-25% of Afromontane species composition (Woldemariam Gole *et al.* 2008). In general, the diverse evergreen Afromontane forests have a lower number of unique species (Friis *et al.* 2010). In this study, five new records were made for the Sidamo floristic region of the *Flora of Ethiopia and Eritrea.* These are *Rhus retinorrhoea, Dracaena afromontana, Erythrococca trichogyne, Sida tenuicarpa* and *Rubus volkensii*.

The high diversity of the Wondo Genet forest is probably the result of diverse physiographic nature of this area, with its mountain slopes, valleys and fluvial landforms, in addition to springs/river flowing from the foot of the mountains, made the vegetation unusually diverse. Several vegetation types and associated tree species occur in this forest. From, The Undifferentiated Afromontane forest (DAF/U) (Friis *et al.* 2010), which is a subtype of the Dry evergreen Afromontane forest and grassland complex (DAF), is clearly represented at Wondo Genet by characteristic species, like *Afrocarpus falcatus, Olea europea* subsp. *cuspidata, Croton macrostachyus, Allophylus abyssinicus, Apodytes dimidiata, Cassipourea malosana, Celtis africana, Millettia ferruginea, Ekebergia capensis, Lepidotrichilia volkensii, Olinia rochetiana, Prunus africana, Vepris dainellii, Teclea nobilis, Pittosporum viridiflorum, Ritchiea albersii* and *Solanecio gigas*. The higher elevation slopes of Wondo Genet harbour some elements of vegetation of the Ericaceous Belt (EB), consisting of scattered trees of *Erica arborea* and *Hypericum revolutum*. According to Friis *et al*. (2010), this is the lower limit of Ericaceous belt (EB) adjoining the Dry Afromontnae forest and grassland complex (DAF).

The moist evergreen Afromontane forest (MAF), predominantly broadleaved characteristic species like *Pouteria adolfi-friderici, Albizia schimperiana, Ficus sur, Ficus thonningii, Ekebergia capensis, Cassipourea malosana* were identified in the Wondo Genet forest. This is the vegetation type found in southwestern Ethiopia and Harrena forest in the southeast Ethiopia, in Bale Mountains (Friis *et al.* 2010). Edges of the moist evergreen Afromontane forest, bushland, woodland and wooded grassland (MAF/BW) are represented at Wondo Genet by *Acacia abyssinica, Cordia africana, Calpurnia aurea, Maesa lanceolata* and *Carissa spinarum*. The Wondo Genet forest also has the riverine vegetation (RV) type along the outlets of springs into the lower valley. In this type, such characteristic species (Friis *et al.* 2010) as *Syzygium guineense, Oncoba spinosa,* *Diospyros mespiliformis, Salix subserrata* and *Phoenix reclinata* were found in this study.

It has been suggested that different elevation and slopes influence species richness, and dispersion behaviour of tree species (Ellu & Obusa 2005). In the Yayu forest, in southwestern Ethiopia, the plant species distribution, and hence the patterns in forest vegetation are mainly influenced by the terrain gradient variables, such as altitude, slope and distance from the river banks (Woldemariam Gole *et al.* 2008). It was found that altitude was significantly and negatively correlated with density and species richness (Sharma *et al.* 2009). In the Wondo Genet forest, both species richness and abundance, hence diversity, were significantly and negatively correlated with altitude. A similar pattern for species richness and diversity was reported for the vegetation around Dello Menna in southeastern Ethiopia (Didita *et al.* 2010).

Slope was also significantly and negatively correlated with density and species richness (Sharman *et al.* 2009). Slope influences drainage, impacting soil formation processes, and chemical properties, since the soils on steeper slopes are influenced by bed rock and tend to be less moist and less acidic (Tewolde 1986, as cited in Woldemariam Gole *et al.* 2008). At Wondo Genet, slope is significantly and negatively correlated with both species richness and abundance.

Aspect-induced regime of fundamental niche characteristics, such as frost, light compensation level and permanent wilting point, enforces some sorting of species (Austin *et al.* 1990). The magnitudes of inter-aspect differences in the mean monthly temperatures were sufficient to contribute to a sorting of canopy species (Bale *et al.* 1998). At Wondo Genet, aspect has significantly influenced species richness; however, the influence of aspect on species abundance was not significant.

