SINET: Ethiop. J. Sci., 31(2):103–120, 2008

ISSN: 0379–2897

FLORISTIC COMPOSITION AND STRUCTURE OF THE DRY AFROMONTANE FOREST AT BALE MOUNTAINS NATIONAL PARK, ETHIOPIA

Haile Yineger [1], Ensermu Kelbessa [2], Tamrat Bekele [2] and Ermias Lulekal [3]

[1] Department of Biology, Jimma University, PO Box 5195, Jimma, Ethiopia
E-mail: haile_mulu@yahoo.com or haile.yineger@ju.edu.et
[2] National Herbarium, Department of Biology, Faculty of Science, Addis Ababa University
PO Box 3434, Addis Ababa, Ethiopia
[3] Department of Biology, Debre Berhan University, PO Box 445, Debre Berhan, Ethiopia

ABSTRACT: The floristic composition and structure of the Dry Afromontane Forest at Bale Mountains National Park was studied from July 2003 to June 2004. A total of 90 plots were established at three sites (Adelle, Boditi and Gaysay) at an altitudinal range of 3010–3410 m. The cover abundance values, density, and diameter at breast height and list of species were recorded in each plot. About 230 species belonging to 157 genera and 58 families were identified and documented. Analysis of vegetation data revealed 5 homogenous clusters. The densities of trees in the diameter class >2 cm were 766 and 458 individuals ha^{-1}in Adelle and Boditi forests, respectively. The basal areas were about 26 and 23 m^{2}ha^{-1} in Adelle and Boditi forests, respectively. About 43% of the basal area in Adelle and 57 in Boditi forests were contributed by *Juniperus procera* and *Hagenia abyssinica*, respectively. Both Adelle and Boditi forests were found at an earlier secondary stage of development and had, more or less, a similar trend of development. The population structures of tree species were assessed and these had clearly signalled the occurrence of excessive cutting of selected diameter classes of ecologically, economically and medically important tree species for various purposes, particularly for construction.

Key words/phrases: Bale Mountains, floristic composition, plant community, vegetation structure

INTRODUCTION

The highland area of Ethiopia was once covered with extensive forest resources (EMA, 1988). However, the country has lost these resources at an alarming rate due to various reasons. According to EFAP (1994), the annual loss of forest resources of the country is estimated between 150,000 and 200,000 ha.

The most important reason behind the rapid deforestation rate in the country is the ever-increasing human population growth. This rapid increase in human population is associated with a very high demand for agricultural and grazing lands, forest resources for firewood, charcoal, timber, construction, and many other purposes. Fire, inappropriate investment activities, and lack of viable land use policy have also been key factors for the rapid decline of forests in the country (Friis, 1992; Taye Bekele *et al*., 1999).

The Bale Mountains National Park (BMNP) is primarily established for the conservation of the critically endangered Ethiopian endemic mammal species, the Ethiopian Wolf (*Canis simensis*) and Mountain Nyala (*Tragelaphus buxtoni*). Nonetheless, the park has extremely diverse habitats that are mainly the results of altitudinal variations, and these have supported so many other endemic flora and fauna (Miehe and Miehe, 1994). Moreover, the park is a site for the origin of numerous water bodies that are incredibly vital for the livelihood of both the lowland and highland dwellers (Williams, 2002). However, the BMNP and many other protected areas in Ethiopia are not well managed and their resources are being exploited unsustainably (Shibru Tedla, 1995).

For effective management and conservation of this unique ecosystem of the country, there is an urgent need to develop a sound management plan, and this, in turn, requires detailed baseline information on the ecology of the area. Menassie Gashaw and Masresha Fetene (1996) studied the plant communities of the Afroalpine vegetation of Sanetti plateau. Miehe and Miehe (1994) studied the *Ericaceous* forests of the Bale Mountains. The National Herbarium (2004) carried out a general biodiversity assessment of the park and surrounding areas. Nevertheless, the floristic composition, plant community and structural analysis of the Dry Afromontane Forest in the Bale Mountains National Park have not previously been investigated. Therefore, the present study was conducted to determine the floristic composition, identify plant communities and carryout structural analysis of the Dry Afromontane Forest in the park, and this is believed to contribute a lot to the effort being made in the development of a sound management plan for effective conservation of the park resources.

MATERIALS AND METHODS

Study area

The study area is located in Oromia National Regional State, Bale Zone, between latitudes 07^{0}05.98′–07^{0}08.99′N and longitudes 039^{0}43.43′–039^{0}45.39′E (Fig. 1). The altitudinal range of this area lies between 3010–3410 m a.s.l. The lava outpourings of the Miocene and Oligocene geological periods were responsible for the formation of the Bale Mountains (Mohr, 1963). The rocks formed from these trapean lavas mainly consist of trachytes, with some amounts of rhyolytes, tuffs, basalts, and associated agglomerates (Morton, 1976). The trachytic and basaltic rocks weather predominantly to the fairly fertile loam soils that are of reddish-brown to black in colour (Miehe and Miehe, 1994).

The study area has a bimodal rainfall distribution from March to October, with the highest rain falling in April and then from July to October (Fig. 2) (NMSA, Personal communication). The dry season extends from November to February. The mean annual rainfall is 1218.64 mm. The mean annual minimum and maximum temperatures of the area are 2.36°C and 15.5°C, respectively. The lowest and highest values of mean monthly minimum temperature were recorded in December (–1°C) and August (6.1°C) respectively. The corresponding values for the mean monthly maximum temperature were observed in October (14°C) and February (21.3°C), respectively.

The vegetation in the northern part of the Bale Mountains forms the southern margin of the ‘widespread, largely undifferentiated Afromontane forest area’ of central and north Ethiopia (Miehe and Miehe, 1994). Altitudinal and associated climatic variations along this site have resulted in the formation of four distinct vegetation zones each of which has its own unique flora and fauna. These are the grasslands of Gaysay valley and Dinsho, the *Juniperus-Hagenia* forests, the *Erica* or heather belt, and the Afro-Alpine moorlands of the plateau and the central peaks (Williams, 2002).

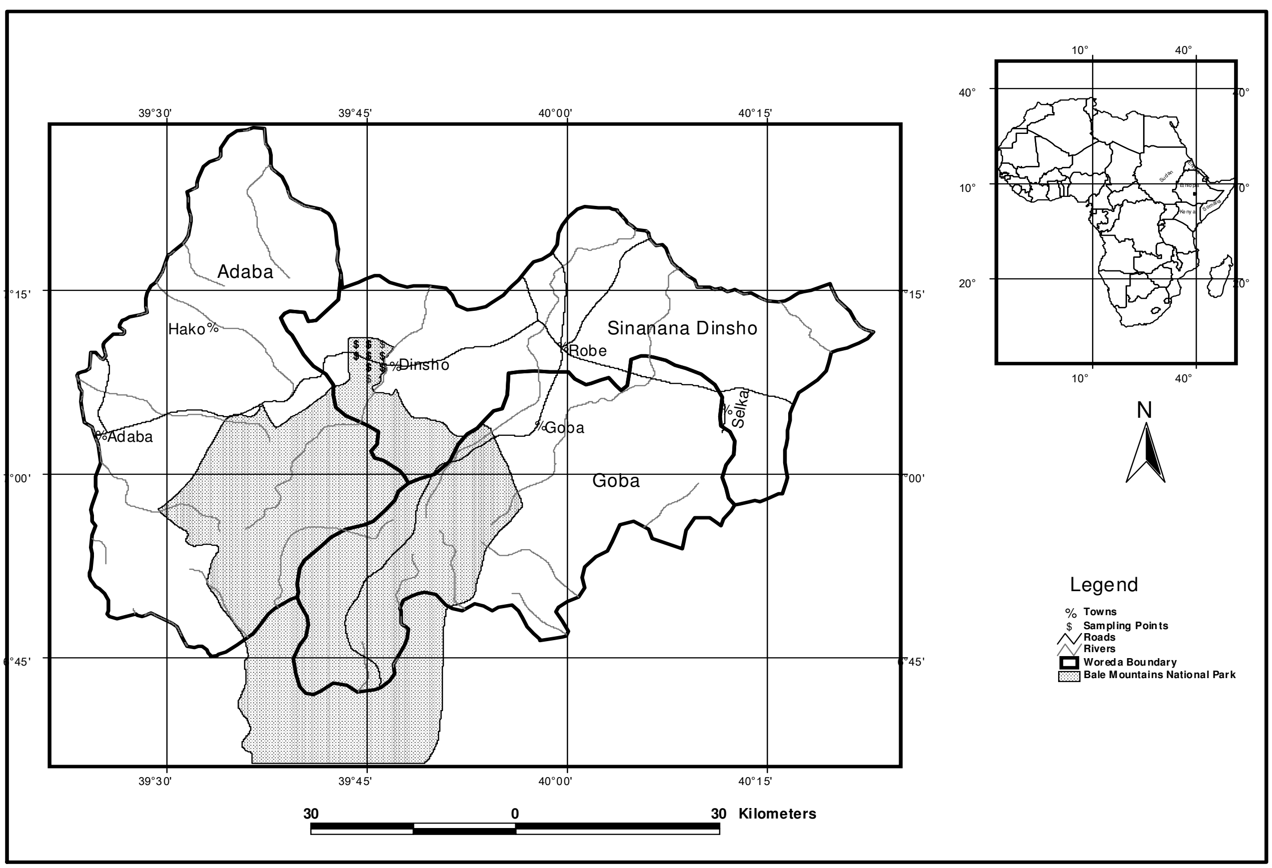

Fig. 1. Map showing the study area.

