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THE UNDIFFERENTIATED AFROMONTANE FOREST OF DENKORO IN THE CENTRAL HIGHLAND OF ETHIOPIA: A FLORISTIC AND STRUCTURAL ANALYSIS

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ABSTRACT: The floristic composition and vegetation structure of Denkoro forest, South Wello Zone of Amhara Region, N. Ethiopia, were described during November–December, 2002. A total of 95 sample plots were analysed, and 174 species of vascular plants representing 66 families were recorded. Out of these, 41 species were new records reported for the first time from Wello. Eleven endemic species, which are included in the IUCN Red List categories, have been recorded. Based on the results of vegetation classification, six clusters were recognized and designated as local plant community types: 1) *Erica arborea - Hypericum revolutum,* 2) *Myrsine melanophloeos - Dombeya torrida,* 3) *Myrsine africana – Maesa lanceolata – Prunus africana,* 4) *Olinia rochetiana – Olea europaea,* 5) *Olinia rochetiana – Allophylus abyssinicus – Apodytes dimidiata*, and 6) *Maytenus gracilipes – Teclea nobilis*. Structural analysis of the forest showed the density of individuals > 10 cm DBH to be almost twice as that of individuals with DBH >20 cm. A higher proportion of woody individuals (ca. 65%) fell in the low height classes (*i.e.*, < 12 m). Analysis of population structure revealed five patterns, depicting the species dynamics in the forest. When compared with other forests in Ethiopia, Denkoro forest shows similarity to the dry evergreen montane forests of the Central Plateau than those elsewhere.

Key words/phrases: Afromontane forest, central plateau, plant community, phytogeography, Wello

INTRODUCTION

A substantial proportion of the land area in highland Ethiopia was once believed to have been covered by forests. However, evidence to verify this assumption is lacking, and according to Friis (1986) it is difficult to establish the precise extent of forest coverage in Ethiopia. Available statistics do not distinguish between the natural high forest, secondary forest and other serial stages in forest regrowth. Any estimation of the past coverage, (*e.g.*, Logan, 1946) is far from being realistic, as it has so far to rest on estimates based on the distribution of rainfall and forest relic patches.

The reduction in forest vegetation was due to climatic changes and human activities (Hamilton, 1974). In the latter case, clearing for cultivation, burning to create pasture lands, and improper cutting practices have reduced the forest area to a small fraction of the total area of the country.

Destruction of forest in the Afromontane zone of Wello, north eastern Ethiopia, has been documented through carbon dating of charcoal as far back as 2450 BP (Hurni, 1985). The forest has been replaced by cultivated fields and by various types of shrub land and grassland (Pichi-Sermolli, 1957; Kebrom Tekle *et al.*, 1997).

In order to maintain the ecological equilibrium of the environment and meet the forest resource requirements of the population, collection of scientific information on the composition, structure and distribution of the species becomes a primary activity in areas where this has not been achieved. Recent studies into the flora and vegetation of South Wello include those that dealt with the ecological rehabilitation of degraded hill slopes (Kebrom Tekle, 1998), flora (Sebsebe Demissew, 1998), and plant population dynamics of selected species (Tesfaye Bekele, 2000).

Denkoro forest is one of the forests that had been designated as a National Forest Priority Area (NFPA) in the country (EFAP, 1994). However, no study so far has been carried on the vegetation of Denkoro forest. This has become a serious handicap for the management and rational utilization of the forest resources of the area. Therefore, species documentation, classification and description of the forest have been found timely. The present study is conducted with the following objectives in mind:

- To analyse the floristic composition of the forest,
- To analyse the vegetation structure of the forest,

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- To classify the forest vegetation into plant community types,
- To make phytogeographical comparisons with other forests in Ethiopia,
- To make some recommendations on the management and conservation of the forest vegetation.

MATERIALS AND METHODS

The study area

The study site is located in the South Wello Zone (Amhara Regional State), and situated approximately between 10° 47′–10° 50′N and 38° 35′ – 38° 42′E (Fig. 1). According to EFAP (1994) the land area of Denkoro forest is 8000 ha, which makes it the smallest forest among the National Forest Priority Areas (NFPA) in Ethiopia. The study area is generally characterized by rough topography with mountains, deeply incised valleys, escarpments and plateaus. South Wello, which ranges from 1500 to 3500 m a.s.l (MoPED, 1993), is in most parts covered by volcanic rocks mainly basalts of Tertiary age (Anonymous, 1988, cited in Tesfaye Bekele, 2000).