5. Conclusions

The Wondo Genet remnant forest contains a substantial amount of Afromontane plant species composition and diversity. The high diversity, coupled with the presence of endemic species, calls for immediate conservation strategies with the involvement of government and local communities that would lead to the restoration and rehabilitation of this remnant forest. Conserving this forest will allow to preserve refugia for many species and also retain the dispersal pool for the restoration and rehabilitation of the forest itself and the nearby degraded areas under agricultural systems.

The further detailed ecological studies concerning the species composition, diversity and distribution of the possible plant community types in relation to other environmental factors such as soil properties, moisture regime, temperature fluctuation, frost occurrence, and the like, which were not the subject of this study, will be of vital importance. Ethnobotanical studies should be conducted to harness the indigenous knowledge on the uses of plant resources contained in the forest.

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Appendix 1. List of plant species recorded in the indigenous Afromontane forest of Wondo Genet

Species	Family	Local name (Oromiffa & sidama)	Habit	Distribution type*
	A. PTERIDOPHYTA			
Doryopteris concolor (Langsd. & Fisch.) Kuhn.	Adianthaceae		H	
Asplenium bugoiense Hieron.	Aspleniaceae		H	
Asplenium mannii Hook.	Aspleniaceae		H	
Asplenium theciferum (Kunth) Mett.	Aspleniaceae		H	
Pteridium aquilinum (L.) Kuhn.	Dennstaedtiaceae		H	
Tectaria gemmifera (Fée) Alston	Dryopteridaceae		H	
Pteris catoptera Kunze	Pteridaceae		H	
Selaginella abyssinica Spring.	Selaginellaceae		H	
Pellaea viridis (Forssk.) Prantl.	Sinoperidaceae		H	
Christella chaseana (Schelpe) Holttum	Thelypteridaceae		H	
	B. GYMNOSPERMAE			
Afrocarpus falcatus (Thunb.) Mirb.	Podocarpaceae	bibirsa	T	DAF/U; MAF/P
	C. ANGOISPERMAE – MONOCTYLEDONAE			
Chlorophytum Ker Gawl.	Anthericaceae		H	
Arisaema Mart.	Araceae	adila	H	
Phoenix reclinata Jacq.	Arecaceae	zenbaba	T	DAF/WG,MAF/ P,BW,RV,FLU
Asparagus africanus Lam.	Asparagaceae	seriti	L	ACB,DAF/WG, EB
Commelina africana L.	Commelinaceae	qortobe	H	
Commelina erecta L.	Commelinaceae	qortobe	H	
Carex chlorosaccus C. B. Clarke	Cyperaceae		H	
Cyperus rigidifolius Steud.	Cyperaceae	dhalladuu	H	
Scleria bulbifera Hochst. ex A. Rich.	Cyperaceae	yetrara ser	H	
Dioscorea bulbifera L.	Discoreaceae	boroda	L	CTW, RV
Dracaena afromontana Mildbr.	Dracaenaceae	lenticho	T	DAF/U, MAF/P
Dracaena steudneri Engl.	Dracaenaceae	serte	T	DAF/U-WG, MAF/P-BW
Aerangis brachycarpa (A. Rich.) Durand. & Schinz	Orchidaceae		H	
Disperis anthoceros Rchb. f.	Orchidaceae		H	
Eulophia guineensis Lindl.	Orchidaceae		H	
Habenaria cultriformis Kraenzl. ex Engl.	Orchidaceae		H	
Nervilia crociformis Seidenf.	Orchidaceae		H	
Polystachya Hook.	Orchidaceae	digalo	H	
Pteroglossaspis eustachya Rchb.f.	Orchidaceae		H	
Andropogon distachyos L.	Poaceae	gasha	H	
Aristida adoensis Hochst.	Poaceae		H	
Brachiaria brizantha (A. Rich.) Stapf	Poaceae		H	
Brachiaria ovalis Stapf	Poaceae		H	
Cynodon dactylon (L.) Pers.	Poaceae	serdo	H	
Digitaria abyssinica (Hochst.) Stapf	Poaceae		H	
Eragrostis schweinfurthii Chiov.	Poaceae		H	
Exotheca abyssinica Andersson.	Poaceae		H	
Hyparrhenia hirta (L.) Stapf	Poaceae		H	
Ischaemum afrum (J. F.Gmel.) Dandy	Poaceae		H	
Melinis repens (Willd.) Zizka	Poaceae		H	
Oplismenus compositus (L.) P. Beauv.	Poaceae		H	
Pennisetum thunbergii Kunth	Poaceae		H	
Setaria megaphylla T. Durand & Schinz	Poaceae		H	
Sporobolus pyramidalis P. Beauv.	Poaceae	muriye	H	
Themeda triandra Forssk.	Poaceae		H	
	D. ANGIOSPERMAE – DICOCTYLEDONAE			
Acanthus eminens C. B. Clarke	Acanthaceae	anshokala	S	DAF/U,MAF/P-RV
Hypoestes Sol. ex R. Br.	Acanthaceae	dergu	H	
Justicia schimperiana T. Anderson.	Acanthaceae	dhumuga	S	DAF/WG;MAF/BW; RV
Cyathula cylindrica Moq.	Amaranthaceae	garbabo	H	