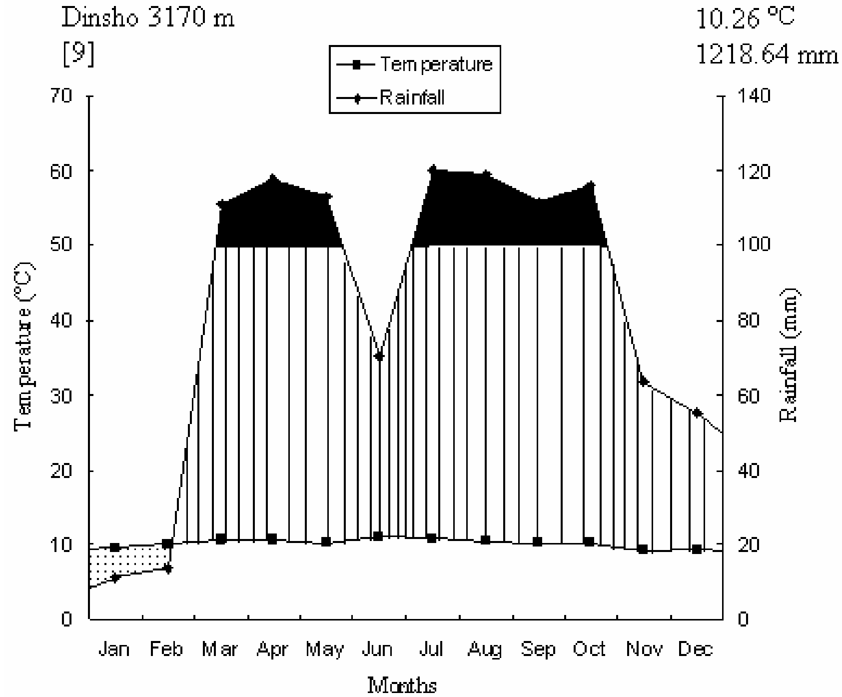

Fig. 2. Climadiagram (after Walter, 1985) showing rainfall distribution and temperature variation from 1994–2002 at Dinsho (BMNP Headquarters). Data source: National Meteorological Service Agency.

Site selection and plot establishment

A reconnaissance survey was made from 30 July to 2 August 2003 to obtain an impression on the general physiognomy of the vegetation and identify sampling sites in the study area. The fieldwork was done between 3 August and 12 August 2003, September and November 2003, and January and June 2004. Based on the reconnaissance survey, three sites (Adelle and Boditi forests, and Gaysay grassland) were chosen within the park area some 5 to 7 km northeast of the Bale Mountains National Park (BMNP) headquarters. These sites were chosen because they were relatively better protected and the extent of human disturbance was relatively less than in the other areas of the Dry Afromontane Forest in the park. The Gaysay grassland is almost a flat area that lies between Adelle and Boditi. The altitudinal ranges of Gaysay grassland, Boditi and Adelle are 3010–3060 m, 3060–3410 m, and 3070–3350 m above sea level, respectively.

Five line transects were laid on each of the two sites (Adelle and Boditi) beginning from the *Ericaceous* zone to the edge of the forests. The distance between transects was 500 m. A total of 32 (Adelle) and 36 (Boditi) nested plots (30 x 30 m for trees, 5 x 5 m for shrubs and 2 x 2 m for herbs) were established at every 35 m drop in altitude along these transects.

Gaysay grassland shows little altitudinal variation, and therefore, floristic data were collected from this site following Kumelachew Yeshitela and Tamrat Bekele (2002) through subjectively selected homogenous representative stands. In such a way, 22 nested plots (5 x 5 m for shrubs and 2 x 2 m for herbs) were analysed from this site.

Altitude was measured for each sample plot using 'Pretel' digital altimeter. GPS readings of latitude and longitude coordinates were also recorded for each plot.

Vegetation data collection

A complete list of herbs (plants whose stem does not produce woody, persistent tissue), shrubs (woody plants having several stems at or near the base of the plant and less than 3 m tall), lianas (woody plants which use trees and other means to climb over the canopy) and trees (woody plants having a dominant stem and more than 6 m tall) were made in each plot. The occurrence of lichens, bryophytes and vascular epiphytes were also noted. The 1–9 modified Braun-Blanquet scale (van der Maarel, 1979) was used to estimate the cover-abundance values of tree and shrub species.

The diameter at breast height (DBH), *i.e.,* 1.3 m from ground was estimated for each tree and shrub species by measuring circumference and later converting to obtain estimates of DBH following Abate Ayalew (2003). In cases where the tree or shrub branched at about breast height, the circumference was measured separately for the branches. Trees and shrubs with DBH > 2 cm were counted in each plot.

Voucher specimens of plants were collected from the study area, allotted collection numbers, pressed, and dried for identification at the National Herbarium (ETH), Addis Ababa University. Some of the plants were identified in the field while most were identified at the National Herbarium by comparing with already identified herbarium specimens and using taxonomic keys in the Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989; 1995; Edwards *et al*., 1995; 2000; Hedberg *et al*., 2003; Hedberg *et al*., 2004). Voucher specimens were eventually kept at the National Herbarium.

Data analyses

Vegetation data was analysed using TWINSPAN program version 1.0 (Hill, 1979). In this program the following options were chosen: Number of pseudospecies cut levels 3; Cut levels 0 6 10; minimum group size for division 3; maximum number of indicators per division 10; maximum number of species in final tabulation 55; weights for levels of pseudospecies 1 3 3; and all the rest of the different options in this program were set to default values.

The plots were thus grouped into clusters by this program, and the community types distinguished from the output were further refined in a synoptic table. The product of average cover-abundance values of a species and its frequency in a community type were taken as the synoptic values of the species in the community type (van der Maarel *et al*., 1987). Eventually, the community types were named after one or more dominant and/or characteristic species.

Vegetation data was also subjected to hierarchical agglomerater cluster analysis in PC-ORD 5.0 (McCune and Mefford, 1999) with the cluster setup of Sorenson's (Bray-Curtis) distance measure and flexible beta (cluster flexible beta value = –0.25) group linkage method so as to obtain dendrogram of communities along with respective sample plots.

Structural analysis was performed on the basis of density, frequency, DBH and basal area per hectare. Ten DBH classes (2–10, 10–20, 20–30, 30–50, 50–70, 70–90, 90–110, 110–130, 130–150, and >150 cm) were constructed after Kitessa Hundera (2003), and the density distribution of tree and shrub species were computed in each class. The distribution of the size classes was evaluated by computing the density of individuals with DBH >10 cm and > 20 cm as well as the ratio of the former to the latter. According to Grubb *et al*. (1963), the ratio of 'density at DBH class >10 cm' to 'density at DBH class >20 cm' can be used as a measure of the distribution of the different size classes. The patterns of species population structure detected were interpreted as a sign for the alteration in population dynamics in the forests (Popma *et al*., 1988).

The following structural parameters were calculated for some species following Mueller-Dombois and Ellenberg (1974) and Martin (1995):

Percent frequency of a species = the number of plots in which that species occurs/total number of plots X 100

Relative frequency = Frequency of species A/total frequency of all species X 100

Density of a species = the number of individuals of that species/area sampled

Relative density = Density of species A/total density of all species X 100

Basal area (m^2) = $(\text{DBH}/200)^2\pi$

where DBH is the diameter at breast height (cm), $\pi = 3.14$

Dominance = Total of basal area / area sampled

Relative dominance = Dominance of species A/total dominance of all species X 100

Importance Value Index = Relative density + Relative frequency + Relative dominance.

RESULTS AND DISCUSSION

Floristic composition

A total of 230 plant species belonging to 157 genera and 58 families were identified in this study indicating that the area was more rich in its plant diversity (see Appendix I) than Jibat Forest (Tamrat Bekele, 1993), Dakata Valley Forest (Demel Teketay, 1995a), Chilimo Forest (Tadesse Woldemariam, 1998), Dodola Forest (Kitessa Hundera, 2003), Denkoro Forest (Abate Ayalew, 2003), Mena Angetu Forest (Ermias Lulekal, 2005), and Yayu Forest (Tadesse Woldemariam *et al*., 2008). Out of the total plant species identified, about 63 species (35.8%) were found to have ethnomedicinal use by the local people and their detailed ethnobotanical descriptions are already reported elsewhere (see Haile Yineger *et al*., 2007;

2008). Recorded plant species compositions served as good evidences to categorize the study area as one of the largely undifferentiated Afromontane forest types described by Friis (1992). Asteraceae was the most dominant plant family with 39 species, followed by Poaceae with 30 species. The family Asteraceae has been reported as dominant in the Afromontane flora of Ethiopia (*e.g.,* Mesfin Tadesse, 2004; Ermias Lulekal, 2005) as well as other North-eastern African countries (*e.g.,* Bytebier and Bussmann, 2000; Abdel-Ghani and Abdel-Khalik, 2006). This could be attributed to its efficient and successful dispersal strategies as well as adaptation to a wide range of ecological conditions. The most dominant growth forms were herbs with 183 species (79%) followed by shrubs with 26 species (11%). The other growth forms include epiphytes with 9 species (3.9%), trees with 6 species (2.6%), herbaceous climbers with 5 species (2.2%) and lianas with 3 species (1.3%).

Plant community types

Analysis of vegetation data using TWINSPAN program revealed five clusters that could be recognized as plant community types. Five community groups were also identified in the dendrogram output of the hierarchical agglomerate classification in PCORD 5.0 (McCune and Mefford, 1999). Community groups in this dendrogram were determined at 25% information remaining within groups (see Appendix II). One or a combination of dominant or characteristic species having high synoptic values in the type was/were used to name these plant community types (Table 1). The description and altitudinal distribution of these plant community types is given below. Unfortunately this study did not address analyses of a range of possible environmental variables except altitude that could shape the distribution of identified plant communities.