The natural vegetation of the study area had been broadly classified as *Juniperus procera* forest or "dry evergreen montane forest" with *J. procera* and/or *Olea europaea* ssp. *cuspidata* as the dominant species (Mesfin Tadesse, 1990; Friis, 1992).

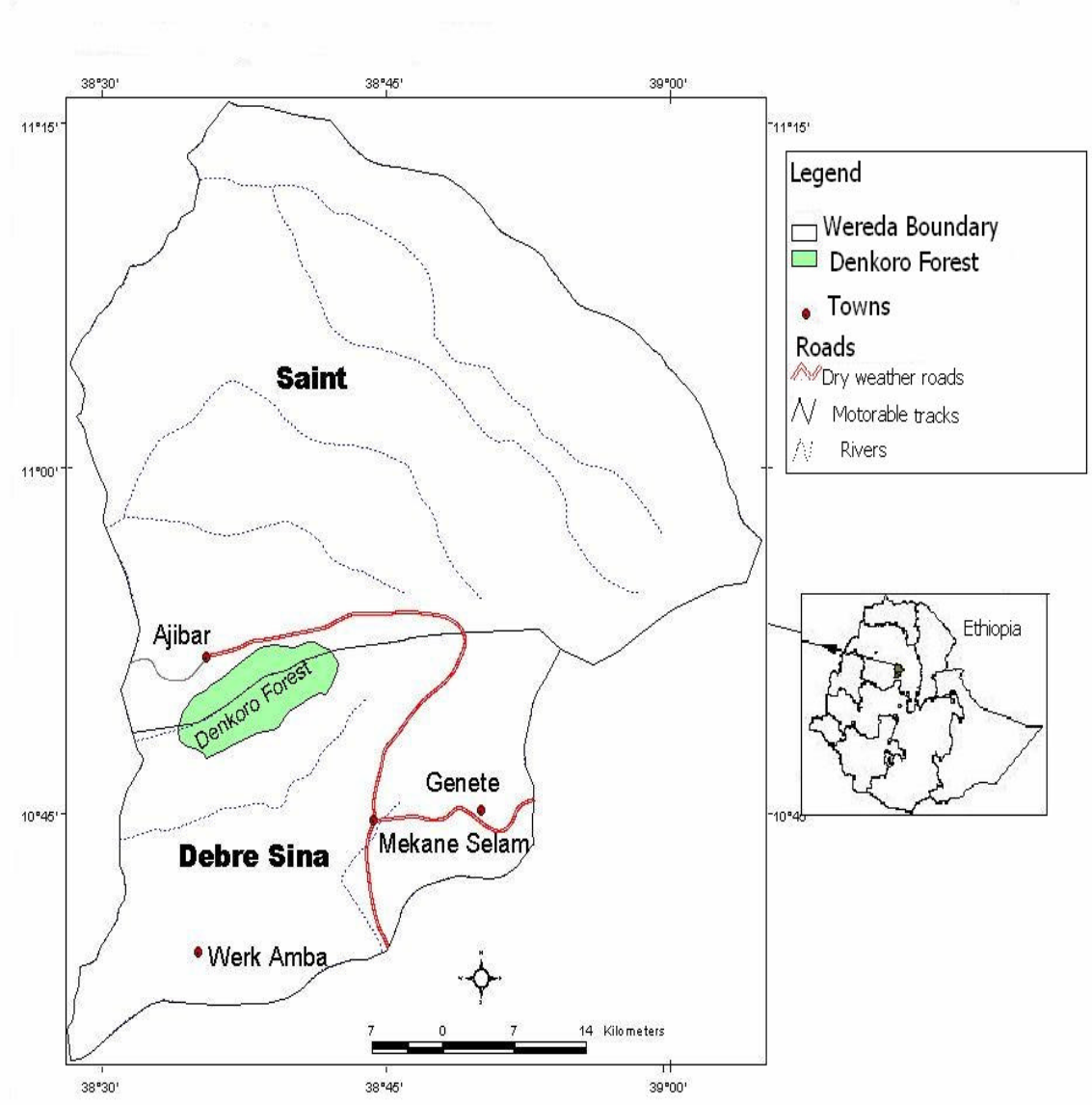

Fig. 1. Location map of the study area.