Species	Family	Local name (Oromiffa & sidama)	Habit	Distribution type*
Aerva lanata (L.) Schult.	Amaranthaceae		H	
Celosia schweinfurthiana Schinz	Amaranthaceae		H	
Rhus retinorrhoea Steud. ex Oliv.	Anacardiaceae	gagabsa	T/S	ACB,DAF/WG
Rhus vulgaris Meikle	Anacardiaceae	tateesa	T/S	ACB,CTW,DAF/WG
Alepidea longifolia E. Mey. ex Steud.	Apiaceae		H	
Heteromorpha arborescens Cham. & Schltdl.	Apiaceae		S	DAF/U-SD-WG-TR
Foeniculum vulgare Mill.	Apiaceae	insilal	H	
Pimpinella L.	Apiaceae		H	
Steganotaenia araliacea Hochst.	Apiaceae		T	ACB,CTW,DAF/WG
Acokanthera schimperi (A. DC.) Schweinf.	Apocynaceae	kararu	T	ACB;DAF/SD-TR-WG
Carissa spinarum L.	Apocynaceae	agamsa	S	ACB,DAF/U-SD,MAF/P,RV
Landolphia buchananii (Hallier f.) Stapf.	Apocynaceae	hopi	H	
Polyscias fulva (Hiern) Harms	Araliaceae	yezingero wanbar	T	MAF/P,TRF
Ceropegia L.	Asclepiadaceae		H	
Gomphocarpus phillipsiae (N. E. Br.) Goyder	Asclepiadaceae		L	
Periploca linearifolia Quart.-Dill. & A. Rich.	Asclepiadaceae	otisa	L	
Sonchus L.	Asteraceae	hato	H	
Acmella caulirhiza Delile.	Asteraceae	yemidr barbere	H	
Ageratum conyzoides L.	Asteraceae	abadebo	H	
Asplia L. M. A. A. Du Petit-Thouars	Asteraceae		H	
Athrixia rosmarinifolia Oliv. & Hiern	Asteraceae		S	DAF/WG;RV
Berkheya spekeana Oliv.	Asteraceae	qoree	H	
Bidens pilosa L.	Asteraceae	chogogit	H	
Bidens L.	Asteraceae		H	
Carduus leptacanthus Fresen.	Asteraceae	uticho	*S*	
Conyza pyrrhopappa Sch. Bip. ex A. Rich.	Asteraceae		H	
Crassocephalum Moench	Asteraceae		H	
Guizotia Cass.	Asteraceae		H	
Helichrysum schimperi Moeser	Asteraceae		S/L	
Plectocephalus varians (A. Rich.) C. Jeffrey in Cufod.	Asteraceae		H	
Solanecio angulatus (Vahl) C. Jeffrey	Asteraceae		J/S	
Solanecio gigas (Vatke) C. Jeffrey	Asteraceae	shokoko goman	T/S	DAF/U;DAF/WG; MAF/P-BW;EB
Solanecio tuberosus (Sch. Bip. ex A. Rich.) C. Jeffrey	Asteraceae		H	
Tagetes minuta L.	Asteraceae	gimal kital	H	
Vernonia auriculifera Hiern	Asteraceae	reeji	T/S	DAF/WG;MAF/BW
Vernonia brachycalyx O. Hoffm.	Asteraceae		S	CTW;DAF/WG
Vernonia hochstetteri Sch. Bip. ex Hochst.	Asteraceae		S	DAF/WG
Vernonia inulaefolia Steud.	Asteraceae		H	
Impatiens hochstetteri Warb	Balsaminaceae		H	
Cordia africana Lam.	Boraginaceae	wadessa	T	CTW,DAF/U, MAF/P-BW,TRF
Cynoglossum coeruleum Hochst. ex DC.	Boraginaceae	maxane	H	
Ehretia cymosa Thonn.	Boraginaceae	ulaga	T	DAF/U-SD-WG, MAF/P-BW, RV
Erucastrum arabicum Fisch. & C. A. Mey.	Brassicaceae	siraro	H	
Wahlenbergia abyssinica (Hochst. ex A. Rich.) Thulin	Campanulaceae		S	
Ritchiea albersii Gilg	Capparidaceae		T	DAF/U, MAF/P
Drymaria cordata Willd. ex Schult	Caryophyllaceae		L	
Hippocratea goetzei Loes.	Celastraceae	homba	L	MAF/P, TRF
Maytenus arbutifolia (Hochst. ex A. Rich) R. Wilczek	Celastraceae	kombolcha	T	DAF/U-WG
Maytenus undata (Thunb.) Blakelock	Celastraceae		T/S	DAF/U-SD;MAF/P
Combretum molle R. Br. ex. G. Don	Combretaceae	abalo	T	CTW, DAF/WG
Dichondra repens J. R. Forst & G. Forst.	Convolvulaceae	yayit joro	H	
Ipomoea kituiensis Vatke	Convolvulaceae	anano	L	DAF/WG, ACB
Kalanchoe lanceolata Pers.	Crassulaceae	hanchura	H	
Momordica foetida Schumach.	Cucurbitaceae	kire	H	
Zehneria scabra Sond.	Cucurbitaceae		L	
Diospyros abyssinica (Hiern) F. White	Ebenaceae	loko	T	DAF/U, MAF/P, TRF, RV
Diospyros mespiliformis Hochst. ex A. DC	Ebenaceae	babe	T/S	RV
Erica arborea L.	Ericaceae	asta	T/S	DAF/U-SD, EB, AA