1. *Erica arborea community*

This community type was dominated by *Erica arborea* and was found at an altitudinal range of 3130–3410 m. A study conducted at Wof-Washa Forest (Demel Teketay, 1995b) also showed particular dominance of this species in the aforementioned altitudinal zone. *Senecio ochrocarpus, Echinops macrochaetus,* and *Carduus leptacanthus* were characteristic species in this community. Significant numbers of *Juniperus procera, Helichrysum splendidum, Ferula communis,* and *Kniphofia foliosa* were also found in this type. Species such as *Myrsine melanophloeos, Hagenia abyssinica, Solanum marginatum, Salvia merjame,* and *Senecio ragazzii,* were common whereas *Hypericum revolutum, Helichrysum quartitianum, Solanum garae* and *Hypericum peplidifolium* were rare in this community type.

2. *Juniperus procera –Myrsine melanophloeos – Hagenia abyssinica* community

This community type lied at an altitudinal range of 3060–3370 m, and *Juniperus procera* and *Hagenia abyssinica* trees mostly dominated the upper canopy. Very significant proportions of *Hypericum revolutum, Myrsine melanophloeos,* and *Kniphofia foliosa* were also found. Characteristic species in this community included *Juniperus procera, Euphorbia dumalis* and *Rosa abyssinica.* Other common species that occurred in the understory layer included *Solanum marginatum, Erica arborea, Helichrysum splendidum, Ferula communis* and *Salvia merjame*.

3. *Hypericum revolutum – Myrsine melanophloeos – Hagenia abyssinica – Solanum marginatum* community

The altitudinal range of this community type lied between 3090 m and 3350 m and *Hypericum revolutum* and *Hagenia abyssinica* trees dominated its upper canopy. *Myrsine melanophloeos* and *Solanum marginatum* were also dominant. *Kalanchoe petitiana, Discopodium eremanthum* and *Solanum marginatum* were characteristic species of this type. Other important species in this community type comprised *Kniphofia foliosa, Salvia merjame, Senecio ragazzii, Euphorbia dumalis* and *Ferula communis*. Some species like *Erica arborea, Juniperus procera, Rosa abyssinica, Malva verticillata,* and *Echinops hoehnelii* occurred infrequently.

4. *Artemisia afra – Nepeta azurea* community

This community type was found at an altitudinal range of 3010–3050 m, and its upper layer was dominated by *Artemisia afra* and *Helichrysum splendidum*. *Nepeta azurea* was the characteristic species and highly associated with *Artemisia afra*. *Kniphofia foliosa* and *Ferula communis* were also common. Plant species like *Hypericum revolutum, Euphorbia depauperata, Hypericum peplidifolium, Astragalus atropilosulus,* and *Rubus erlangeri* were rarely seen.

5. *Ferula communis - Helichrysum splendidum* community

This community type was found at an altitudinal range of 3010–3060 m, and *Ferula communis* was the dominant species. Substantial numbers of *Salvia* *merjame, Helichrysum splendidum, Kniphofia foliosa* and *Artemisia afra* were also present. *Euphorbia depauperata* and *Helichrysum foetidum* were other common species whereas *Hypericum revolutum* and *Hypericum peplidifolium* were rare.

Communities 1, 2, 3, 4 and 5 were found to accommodate about 35, 44, 40, 25 and 24 ethnomedicinal plant species, respectively (Haile Yineger *et al.*, 2007; 2008). Community type 1 was found near the top of Boditi hill while community type 2 occurred in Adelle. Community type 3 was partially found in Adelle but it formed the major tree layer in Boditi Forest. Friis (1992) has indicated the occurrence of such communities at higher elevations in the largely undifferentiated Afromontane forests of Ethiopian highlands. The remaining two communities were found in between the two forests at Gaysay grassland.

Altitude has been investigated in a number of studies (*e.g.*, Tamrat Bekele, 1993; Miehe and Miehe, 1994; Demel Teketay, 1995b; Sebsebe Demissew, 1988; Abate Ayalew, 2003; Ermias Lulekal, 2005; Tadesse Woldemariam *et al.*, 2008;) as one of the major environmental gradients that could shape the species composition and distribution of plant communities. This environmental variable seems to have significant contribution in the current study area in determining plant community compositions and zones despite the presence of overlaps with some community types (see altitudinal distribution of the aforementioned five communities)

Table 1. Synoptic table of species reaching a value of ≥ 0.1 in at least one community type.

Cluster Number	1	2	3	4	5
Cluster Size	11	36	22	11	9
Echinops macrochaetus	0.3	0	0	0	0
Senecio ochrocarpus	1.2	0	0	0	0
Helichrysum quartitianum	0.1	0	0	0	0
Carduus leptacanthus	0.2	0	0	0	0
Solanum garae	0.1	0	0	0	0
Erica arborea	8.0	0.9	0.1	0	0
Juniperus procera	0.8	4.9	0.1	0	0
Hypericum revolutum	0.1	4.9	5.1	0.1	0.1
Myrsine melanophloeos	0.3	4.7	3.7	0	0
Hagenia abyssinica	0.3	2.0	2.0	0	0
Solanum marginatum	0.3	0.4	3.1	0	0
Salvia merjame	0.3	0.2	0.5	0	1.7
Kniphofia foliosa	0.4	2.8	1.2	1.4	1.3
Euphorbia dumalis	0	0.8	0.3	0.1	0
Malva verticillata	0	0	0.1	0.1	0
Echinops hoehnelii	0	0	0.1	0	0
Discopodium eremanthum	0	0	0.7	0	0
Kalanchoe petitiana	0	0	0.9	0	0
Senecio ragazzii	0.3	0	0.3	0	0
Hypericum peplidifolium	0.1	0	0	0.1	0.1
Rosa abyssinica	0.0	0.5	0.1	0	0
Artemisia afra	0	0	0	4.3	1.2
Nepeta azurea	0	0	0	4.2	0
Helichrysum splendidum	0.6	0.4	0	2.5	1.8
Ferula communis	0.4	0.3	0.2	0.2	4.8
Euphorbia depauperata	0	0	0	0.1	0.3
Helichrysum foetidum	0	0	0	0	0.4
Astragalus atropilosulus	0	0	0	0.1	0
Rubus erlangeri	0	0	0	0.1	0

Density of tree and shrub species

The densities of trees and shrubs were 898 individuals ha^{-1} in Adelle Forest and 498 individuals ha^{-1} in Boditi Forest at DBH > 2 cm (Table 2). These densities are low compared to some other Afromontane forests in Ethiopia, for example, Kimphee Forest (3059 stems ha^{-1}) (Feyera Senbeta and Demel Teketay, 2003), Masha-Anderacha Forest (1709 stems ha^{-1}) (Kumlachew Yeshitela and Taye Bekele, 2003), and Dindin Forest (1750 stems ha^{-1}) (Simon Shibru and Girma Balcha, 2004). This could be attributed to variations in landscape topographic gradients as well as habitat qualities linked to ecological requirements of component tree and shrub species in the respective forests. At DBH > 10 cm, the densities of trees and shrubs were 432 and 283 individuals ha^{-1} in Adelle and Boditi forests, respectively. The corresponding densities at DBH > 20 cm were 174 and 125 individuals ha^{-1} in Adelle and Boditi forests, respectively.

The density of trees alone at the DBH class > 2 cm was 766 individuals ha^{-1} in Adelle Forest, accounting for 85.3% of the total density of trees and shrubs (Table 2). This was actually greater than density of tree species at Mana Angetu Forest (408 stems ha^{-1}) (Ermias Lulekal, 2005). The corresponding density in Boditi Forest was 458 individuals ha^{-1}, representing 92% of the total density of trees and shrubs. Tree density in Adelle Forest at the DBH class >10 cm was 413 individuals ha^{-1}, accounting for 96% of the total density of trees and shrubs. The corresponding value in Boditi Forest at the same DBH class was 256 individuals ha^{-1}, and it accounted for 91% of the total density of trees and shrubs. Similarly, at the DBH class > 20 cm, the tree density in Adelle Forest was 164 individuals ha^{-1}, representing 94% of the total density of trees and shrubs while that of Boditi Forest was 114 individuals ha^{-1}, and this accounted for 91% of the total density of trees and shrubs.

The ratio of 'density at DBH class >10 cm' to 'density at DBH class > 20 cm' in Adelle was 2.52 and 2.25 in Boditi (Table 2). These comparisons indicated that both Adelle and Boditi forests were dominated by more numbers of small-sized individuals. The dominance of small-sized individuals was slightly greater in Adelle than in Boditi. This predominance of small-sized individuals was largely due to the high density of *Myrsine melanophloeos* in Adelle Forest and *Hypericum revolutum* in Boditi Forest. Similar conditions were reported from Dindin Forest where *Olinia rochetiana* and *Myrsine africana* were dominant (Simon Shibru and Girma Balcha, 2004); and in Masha-Anderacha Forest where *Cyathea manniana* dominated (Kumelachew Yeshitela and Taye Bekele, 2003). Another major reason was due to the fact that the trees and shrubs were found at their upper altitude limits, *i.e.*, 3010–3410 m. Selective cutting of medium sized individuals for a variety of purposes, mainly for construction, was the other reason.

Table 2. Density of trees and shrubs in Adelle and Boditi forests with DBH > 2 cm, > 10 cm and > 20 cm individuals (Ind.) ha^{-1}.