Species	Family	Local name (Oromiffa & sidama)	Habit	Distribution type*
Croton macrostachyus Hochst. ex Delile.	Euphorbiaceae	bakanisa	T/S	CTW, DAF/U, WG, MAF/P-BW
Clutia lanceolata Forssk.	Euphorbiaceae	muka foni	S	DAF/U-SD-WG,EB
Erythrococca trichogyne Prain.	Euphorbiaceae	muka kara	T/S	MAF/P
Euphorbia schimperiana Hochst. ex A. Rich	Euphorbiaceae	bingile	H	
Phyllanthus L.	Euphorbiaceae		H	
Tragia L.	Euphorbiaceae		H	
Dalbergia lactea Vatke	Fabaceae	yagbero	S/L	DAF/U-WG,MAF/P,RV
Acacia abyssinica Hochst. ex Benth	Fabaceae	lafto	T	DAF/WG,MAF/BW
Acacia brevispica Harms	Fabaceae	ledi	L/S	ACB,DAF, WG
Albizia schimperiana Oliv.	Fabaceae	sasa	T	DAF/U-WG;MAF/P-BW;TRF
Calpurnia aurea Benth.	Fabaceae	cheqa	S	DAF/U-WG,MAF/P-BW
Crotalaria incana L.	Fabaceae	titako	H	
Desmodium repandum (Vahl.) DC.	Fabaceae		H	
Entada abyssinica Steud.	Fabaceae	ganchacha	T	CTW; DAF/WG
Eriosema (DC.) Desv.	Fabaceae	yemidr kolo	H	
Indigofera L.	Fabaceae		H	
Millettia ferruginea Hochst.	Fabaceae	birbira	T	DAF/U,MAF/P
Senna septemtrionalis (Viv.) H. S. Irwin & Barneby	Fabaceae		S	
Zollernia paraensis Huber.	Fabaceae		T	
Dovyalis verrucosa Warb.	Flacourtiaceae		T/S	DAF/U-SD,EB
Flacourtia indica (Burm.f) Merr.	Flacourtiaceae	hagala	T	ACB;DAF/U-WG;RV
Oncoba spinosa Forssk.	Flacourtiaceae	akuku	T/S	CTW, DAF/WG,RV
Geranium L.	Geraniaceae		H	
Pelargonium L'Hér.	Geraniaceae		H	
Hypericum peplidifolium A. Rich.	Hypericaceae		H	
Hypericum quartinianum A. Rich.	Hypericaceae	garamba	S	DAF/U-WG
Hypericum revolutum Vahl	Hypericaceae	garmaba	T	DAF/U;EB;AA
Hypoxis villosa L.f.	Hypoxidaceae		H	
Apodytes dimidiata E. Mey. ex Arn.	Icacinaceae	dongicho	T	DAF/U-WG, MAF/P-BW, RV
Aristea abyssinica Pax ex Engl.	Iridaceae		H	
Hesperantha petitiana Baker	Iridaceae		H	
Clerodendrum myricoides R. Br.	Lamiaceae	marachisa	S	CTW,DAF/U-SD-TR-WG
Aeollanthus abyssinicus Hochst. ex Benth.	Lamiaceae		H	
Fuerstia africana T. C. E. Fr.	Lamiaceae		H	
Leucas martinicensis (Jacq.) R. Br.	Lamiaceae		H	
Ocimum grandiflorum (Lam.) Pic. Serm.	Lamiaceae		S	ACB; DAF/WG
Ocimum lamiifolium Hochst.	Lamiaceae	chabicha	S	ACB, DAF/WG
Plectranthus punctatus L'Hér.	Lamiaceae		H	
Salvia tiliifolia Vahl.	Lamiaceae		H	
Satureja punctata (Benth.) Briq. subsp. *ovata* (Benth.) Seybold	Lamiaceae		S	
Stachys L.	Lamiaceae		H	
Buddleja polystachya Fresen.	Loganiaceae	bulancho	T/S	DAF/SD-WG;EB
Nuxia congesta R. Br.	Loganiaceae	bitana	T	DAF/U-SD-WG;MAF/P-BW;EB
Phragmanthera macrosolen (Steud. ex A. Rich.) M. G. Gilbert	Loranthaceae	tekatila	H	
Abutilon bidentatum (Hochst.) ex A. Rich.	Malvaceae	danisa	T	
Sida tenuicarpa Vollesen.	Malvaceae	chifreg	S	ACB
Dissotis Benth.	Melastomataceae		H	
Ekebergia capensis Sparrm.	Meliaceae	ononu	T	DAF/U-SD;MAF/P-BW
Lepidotrichilia volkensii (Güerke) J. -F. Leroy	Meliaceae	alayo	T	DAF/U;MAF/P;RV
Bersama abyssinica Fresen	Melianthaceae	azamir	T	DAF/U-SD-WG;MAF/P-BW;RV
Stephania abyssinica Walp.	Menispermaceae	kalala	L	
Tiliacora troupinii Cufod.	Menispermaceae	lukuta	L	DAF/U, MAF/P
Ficus sur Forssk.	Moraceae	harbu	T	DAF/U, MAF/P, TRF, RV
Ficus thonningii Blume.	Moraceae	dimbicho	T/s	DAF/U, MAF/P, TRF, RV