	> 2cm				>10 cm				> 20cm				>10/>20 cm	
	Adelle		Boditi		Adelle		Boditi		Adelle		Boditi		Adelle	Boditi
Species	Ind. ha^{-1}	%	Ind. ha^{-1}	%	Ind. ha^{-1}	%	Ind. ha^{-1}	%	Ind. ha^{-1}	%	Ind. ha^{-1}	%		
*Erica arborea**	29.17	3	46.91	9	19.44	5	17.28	6	2.778	2	4.012	3	7.00	4.31
*Hagenia abyssinica**	12.85	1	20.37	4	12.85	3	18.52	7	12.85	7	18.52	15	1.00	1.00
*Hypericum revolutum**	145.5	16	190.4	38	128.5	30	129	46	60.76	35	59.26	47	2.11	2.18
*Juniperus procera**	110.4	12	7.716	2	110.4	26	6.173	2	85.42	49	6.173	5	1.29	1.00
*Myrsine melanophloeos**	466.3	52	191.7	38	139.9	32	84.57	30	0	0	25.62	20		3.30
*Pittosporum viridiflorum**	1.736	0.19	0.617	0.12	1.736	0.4	0.617	0.22	1.736	1	0.617	0.5	1.00	1.00
Discopodium eremanthum	4.861	1	11.11	2	4.861	1	9.568	3	4.514	3	7.716	6	1.08	1.24
Rosa abyssinica	6.597	1	0.926	0.19	3.472	1	0.617	0.22	1.042	1	0	0	3.33	
Rubus steudneri	75	8	0.309	0.06	0.346	0.08	0	0	0	0	0	0		
Solanum garae	2.431	0.27	1.543	0.31	0	0	0	0	0	0	0	0		
Solanum marginatum	42.01	5	25	5	9.375	2	16.05	6	4.938	3	3.395	3	1.90	4.73
Maytenus obscura	0.694	0.08	0	0	0.694	0.16	0	0	0	0	0	0		
Solanum anguivi	0	0	0.617	0.12	0	0	0	0	0	0	0	0		
Rubus apetalus	0	0	0.617	0.12	0	0	0.617	0.22	0	0	0	0		
Total	898	100	498	100	432	100	283	100	174	100	125	100	2.48	2.26
Total (Trees alone)	766	85.3	458	92	413	96	256	91	164	94	114	91	2.52	2.25

* = Tree species

Diameter at Breast Height (DBH)

The general pattern of distribution of trees and shrubs in the two forests along the different DBH classes was more or less similar and assumed an inverted J shape (Fig. 3). An inverted J shape population age distribution could somehow indicate a healthy regeneration status of the forests (Demel Teketay, 1997) though analysis of population structures for each individual tree and shrub species could provide more realistic and specific information for conservation measures. Similar overall population patterns were reported for Kimphee Forest (Feyera Senbeta and Demel Teketay, 2003) and for the vegetation in the islands of Lake Ziway (Haileab Zegeye *et al*., 2006). About 53% of the individuals in Adelle and about 51% of the individuals in Boditi forests lied in the DBH class 2–10 cm.

Comparison of the percentage of stems with DBH < 50 cm in the two forests revealed very close figures, about 97% for Adelle Forest and about 96% in Boditi Forest, showing that both Adelle and Boditi possessed many small-sized individuals and very few large-sized individuals. This indicated that Adelle and Boditi were found at an earlier secondary stage of development and had more or less a similar trend of development. This was mainly due to the occurrence of excessive cutting especially during the occupation of the main park area by people from Gojera and Sidamo immigrants between 1974 and 1991 (The National Herbarium, 2004).

Basal area

The total basal area in Adelle Forest was about 26 $m^2\ ha^{-1}$ while that in Boditi Forest was about 23 $m^2\ ha^{-1}$ (Table 3). These are more or less similar figures indicating that both Adelle and Boditi forests were found in a similar trend of development. Basal areas of Adelle and Boditi are much less than reported for many other Afromontane forests in the country, for example, Wof-Washa Forest (about 102 m^2ha^{-1}), Jibat Forest (about 50 m^2ha^{-1}), Menagesha Forest (about 36 m^2ha^{-1}), Chilimo Forest (about 30 m^2ha^{-1}) (Tamrat Bekele, 1993), Denkoro Forest (45 m^2ha^{-1}) (Abate Ayalew, 2003) and Mana Angetu Forest (94 m^2ha^{-1}) (Ermias Lulekal, 2005). About 43% of the basal area in Adelle Forest was contributed by *Juniperus procera* whereas about 57% of the basal area at Boditi Forest was contributed by *Hagenia abyssinica*. These were followed at Adelle Forest by *Hagenia abyssinica* (about 25%) and at Boditi Forest by *Hypericum revolutum* (about 20%). This implies that *Juniperus procera* had the highest dominance in Adelle whereas *Hagenia abyssinica* exhibited the highest dominance in Boditi. Thus, these two species had more numbers of large-sized individuals than the other species. *Pittosporum viridiflorum* had the least input to the total basal area in both Adelle (0.2%) and Boditi (about 1%) forests.

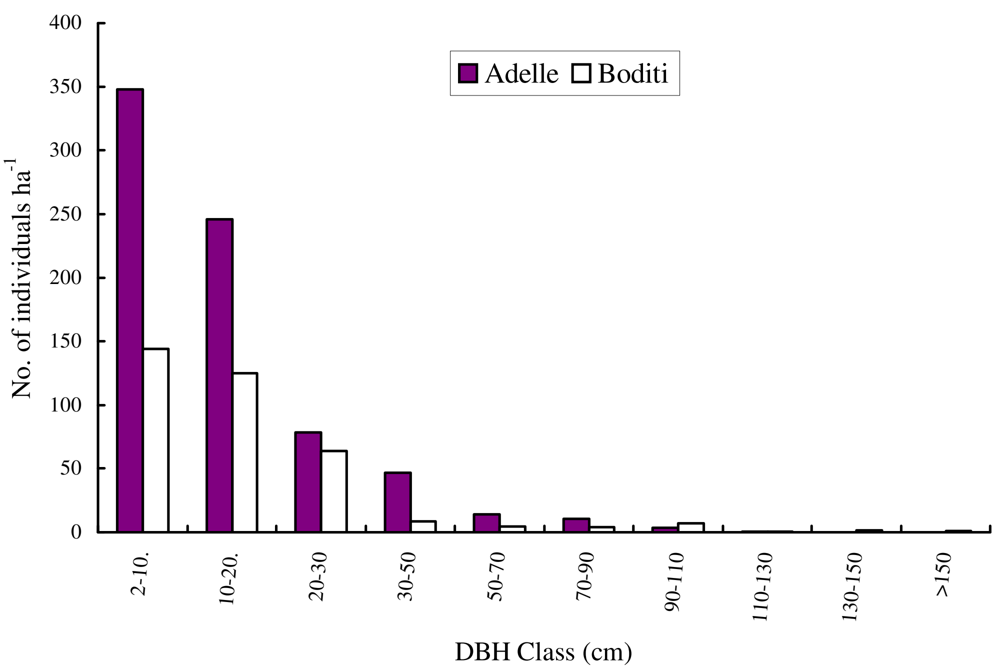

Fig. 3. Distribution of tree and shrub species at Adelle and Boditi forests along the different DBH classes.

Table 3. Basal area (BA) (m^2 ha^{-1}) and percentage input of tree species in Adelle and Boditi forests.

Species	Adelle		Boditi	
	BA (m2 ha^{-1})	%	BA (m2 ha^{-1})	%
Juniperus procera	11.54	43.74	2.29	9.83
Erica arborea	0.37	1.40	0.68	2.90
Hagenia abyssinica	6.71	25.42	13.22	56.65
Hypericum revolutum	4.53	17.15	4.55	19.51
Myrsine melanophloeos	3.19	12.08	2.33	10.00
Pittosporum viridiflorum	0.06	0.22	0.26	1.11
Total	26.39	100	23.34	100

The relative importance of tree species in a forest can better be depicted from measurements of basal area than stem counts (Cain and Castro, 1959). Our results showed that *Juniperus procera* and *Hagenia abyssinica* were the most important tree species in Adelle Forest whereas *Hagenia abyssinica* and *Hypericum revolutum* were the most important species in Boditi Forest.

Importance Value Index (IVI)

The relative ecological significance and/or dominance of tree species in a forest ecosystem could best be unravelled from analysis of IVI values (Curtis and Mcintosh, 1950). Our results of the calculation of IVI thus helped to identify the dominant tree species in both Adelle and Boditi forests (Table 4). In Adelle Forest, *Myrsine melanophloeos* exhibited the highest IVI (about 99) followed by *Juniperus procera* (about 82), indicating that the two species were the dominant tree species in this forest. The highest IVI in Boditi Forest was exhibited by *Hypericum revolutum* (about 86) followed by *Hagenia abyssinica* (about 83), which shows that the two species are the dominant in Boditi Forest. *Pittosporum viridiflorum* was the least dominant species at both forests because it had the least relative dominance, relative density and relative frequency.

Population structure

Examination of patterns of species population structures could provide valuable formation about their regeneration and/or recruitment status as well as viability status of the population that could further be employed for devising evidence based conservation and management strategies (Demel Teketay, 2005; Abrham Abiyu *et al*., 2006). Various patterns of species population structures have been reported for different species in other Afromontane forests of the country (*e.g.,* Demel Teketay, 1997; Abate Ayalew, 2003; Feyera Senbeta and Demel Teketay, 2003; Kumlachew Yeshitela and Taye Bekele, 2003; Simon Shibru and Girma Balcha, 2004; Ermias Lulekal, 2005; Haileab Zegeye *et al.*, 2006).

Table 4. Importance value index (IVI) OF tree species in Adelle and Boditi forests.