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Ficus vasta Forssk	Moraceae	qilxu	T	DAF/WG, RV
Embelia schimperi Vatke	Myrsinaceae	kanku	T/L	DAF/U;RV
Maesa lanceolata Forssk.	Myrsinaceae	abayi	T/S	DAF/U-SD-WG;MAF/BW;RV
Myrsine africana L.	Myrsinaceae	qacama	T/S	DAF/U;EB/AA
Syzygium guineense (Willd.) DC. subsp. guineense	Myrtaceae	dokma	T	RV, FLU/MFS
Syzygium guineense (Willd.) DC. subsp. *macrocarpum* (Engl.) F. White	Myrtaceae	dokma	T	CTW/DAF/WG
Ochna holstii Engl	Ochnaceae		T/S	DAF; MAF/P
Chionanthus mildbraedii (Gilg & G. Schellenb.) Stearn	Oleaceae	sigida dhala	T/S	DAF/U;MAF/P
Jasminum abyssinicum R.Br.	Oleaceae	xorsicho	L	DAF/U-WG
Olea europaea L. subsp. *cuspidata* (Wall. ex G. Don) Cif.	Oleaceae	waira	T	DAF/U-SD-TR-WG
Olea welwitschii (Knobl.) Gilg. & Schellenb.	Oleaceae	walincho	T	DAF/U;MAF/P
Schrebera alata Welw.	Oleaceae	dhamaye	T/S	DAF/U-SD-TR-WG
Olinia rochetiana A. Juss.	Olinaceae	nole	T	DAF/U, EB
Opilia amentacea Roxb.	Opiliaceae		L	DAF/WG, RV
Oxalis obliquifolia Steud. ex A. Rich.	Oxalidaceae	yebrechew	H	
Peperomia abyssinica Miq.	Piperaceae		L	
Peperomia tetraphylla (G. Forst.) Hook. & Arn.	Piperaceae		H	
Pittosporum viridiflorum Sims	Pittosporaceae	ara	T/S	DAF/U, MAF/P-BW
Plantago palmata Hook.f.	Plantaginaceae	karkasho	H	
Drynaria volkensii Hieron.	Polygonaceae		H	
Pleopeltis macrocarpa (Bory. ex Wild.) Kaulf.	Polygonaceae		H	
Rumex abyssinicus Desf.	Polygonaceae	inbwacho	H	
Rumex nepalensis Spreng.	Polygonaceae	shult	S	
Lysimachia ruhmeriana Vatke	Primulaceae	bashanka	H	
Protea gaguedi J. F. Geml.	Proteaceae	danshe	T/S	DAF/WG
Clematis hirsuta Guill. & Perr.	Ranunculaceae	haso	L	DAF/U-SD, MAF, BW, EB
Thalictrum rhynchocarpum Quart. -Dill. & A. Rich.	Ranunculaceae		H	
Caylusea abyssinica Fisch. & C. A. Mey	Resedaceae	arencho	H	