Species	Relative Dominance		Relative Density		Relative Frequency		IVI	
	Adelle	Boditi	Adelle	Boditi	Adelle	Boditi	Adelle	Boditi
Juniperus procera	43.74	9.83	14.41	1.68	23.89	12.15	82.04	23.66
Erica arborea	1.40	2.90	3.81	10.24	12.39	18.69	17.6	31.83
Hagenia abyssinica	25.42	56.65	1.68	4.45	11.51	21.50	38.6	82.59
Hypericum revolutum	17.15	19.51	18.99	41.58	25.66	25.23	61.81	86.32
Myrsine melanophloeos	12.08	10.00	60.87	41.85	25.66	21.50	98.62	73.34
Pittosporum viridiflorum	0.22	1.11	0.23	0.14	0.89	0.94	1.34	2.18
Total	100	100	100	100	100	100	300	300

In the current study, the population structure of six tree species (*Erica arborea, Myrsine melanophloeos, Juniperus procera, Hypericum revolutum, Hagenia abyssinica* and *Pittosporum viridiflorum*) was determined using their density at the various DBH classes. Consequently, four representative patterns were detected in both Adelle and Boditi forests (Fig. 4). The first pattern indicated a high number of individuals in the first DBH class followed by a progressive decline in the number of individuals with increasing DBH. This pattern, exemplified by *Myrsine melanophloeos* and *Erica arborea* (at Boditi), suggests good recruitment and good regeneration (Fig. 4A). A similar pattern was also reported by Demel Teketay (1997) for 17 and 18 species at Gara Ades and Menagesha dry Afromontane forests, respectively. The second pattern, exemplified by *Juniperus procera* in Boditi, indicated absence or very few numbers of individuals in the lower three DBH classes, few numbers of individuals in the next four DBH classes, absence of individuals in the 8th and 9th DBH classes and some individuals with DBH > 150 cm (Fig. 4B). This pattern indicates hampered regeneration caused by heavy human pressure on the species leading to scarcity of mature individuals that can serve as seed sources. This pattern was more or less similar to population structures of 14 species in Gara Ades and 7 species in Menagesha dry Afromontane forests (Demel Teketay, 1997). The third pattern, exemplified by *Juniperus procera* in Adelle Forest and *Hypericum revolutum* in both Adelle and Boditi forests, indicated lower number of individuals at the first DBH class, increasing number of individuals in the next four DBH classes and a sharp decline of number of individuals in the next higher DBH classes (Fig. 4B). This pattern shows hampered regeneration, which could be attributed to poor recruitment coupled with selective cutting of individuals in the higher DBH classes. Feyera Senbeta and Demel Teketay (2003) reported similar population patterns in Kimphee Forest represented by *Olea welwitschii* and *Apodytes dimidiata*. The fourth pattern, best exemplified by *Hagenia abyssinica* and *Pittosporum viridiflorum*, indicates representation of only individuals in the higher DBH classes, suggesting lack of seedling recruitment and hampered regeneration (Figure 4D). The species that exhibited the fourth pattern of population structure are in the verge of local extermination. This pattern of population was nearly comparable to reported structure of *Hagenia abyssinica* in Dindin Forest (Simon Shibru and Girma Balcha, 2004) suggesting that the species was under sever threat not only in the current study area but also in other similar forests of the country. This raises concerns for its conservation and sustainable utilization.

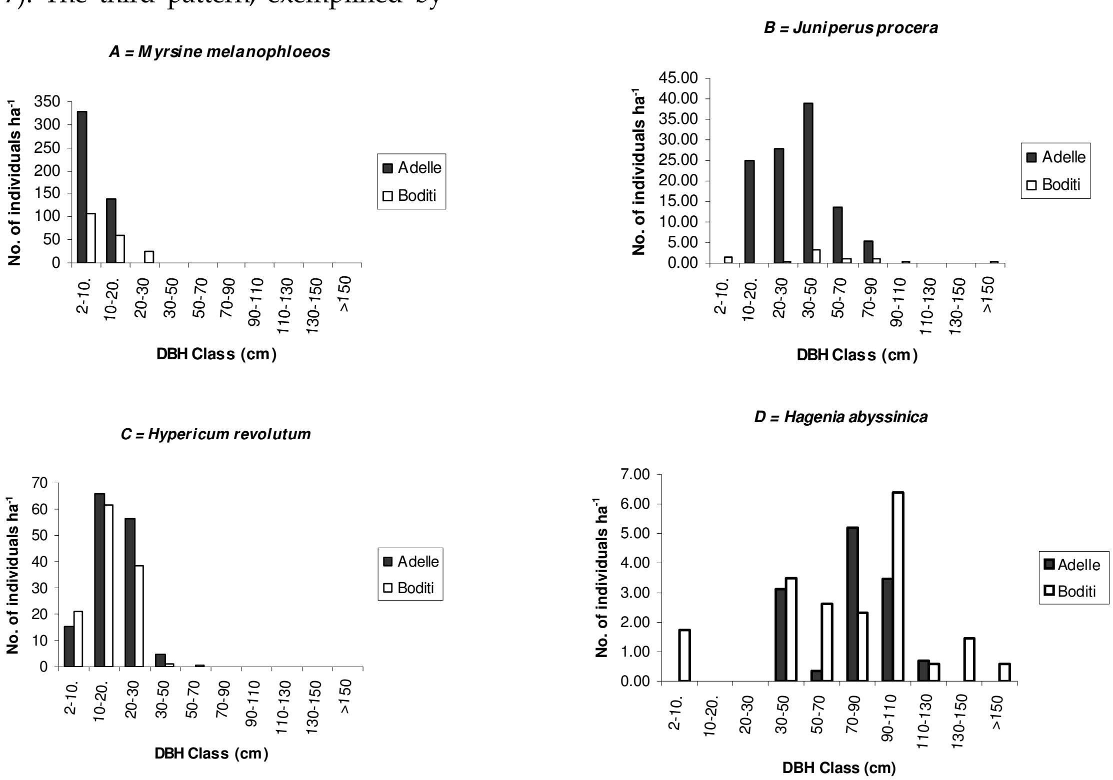

Fig. 4 (A-D). Population structure of representative tree species at Adelle and Boditi forests.

According to its IVI value, *Myrsine melanophloeos* was the most dominant tree species at Adelle Forest. However, when the population structure of this species was critically evaluated at the different DBH classes, it was found only at the 2–10 cm and 10–20 cm DBH classes and was absent in the higher DBH classes. Of course, its largest density was in the DBH class 2–10 cm. The absence of this species at the higher DBH classes was due to the growth nature of the species. The density of this species was higher in Adelle than Boditi forests in the first two DBH classes. The number of individuals declined from DBH classes 20–30 cm to 30–50 cm in Boditi Forest whereas there were no individuals in these DBH classes in Adelle Forest (Fig. 4A), which could be attributed to selective cutting of individuals of the species for construction and fencing purposes

The other most dominant tree species in Adelle Forest was *Juniperus procera*. This species had its highest density in the DBH class 50–70 cm and there were no individuals in the first DBH class (2–10 cm). The absence of individuals in the first diameter class indicated its poor regeneration capacity. The population structure of this species assumed a bell-shaped distribution with very few individuals at the lower DBH classes, high number of individuals at the middle DBH classes and very few individuals again at the higher DBH classes. The relatively smaller proportions of this species in the DBH classes 10–20 cm and 20–30 cm was due to selective removal of individuals for various purposes, mainly for construction. Significant numbers of stumps were observed during data collection. Only few individuals, at DBH classes 2–10 cm, 90–110 cm and > 150 cm, were encountered in Boditi Forest. At Adelle Forest, there were no individuals in these three DBH classes. The major reason for the relative absence of this species in Boditi Forest as compared to Adelle Forest may be due to the difference in the moisture content of the two forests, which in turn is due to the position of the two mountains. Adelle is situated on the leeward side and is relatively dry while Boditi is situated on the windward side and receives wet air. Demel Teketay (1999) mentioned this species as one of the characteristic species in the dry Afromontane forests of the country. This implies that the species prefers relatively dry montane areas like Adelle Forest than wet areas like Boditi Forest. Another possibility might be due to fire treatment requirements of *Juniperus procera* seeds for germination. Adelle was burnt some years back and seeds of this species were treated with fire that facilitated their germination in that area while Boditi was not burnt and seeds had no chance for fire treatment causing for the relative absence of the species in Boditi (Rainer W. Bussmann, personal communication). However, the absence of individuals in some of DBH classes in Boditi Forest still requires detailed and independent study.

Hypericum revolutum was the most dominant tree species at Boditi Forest. The density of this species had an increasing trend from the first to the 20–30 cm DBH classes and a decreasing trend from this point towards the higher DBH classes both at Boditi and Adelle forests (Fig. 4C). Its absence in the higher DBH classes was due to its growth nature. The regeneration capacity of this species was relatively better than *Juniperus procera* and *Hagenia abyssinica*.

The second most dominant tree species at Boditi Forest was *Hagenia abyssinica*. Individuals of this species were absent in the three lower DBH classes in both forests, except very few individuals in the first DBH class in Adelle. The available individuals of this species were relatively mature, and this was true particularly in Boditi Forest than at Adelle Forest (Fig. 4D). This species was, thus, with the poorest regeneration status than the others. This might have happened due to the poor reproductive capacities of its old individuals. The regeneration ecology and reproductive biology of this and the other species should, therefore, be investigated in the study and other similar areas in the country.

ACKNOWLEDGEMENTS

The World Bank is gratefully acknowledged for provision of financial support through the Conservation and Sustainable Use of Medicinal Plants Project in Ethiopia. The staff members of the National Herbarium are also thanked for letting us use the herbarium facilities. The National Meteorological Service Agency was the source of the climate data without which construction of the climadiagram would have been impossible. We thank Ato Zeleke Kebede, a GIS specialist, for preparing map of the study area. Two anonymous reviewers and associate editor of the journal are thanked for their valuable comments in the earlier versions of this paper.

REFERENCES

1. Abate Ayalew (2003). Floristic composition and structural analysis of the Denkoro Forest. (Unpublished MSc thesis), Addis Ababa University.

2. Abdel-Ghani, M.M. and Abdel-Khalic, K.N. (2006). Floristic diversity and phytogeography of the Gebel Elba National Park, South-East Egypt. *Turkish Journal of Botany* **30**:121–136.

3. Abrham Abiyu, Vacik, H. and Glatzel, G. (2006). Population viability risk management applied to *Boswellia papyfera* (Del.) Hochst in North-eastern Ethiopia. *Journal of the Drylands* **1**(2):98–107.

4. Bytebier, B. and Bussmann, R.W. (2000). The vegetation of Mount Nyiru (Samburu district, Kenya): A checklist and synt axonomical survey. *Journal of East African Natural History* **89**:45–71.

5. Cain, S.A. and Castro, G.M.O. (1959). *Manual of Vegetation Analyses*. Harper and Brothers, New York, 325 pp.

6. Curtis, J.T. and Mcintosh, R.P. (1950). The interrelationship of certain analytic and synthetic phytosociological characters. *Ecology* **31**:434–455.