Gouania longispicata Engl.	Rhamnaceae		L	DAF/U-WG, MAF/P-BW, TRF,RV
Helinus mystacinus E. Mey. ex Steud.	Rhamnaceae	galimo	L	DAF/WG, RV
Rhamnus prinoides L'Hér.	Rhamnaceae	gesho	T/S	DAF/U-SD-WG, MAF/P, EB, RV
Cassipourea malosana Alston	Rhizophoraceae	tilo	T/S	DAF/U, MAF/P, EB
Prunus africana (Hook.f.) Kalkman	Rosaceae	tikurenchet	T	DAF/U;MAF/P
Rubus niveus Thunb.	Rosaceae	gora	L	
Rubus steudneri Schweinf.	Rosaceae	gora	S/L	DAFU-WG
Rubus volkensii Engl.	Rosaceae	injori	L	
Canthium oligocarpum Hiern	Rubiaceae	gallo	T/S	ACB/;DAF/TR-WG;MAF/P-BW
Coffea arabica L.	Rubiaceae	buna	T/S	MAF/P;TRF
Gardenia ternifolia Schumach.	Rubiaceae		T	CTW; DAF/WG
Kohautia platyphylla (K. Schum.) Bremek.	Rubiaceae		H	
Oxyanthus speciosus DC.	Rubiaceae	mukabuna	T/S	DAF/U;MAF/P;RV
Pavetta abyssinica Fresen.	Rubiaceae		T/S	DAF/SD-WG;RV
Pentas lanceolata (Forssk.) Deflers	Rubiaceae		S	CTW;DAF/WG;MAF/P-BW
Psydrax schimperiana (A. Rich.) Bridson	Rubiaceae	seged	T/S	ACB; CTW; DAF/WG
Rubia cordifolia L.	Rubiaceae		H	
Fagaropsis angolensis (Engl.) H. M.Gardner	Rutaceae	sisa	T/S	DAF/U;MAF/P;TRF
Teclea nobilis Delile	Rutaceae	hadhessa	T/S	DAF/U-SD;MAF/P;RV
Teclea simplicifolia (Engl.) Engl.	Rutaceae		T	DAF/U-SD-WG
Toddalia asiatica Lam.	Rutaceae	gao	L	DAF/U-WG;EB;RV
Vepris dainellii (Pic. Serm.) Kokwaro	Rutaceae	lela	T/S	DAF/U;MAF/P;TRF
Salix subserrata Willd.	Salicaceae		T/S	
Osyris quadripartita Salzam. ex Decne.	Santalaceae	karo	T/S	DAF/U-WG
Allophylus abyssinicus Radlk.	Sapindaceae	hirkamo	T	DAF/U-SU;MAF/P-BW;RV
Allophylus macrobotrys Gilg.	Sapindaceae		T/S	MAF/P
Dodonaea angustifolia L. f.	Sapindaceae	kitkita	S	DAF/U-SD-WG-TR
Pouteria adolfi-friedericii (Engl.) Baehni	Sapotaceae	qeraro	T	MAF/P
Sopubia ramosa Hochst	Scrophulariaceae		H	

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Verbascum L.	Scrophulariaceae	gurahare	H	
Brucea antidysenterica J. F. Mill.	Simaroubaceae	hatawicho	T/S	DAF/U-WG;MAF/P-BW
Discopodium penninervium Hochst.	Solanaceae	meraro	T	DAF/U-SD-WG, EB, AA
Physalis peruviana L.	Solanaceae	awut	H	
Solanum giganteum Jacq.	Solanaceae		T/S	DAF/U, MAF/BW, TRF, RV
Solanum incanum L.	Solanaceae	tunaye	H	
Solanum nigrum L.	Solanaceae	hidi warabesa	H	
Solanum villosum Mill.	Solanaceae	tunaye	H	
Gnidia chrysantha (Sch.) Gilg.	Thymelaeaceae	ya'aa	H	
Gnidia lamprantha Gilg.	Thymelaeaceae		S	CTW, DAF/WG
Grewia ferruginea Hochst.	Tiliaceae	dokonu	T/S	DAF/U-SD-WG
Triumfetta rhomboidea Jacq.	Tiliaceae	daro	H	
Celtis africana Burm.f.	Ulmaceae	qawut	T	DAF/U, MAF/P, RV
Droguetia iners Schweinf.	Urticaceae		H	
Girardinia bullosa (Hochst. ex Steud.) Wedd.	Urticaceae	dobi	S	
Girardinia diversifolia (Link) Friis	Urticaceae	sonicho	H	
Premna schimperi Engl.	Verbanaceae	urgessa	T	DAF/WG, RV
Ampelocissus abyssinica Planch.	Vitaceae	sariti	L	
Cayratia gracilis (Guill. & Perrott..) Suess. & Suess	Vitaceae		L/H	
Cyphostemma niveum (Hochst ex Schweinf.) Desc.	Vitaceae	alqa	H	
Rhoicissus tridentata (L.f.) Wild. & R. B. Drumm.	Vitaceae		S/L	ACB, CTW, DAF/SD-WG

Explanations: T – tree, S – shrub, H – herb, L – liana, T/S – tree shrub, T/L – tree liana, S/L – shrub liana; * – for the distribution types see the Introduction part