7. Demel Teketay (1995a). Floristic composition of Dakata Valley, south-eastern Ethiopia, an implication for the conservation of biodiversity. *Mountain Research and Development* **15**:183–186.

8. Demel Teketay (1995b). Floristic composition of Wof-washa natural forest, central Ethiopia: implications for the conservation of biodiversity. *Feddes Repertorium* **106**:127–147.

9. Demel Teketay (1997). Seedling populations and regeneration of woody species in dry Afromontane forests of Ethiopia. *Forest Ecology and Management* **98**:149–165.

10. Demel Teketay (1999). Past and present activities, achievements and constraints in forest genetic resources conservation in Ethiopia. In: *Forest Genetic Resources Conservation: Principles, Strategies and Actions,* pp. 49–72, (Edwards, S., Abebe Demissie, Taye Bekele and Haase, G., eds). Proceedings. The National Forest Genetic Resources Conservation Strategy Development Workshop, June 21–22, 1999; IBCR and GTZ, Addis Ababa, Ethiopia.

11. Demel Teketay (2005). Seed and regeneration ecology in dry Afromontane forests of Ethiopia: I. Seed production - population structures. *Tropical Ecology* **46**(1):29–44.

12. Edwards, S., Mesfin Tadesse and Hedberg, I. (eds) (1995). *Flora of Ethiopia and Eritrea.* Volume 2, Part 2. *Canellaceae to Euphorbiaceae*. The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala.

13. Edwards, S., Mesfin Tadesse, Sebsebe Demissew and Hedberg, I. (eds) (2000). *Flora of Ethiopia and Eritrea.* Volume 2, Part 1. *Magnoliaceae to Flacourtiaceae.* The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala.

14. EMA (1988). *National Atlas of Ethiopia*. Ethiopian Mapping Authority, Addis Ababa.

15. EFAP (1994). *Ethiopian Forestry Action Program*. (EFAP), Addis Ababa.

16. Ermias Lulekal (2005). Ethnobotanical study of medicinal plants and floristic composition of the Mena Angetu moist montane forest, Bale, Ethiopia. (Unpublished M.Sc. thesis), Addis Ababa University.

17. Feyera Senbeta and Demel Teketay (2003). Diversity, community types and population structure of woody plants in Kimphee Forest, a virgin nature reserve in Southern Ethiopia. *Ethiopian Journal of Biological Sciences* **2**(2):169–187.

18. Friis, I. (1992). *Forest and Forest Trees of Northeast Tropical Africa: Their Natural Habitats and Distribution Pattern in Ethiopia, Djibouti and Somalia*. Her Majesty's Stationary Office, London, 396 pp.

19. Grubb, P.J., Lloyd, J.R., Pennington, J.D. and Whitmore, J.C. (1963). A comparison of montane and lowland rain forest in Ecuador. I. The forest structure, physiognomy and floristics. *Journal of Ecology.* **51**:567–601.

20. Haile Yineger, Ensermu Kelbessa, Tamrat Bekele and Ermias Lulekal (2007). Ethnoveterinary medicinal plants at Bale Mountains National Park, Ethiopia. *Journal of Ethnopharmacology* **112**:55–70.

21. Haile Yineger, Ensermu Kelbessa, Tamrat Bekele and Ermias Lulekal (2008). Plants used in traditional management of human ailments at Bale Mountains National Park, South-eastern Ethiopia. *Journal of Medicinal Plants Research* **2**(6):132–153.

22. Haileab Zegeye, Demel Teketay and Ensermu Kelbessa (2006). Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Ziway, south-central Ethiopia. *Flora* **201**:483–489.

23. Hedberg, I. and Edwards, S. (eds.) (1989). *Flora of Ethiopia and Eritrea*. Volume 3. *Pittosporaceae to Araliaceae*. The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala.

24. Hedberg, I. and Edwards, S. (eds.) (1995). *Flora of Ethiopia and Eritrea*. Volume 7. *Poaceae (Gramineae)*. The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala.

25. Hedberg, I., Edwards, S. and Sileshi Nemomissa (eds) (2003). *Flora of Ethiopia and Eritrea.* Volume 4, Part 1. *Apiaceae to Dipsacaceae*. The National Herbarium, Addis Ababa University, Addis

Ababa and Department of Systematic Botany, Uppsala University, Uppsala.

26. Hedberg, I., Friis, I. and Edwards, S. (eds) (2004). *Flora of Ethiopia and Eritrea*. Volume 4, Part 2. *Asteraceae (Compositae)*. The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala.

27. Hill, M.O. (1979). TWINSPAN. *A Fortran Program for Arranging Multivariate Data in an Ordered Two-way Table by Classification of Individuals and Attributes*. Ecology and systematics, Cornell University, Ithaca, New York.

28. Kitessa Hundera (2003). Floristic composition and structure of the Dodola Forest, Bale Zone, Oromiya Regional State. (Unpublished M.Sc. thesis), Addis Ababa University.

29. Kumelachew Yeshitela and Tamrat Bekele (2002). Plant community analysis and Ecology of Afromontane and transitional rainforest vegetation of Southwest Ethiopia. *SINET: Ethiopian Journal of Science* **25**(2):155–175.

30. Kumelachew Yeshitela and Taye Bekele (2003). The woody species composition and structure of Masha-Anderacha Forest, South-western Ethiopia. *Ethiopian Journal of Biological Sciences* **2**(1):31–48.

31. Martin, G.J. (1995). *Ethnobotany: a Methods Manual*. Chapman and Hall, London, UK, 268 pp.

32. McCune, B. and Mefford, M.J. (1999). *PC-ORD. Multivariate Analysis of Ecological Data. Version 5.0*. MjM Software, Gleneden Beach, Oregon, U.S.A.

33. Menassie Gashaw and Masresha Fetene (1996). Plant communities of the Afroalpine vegetation of Sanetti Plateau, Bale Mountains, Ethiopia. *SINET: Ethiopian Journal of Science* **19**(1):65–86.

34. Mesfin Tadesse (2004). Asteraceae (Compositae). In: *Flora of Ethiopia and Eritrea,* Volume 4, Part 2 (Hedberg, I., Friis, I. and Edwards, S., eds). The National Herbarium, Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala.

35. Miehe, S. and Miehe, G. (1994). *Ericaceous Forests and Heath Lands in the Bale Mountains of South Ethiopia: Ecology and Man's Impact*. Stiftung Walderhaltung in Africa, D-22 113 Hamburg, Rote Brucke 6–15, 206 pp.

36. Mohr, P.A. (1963). *The Geology of Ethiopia*. Haile Selassie I University Press, Addis Ababa.

37. Morton, B. (1976). *A Field Guide to Ethiopian Minerals, Rocks and Fossils*. Addis Ababa University Press, Addis Ababa.

38. Mueller-Dombois, D. and Ellenberg, H. (1974). *Aims and Methods of Vegetation Ecology*. Wiley and Sons, New York.

39. Popma, J., Bongers, F. and Meave del Castillo, J. (1988). Patterns in the vertical structure of tropical lowland rain forest of Los Tuxtals, Mexico. *Vegetatio* **74**:81–91.

40. Sebsebe Demissew (1988). The floristic composition of Menagesha State Forest and the need to conserve such forests in Ethiopia. *Mountain Research and Development* **8**:243–247.

41. Shibru Tedla (1995). Protected Areas management crisis in Ethiopia. *Walia* **16**:17–30

42. Simon Shibru and Girma Balcha (2004). Composition, structure and regeneration status of woody species in Dindin Natural Forest, Southeast Ethiopia: An implication for conservation. *Ethiopian Journal of Biological Sciences* **3(1):**15–35.

43. Tadesse Woldemariam (1998). Diversity of woody plants and Avifauna in a dry Afromontane forest on the central plateau of Ethiopia. M.Sc. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.

44. Tadesse Woldemariam, Borsch, T., Denich, M. and Demel Teketay (2008). Floristic composition and environmental factors characterizing coffee forests in Southwest Ethiopia. *Forest Ecology and Management* **255**:2138–2150.

45. Tamrat Bekele (1993). Vegetation ecology of remnant Afromontane forests on central plateau of Shewa, Ethiopia. PhD Dissertation. Uppsala University, Uppsala, Sweden.

46. Taye Bekele, Haase, G. and Teshome Soromessa (1999). Forest genetic resources of Ethiopia: Status and proposed actions. In: *Forest Genetic Resources Conservation: Principles, Strategies and Actions,* pp. 39–47, (Edwards, S., Abebe Demissie, Taye Bekele and Haase, G., eds). Proceedings. The National forest genetic resources conservation strategy development workshop, June 21–22, 1999, IBCR and GTZ; Addis Ababa, Ethiopia.

47. The National Herbarium (2004). Biodiversity Assessment of the Bale Mountains National Park and Surrounding Areas. Conservation and Sustainable Utilization of Medicinal Plants Project. Addis Ababa, 88 pp.

48. van der Maarel, E. (1979). Transformation of cover-abundance values in phytosociology and its effects on community similarity. *Vegetatio* **39**:97–114.

49. van der Maarel, E., Espejel, I. and Moreno-Casasola, P. (1987). Two-step vegetation analysis based on very large data sets. *Vegetatio* **68**:139–143.

50. Walter, H. (1985). *Vegetation of the Earth and Ecological System of the Geobiosphere,* 3rd ed. Berlin, Heidelberg, New York, 318 pp.

51. Williams, S. (2002). *Bale Mountains: A guidebook*. EWCP, 52 pp.

Appendix I. List of species in the Dry Afromontane Forest of Bale Mountains National Park. {Key: GF [growth form], H [herb], S [shrub], T [tree], Li [liana], H(clim) [herbaceous climber], E [epiphyte], PH [parasitic herb]}

Scientific Name	Family	Local Name	GF	Coll.No
Achyranthes aspera L.	Amaranthaceae	Roppe, Qorsa Waranssa	H	200
Agrocharis melanantha Hochst.	Apiaceae	Hindriffa, Bobonka	H	256
Agrostis sclerophylla C.E. Hubb.	Poaceae	Merga	H	356
Ajuga bracteosa Wall. ex Benth. in Wall.	Lamiaceae		H	333
Alchemilla abyssinica Fresen.	Rosaceae	Hindriff	H	266
Alchemilla ellenbeckii Engl.	Rosaceae	Hidhanhidhoo	H	191
Alchemilla pedata A. Rich.	Rosaceae	Hindriff, Indriif Hindriiffi bala	H	264
Alepidea peduncularis Steud. ex A. Rich.	Apiaceae		H	399
Anaptychia liucomeleana Wain	Lichen		E	345
Anchusa affinis R.Br.	Boraginaceae	Burii Jeldessa	H	300
Andropogon amethystinus Steud.	Poaceae	Bulto	H	384
Andropogon lima (Hack.) Stapf	Poaceae	Wegel Seber (Amh)	H	379
Anthemis tigreensis J. Gay ex A. Rich.	Asteraceae		H	287
Anthoxanthum aethiopicum I. Hedberg	Poaceae		H	375
Argyrolobium confertum Polhill	Fabaceae		H	192
Arisaema schimperianum Schott	Araceae	Chobii	H	319
Aristida tuniculata Trin. and Rupr.	Poaceae	Laancaa	H	370
Artemisia abyssinica Sch. Bip.	Asteraceae	Merga dima	H	227
Artemisia afra Jacq. ex Willd.	Asteraceae	Tepeno	S	286
Asparagus africanus Lam.	Asparagaceae	Seriti	S	301
Asparagus setaceus (Kunth) Jessap	Asparagaceae	Seriti	S	79
Asplenium aethiopicum (Burm.f.) Bech.	Aspleniaceae	Qumbuta	E	339
Asplenium monanthes L.	Aspleniaceae	Qumbuta	H	340
Asplenium theciferum (Kunth) Merr.	Aspleniaceae		E	341
Astragalus atropilosulus (Hochst.) Bange	Fabaceae	Hara	S	246
Bartsia abyssinica Hochst. ex Benth.	Scrophulariaceae	Daffura	H	294
Bartsia petitiana (A. Rich.) Hemsl.	Scrophulariaceae		H	298
Bidens macroptera (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	Hade gola	H	44
Bidens prestinaria (Sch. Bip.) Cuf.	Asteraceae	Hade gola	H	289
Brachycorythis buchananii (Schltr.) Rolfe	Orchidaceae	Shumbura gala	H	310
Bromus pectinatus Thunb.	Poaceae	Alanmuressa	H	388
Campanula edulis Forssk.	Campanulaceae	Rirmu	H	303
Cardamine hirsuta L.	Brassicaceae	Biribina	H	234
Cardamine obliqua A. Rich.	Brassicaceae	Raffuu simbira	H	242
Carduus nyassanus (S. Moore) R.E. Fries	Asteraceae	Qore Haree	H	49
Carduus leptacanthus Fresen.	Asteraceae	Qore Haree	H	398
Carex bequaertii De Wild.	Cyperaceae	Alanmuressa	H	368
Carex chlorosaccus C.B. Clarke	Cyperaceae		H	383
Carex conferta Hochst. ex A. Rich.	Cyperaceae	Alando, Alanmuressa	H	362
Carex echinochloë Kunze	Cyperaceae		H	360
Carex simensis Hochst. ex A. Rich.	Cyperaceae	Alanmuressa	H	365
Carex thomasii Nelmes	Cyperaceae	Alanmuressa	H	366
Centella asiatica (L.) Urb.	Apiaceae	Balee, Qudu	H	233
Centhrus setigerus Vahl	Poaceae	Serdo (Amh)	H	386
Cerastium afromontanum Th. Fr. jr. and Weimarck	Caryophyllaceae	Duqusha chuffa	H	237
Ceropegia cufodontis Chiov.	Asclepiadaceae	Xxorso	H(clim)	224
Cheilanthes farinosa (Forssk.) Kaulf.	Sinopteridaceae		H	157
Chiliocephalum schimperi Benth.	Asteraceae	Badubera, Muka Dadi	H	204
Chlorophytum tenuifolium Bak.	Anthericaceae		H	315
Cineraria abyssinica Sch. Bip. ex A.Rich	Asteraceae	Gori Amaa, Gale Simbira	H	211
Clematis hirsuta Perr. and Guill.	Ranunculaceae	Fitii	Li	241
Commelina africana L.	Commelinaceae	Gura Jarsa	H	305
Commelina foliacea Chiov.	Commelinaceae	Marga Simbira	H	78
Conyza tigreensis Oliv. and Hiern	Asteraceae	Anamuro, Qumbi, Darara Simbira	H	210
Conyza variegata Sch. Bip. ex A. Rich.	Asteraceae		H	212

Appendix I. (Contd).

Scientific Name	Family	Local Name	GF	Coll.No
Crassula alba Forssk.	Crassulaceae	Burii Jeldessa	H	400
Crassula schimperi Fisch. and Mey	Crassulaceae		H	231
Craterostigma plantagineum Hochstetter	Scrophulariaceae		H	307
Crepis carbonaria Sch. Bip.	Asteraceae	Marga Hoffi	H	218
Crepis ruepellii Sch. Bip.	Asteraceae		H	45
Cuscuta kilimanjari Oliv.	Cuscutaceae	Segeniti	PH	293
Cyanotis polyrrhiza Hochst. ex Hassk.	Commelinaceae		H	302
Cycniopsis humifusa (Forssk.) Engl.	Scrophulariaceae		H	295
Cynoglossum amplifolium Hochst. ex DC.	Boraginaceae	Qarccabbaa	H	299
Cynoglossum coeruleum Hochst.	Boraginaceae	Qarccabbaa	H	74
Cyperus elegantulus Steud.	Cyperaceae		H	389
Cyperus platycaulis Baker	Cyperaceae		H	363
Cyperus rigidifolius Steud.	Cyperaceae	Alandoo, Aladoo (Or.), Engicha (Amh)	H	361
Cyperus schimperianus Steud.	Cyperaceae	Alando	H	358
Deschampsia caespitosa (L.) P. Beauv.	Poaceae	Looyaa, BuriiJaldeessa	H	374
Dichondra repens J.R. and G.Frost.	Convolvulaceae	Bala Toko	H	312
Dicrocephala chrysanthemifolia (Blume) DC.	Asteraceae	Marga Simbira	H	206
Dicrocephala integrifolia (L.f.) Kuntze	Asteraceae	Rafu Osole	H	284
Digitaria abyssinica (Hochst. ex A. Rich.) Stapf	Poaceae	Meqala	H	378
Discopodium eremanthum Chiov.	Solanaceae	Meraro	S	320
Indigofera lupatana Bak.f.	Fabaceae	Shashamane	H	245
Echinops hoehnelii Schweinf.	Asteraceae	Qore Haree	S	291
Echinops macrochaetus Fresen.	Asteraceae	Tuqa, Qoree	H	290
Ehrharta erecta Lam.	Poaceae		H	377
Eleusine floccifolia (Forssk.) Spreng.	Poaceae	Maqala (Or.), Akirima (Amh)	H	351
Eragrostis schweinfurthii Chiov.	Poaceae		H	367
Erica arborea L.	Ericaceae	Satoo	S/T	250
Erigeron alpinus L.	Asteraceae		H	285
Erodium moschatum (L.) Ait.	Geraniaceae		H	199
Euphorbia depauperata A. Rich.	Euphorbiaceae	Guri Xixiqo	H	258
Euphorbia dumalis S. Carter	Euphorbiaceae	Gurii	S	20
Euphorbia platyphyllos L.	Euphorbiaceae		H	198
Eurynchium pulchellum (Hedw.) Jenn.	Bryophytes	Hansufe	E	347
Felicia abyssinica Sch. Bip. ex A. Rich.	Asteraceae		H	230
Ferula communis L.	Apiaceae	Gnida	H	257
Festuca richardii Alexeev	Poaceae	Yeqoq Sar (Amh)	H	353
Festuca simensis Hochst. ex A. Rich.	Poaceae	Lancha	H	382
Ficinia clandestina (Steud.) Bock.	Cyperaceae	Chekorsa	H	357
Galium simense Fresen.	Rubiaceae	Maxxane (Or.), Asheket (Amh)	H	251
Galium thunbergianum Eckl. and Zeyh.	Rubiaceae	Xooshinbaate	H	238
Geranium arabicum Forssk.	Geraniaceae	Bucha	H	265
Geranium kilimandscharicum Engl.	Geraniaceae	Balee Tiqo	H	190
Gerbera piloselloides (L.) Cass.	Asteraceae		H	280
Gladiolus candidus (Rendle) Goldblatt	Iridaceae	Hanxxaye	H	393
Gnaphalium rubriflorum Hilliard	Asteraceae	Badubera	H	216
Guizotia scabra (Vis.) Chiov.	Asteraceae	Hadaa (Or.), Mech (Amh)	H	209
Gynura pseudochina (L.) DC.	Asteraceae	Raffu	H	220
Habenaria peristyloides A. Rich.	Orchidaceae	Kerkashaw	H	309
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	Hexxoo	T	51
Haplocarpha rueppellii (Sch. Bip.) Beauv.	Asteraceae		H	276
Hebenstretia angolensis Rolfe	Scrophulariaceae		H	296
Helichrysum citrispinum Del.	Asteraceae		S	279
Helichrysum foetidum (L.) Moench.	Asteraceae		H	283
Helichrysum globosum A. Rich.	Asteraceae		H	281
Helichrysum gofense Cufod.	Asteraceae	Irsha	H	43
Helichrysum harenensis Mesfin.	Asteraceae	Hoffii	H	215

Appendix I. (Contd).

Scientific Name	Family	Local Name	GF	Coll.No
Helichrysum quartinianum A. Rich.	Asteraceae	Agadena	H	205
Helichrysum schimperi (Sch. Bip. ex A. Rich.) Moeser	Asteraceae	Badubera	H	292
Helichrysum splendidum (Thunb.) Less.	Asteraceae	Badubera	S	214
Helictotricon elongatum (Hochst. ex A. Rich.) C.E. Hubb.	Poaceae	Maaxaa	H	373
Heracleum abyssinicum (Boiss.) Norman	Apiaceae	Bosoqa	H	271
Heracleum elongense (Wolff) Bullock	Apiaceae	Qumbuta	H	272
Heterophyllum haldanianum (Grev.) Kindb.	Bryophytes		E	346
Hydrocotyle mannii Hook.f.	Apiaceae		H	273
Hyparthelia dissoluta (Steud.) W.D. Clayton.	Poaceae	Loya	H	381
Hypericum annulatum Moris	Hypericaceae	Sissa	H	195
Hypericum peplidifolium A. Rich.	Hypericaceae		H	193
Hypericum revolutum Vahl	Hypericaceae	Garamba	T/S	27
Hypericum scioanum Chiov.	Hypericaceae		H	196
Impatiens rothii Hook. f.	Balsaminaceae		H	255
Juncus effusus L.	Juncaceae	Alando	H	311
Juniperus procera L.	Cupressaceae	Hindessa	T	53
Kalanchoe petitiana A. Rich.	Crassulaceae		S	28
Kniphofia foliosa Hochst.	Asphodelaceae	Lela	H	317
Kniphofia insignis Rendle.	Asphodelaceae	Lela Xixiqo	H	314
Kniphofia isoetifolia Steud. ex Hochst.	Asphodelaceae	Lela Xixiqo	H	316
*Koeleria capensis (*Steud.) Nees	Poaceae		H	355
Kyllinga bulbosa Vahl	Cyperaceae	Qumbura	H	364
Linum trigynum L.	Linaceae		H	225
Lobelia erlangeriana Engl.	Lobeliaceae		H	308
Lobelia holstii Engl.	Lobeliaceae		H	306
Lobelia neumannii T.C.E. Fries	Lobeliaceae		H	304
Lobularia sp.1	Lichen		E	348
Lobularia sp.2	Lichen		E	349
Lotus corniculatus L.	Fabaceae	Toshimbata, Qeticha	H	187
Lotus goetzei Harms	Fabaceae	Garasita	H	185
Lotus schoelleri Schweinf.	Fabaceae	Garasita	H	275
Malva verticillata L.	Malvaceae	Lita	S	136
Maytenus obscura (A. Rich.) Cuf.	Celastraceae	Kombolcha	S	208
Mentha aquatica L.	Lamiaceae	Buchaa, Duqusha (Or.), Yemich medihanit (Amh)	H	327
Merendera schimperiana Hochst.	Colchicaceae		H	313
Microchloa kunthii Desv.	Poaceae	Marga Dima	H	352
Microlepia speluncae (L.) Moore	Dennstaediaceae	Kumbuta	H	343
Mikaniopsis clematoides (Sch. Bip. ex A. Rich.) Milne-Redh.	Asteraceae	Kumbuta	Li	207
Minuartia filifolia (Forssk.) Mattf.	Caryophyllaceae	Qerqora, Qerqora gale	H	244
Moraea schimperi (Hochst.) Pic.-Serm.	Iridaceae	Loga	S	318
Myrsine melanophoeos (L.) R. Br.	Myrsinaceae	Tuullaa	T	250
Nepeta azurea R.Br. ex Benth.	Lamiaceae		S	329
Oldenlandia herbacea (L.) Roxb.	Rubiaceae	Omachessaa	H	228
Oldenlandia monanthos (A. Rich.) Hiern	Rubiaceae	Marga Dima	H	229
Oxalis anthelmintica A. Rich.	Oxalidaceae	Soqido	H	260
Oxalis obliquifolia A. Rich.	Oxalidaceae		H	263
Oxalis radicosa A. Rich.	Oxalidaceae		H	261
Oxystelma bornouense R. Br.	Asclepiadaceae	Xxorso, Anano	H(clim)	201
Pelargonium glechomoides Hochst.	Geraniaceae		H	189
Pennisetum humile Hochst. ex A. Rich.	Poaceae		H	369
Pennisetum sphacelatum (Nees) Th. Dur. and Schinz	Poaceae	Wixxa	H	380
Pentarrhinum balense (Liede) Liede	Asclepiadaceae		H(clim)	203
Phalaris arundinacea L.	Poaceae		H	376
Pittosporum viridiflorum Sims	Pittosporaceae	Ara	T	249
Plantago africana Verdc.	Plantaginaceae	Qinxaa, Baallee	H	297
*Plectocephalus varians (*A. Rich.) C. Jeff. ex Cuf.	Asteraceae	Qumbura	H	277

Appendix I. (Contd).

Scientific Name	Family	Local Name	GF	Coll.No
Plectranthus puberulentus J.H. Morton	Lamiaceae	Biranbira	H	336
Pleopeltis macrocarpa (Willd.) Kaulf	Polypodiaceae		E	342
Poa schimperiana Hochst. ex A. Rich.	Poaceae		H	371
Pollichia campestris Ait.	Caryophyllaceae		H	235
Polygala steudneri Chod.	Polygalaceae	Garasita	H	186
*Polypogon schimperianus (*Hochst. ex Steud.) Cope	Poaceae		H	354
*Polystichum ammifolium (*Poir.) C.Chr.	Dryopteridaceae	Qumbuta, Gammanyee	H	338
Pseudognaphalium luteo-album (L.) Hilliard and Burtt	Asteraceae		H	282
Ranunculus multifidus Forssk.	Ranunculaceae	Sherif	H	267
Ranunculus simensis Fresen.	Ranunculaceae		H	268
Rosa abyssinica Lindley	Rosaceae	Gora	S	142
Rubus apetalus Poir.	Rosaceae		S	262
Rubus erlangeri Engl.	Rosaceae	Hato	S	202
Rubus steudneri Schwienf.	Rosaceae	Gora	S	14
Rumex abyssinicus Jacq.	Polygonaceae	Shabee Haga	H	269
Rumex nepalensis Spreng.	Polygonaceae	Shabee	H	29
*Rytidosperma subulata (*A. Rich.) Cope	Poaceae	Marga Hori, Qecha	H	359
Salvia merjame Forssk.	Lamiaceae	Okotu	S	330
Salvia nilotica Jacq.	Lamiaceae	Okotu	H	332
Sanicula elata Buch. -Ham. ex D.Don	Apiaceae	Galee Simbira, Sidissa	H	270
*Satureja biflora (*Don.) Briq.	Lamiaceae	Tosign	H	335
Satureja kilimandeschari (Gurke) Hedberg	Lamiaceae		H	324
Satureja pseudosimensis Brenan	Lamiaceae	Toshimbata	H	325
*Satureja punctuta (*Benth.) Briq.	Lamiaceae		H	326
*Satureja simensis (*Benth.) Briq.	Lamiaceae	Toshimbata	H	328
Scabiosa columbaria L.	Dipsacaceae	Anamuro	H	222
Sedum baleensis M. Gilbert	Crassulaceae	Qorso gogorii	H	274
Senecio ochrocarpus Oliv. and Hiern	Asteraceae	Agadena	H	278
Senecio ragazzii Chiov.	Asteraceae	Agadena	H	221
Silene macrosolen A. Rich.	Caryophyllaceae	Wagarti	H	248
Solanum anguivi Lam.	Solanaceae	Mujule Worabessa	S	69
Solanum benderianum Schimper ex Dammer	Solanaceae		S	322
Solanum garae Friis	Solanaceae		S	321
Solanum marginatum L.f.	Solanaceae	Hidii	S	68
Sonchus bipontini Aschers	Asteraceae	Kartassa, Maaracaa	H(clim)	288
Sporobolus africanus (Poir.) Robyns and Tournay	Poaceae	Marga Hilensa (Or.), Mure (Amha)	H	350
Stachys alpigena T.C.E.Fries	Lamiaceae	Qorsa alati, Merga simbira, Qoricha gemogi, Dara simbira	H	334
*Stellaria media (*L.) Vill.	Caryophyllaceae	Mosiye (Amh)	H	226
Stellaria sennii Chiov.	Caryophyllaceae	Duqushu, Dinbiba	H	239
Thalictrum rhynchocarpum Dill. and A. Rich.	Ranunculaceae	Sire Bizu (Amh)	H	254
Thymus schimperi Ronniger	Lamiaceae	Tossigne	H	331
Trifolium burchellianum Ser.	Fabaceae		H	183
Trifolium substerraneum L.	Fabaceae	Sidissa	H	184
Trifolium cryptopodium Steud. ex A. Rich.	Fabaceae		H	194
Trifolium rueppellianum Fresen.	Fabaceae	Sidissa (Maget)	H	182
Trifolium semipilosum Fresen.	Fabaceae	Sidissa	H	181
Trifolium simense Fresen.	Fabaceae		H	247
Lychnis abyssinica (Hochst.) Lidén	Caryophyllaceae	Balee	H	240
Ursinia nana DC.	Asteraceae	Qinxxa	H	219
Urtica simensis Steudel	Urticaceae	Dobii	H	252
Usnea africana Motyka	Lichen	Ye' Abuye tsim	E	344
Verbascum benthamianum Hepper	Scrophulariaceae	Rafuu Mada	H	323
Vicia sativa L.	Fabaceae		H	197
Viola abyssinica Oliv.	Violaceae		H	337
Zehneria scabra (Linn.f.) Sond.	Cucurbitaceae	Harola	H(clim)	124

Appendix II. Dendrogram output of the cluster analysis showing the five communities and respective plots.