The distribution of rainfall in South Wello is bimodal, characterized by a prolonged wet season from June to September (big rains), and a short season from March to April (small rains). The small rainy season is erratic and highly variable. There is a long dry period from the beginning of November to the end of February, and a short dry spell in May. The climatic diagram of Mekane Selam station, about 20 km from the forest, is presented in Fig. 2.

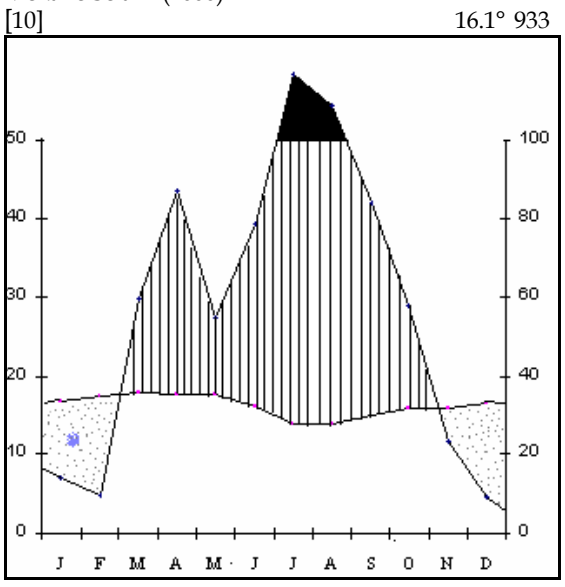

Fig. 2. Climatic diagram for the town of Mekane Selam, (Drawn after Walter, 1985). (Source of climate data: National Metrological Service Agency).

Floristic data collection

A reconnaissance survey of Denkoro forest was made between November 10 and 12/ 2002 in order to obtain an impression of the floristic diversity of the vegetation. Actual field data were collected from November 13 to December 6, 2002. A total of 95 relevés were analysed from the whole forest. Sample plots were systematically selected following the Braun-Blanquet approach as described in van der Maarel (1979).

Trees and shrubs were sampled in 25m x 25m quadrats, while herbaceous and graminoid species were analyzed in 1m x 1m quadrats that are subjectively placed within the larger quadrat. A complete list of trees, shrubs and herbs was made from each plot. Percent cover value was estimated for each species and later converted to the Braun-Blanquet 1–9 scale as modified by van der Maarel (1979).

Additional plant species occurring out of the plots, but inside the forest, were recorded. Climbers were noted as present when encountered. Notes were also made on the total number of dead standing trees, stumps and logs in the plot. At each sampling site, altitude was measured using Pretzel digital altimeter, and aspect using Suunto M-3D Leader Compass.

Plant specimens in each quadrat were recorded, along with their vernacular names when available, and collected and pressed for later identification. Identification was made at the National Herbarium, Addis Ababa University, following the Flora of Ethiopia (Hedberg and Edwards, 1989; 1995; Edwards *et al*., 1995; 1997; 2000). Voucher specimens are kept in the National Herbarium.

Structural data collection

All individuals of trees and shrubs with a diameter at breast height (DBH) greater than 2 cm, and height greater than 2 m were measured for height and DBH. Individuals with DBH less than 2 cm, and height less than 2 m were counted. Height measurement was done with Suunto Height Meter and DBH with measuring Caliper and Meter tape. Where slope, topography and/or crown structure made it difficult to use the height meter, heights were estimated visually. If the tree branched at about breast height, the diameter was measured separately for the branches.

Data analysis

Releve's were grouped into clusters with the aid of the program TWINSPAN (Hill, 1979). The clusters were further refined in a synoptic table where each column represents a community type, and species occurrences were summarized by synoptic cover-abundance values. Synoptic values are the products of the species' frequency and average cover-abundance values (van der Maarel *et al*., 1987). The clusters were designated as local plant community types and given names after one, two or three dominating and/or characteristic tree and shrub species as selected by their synoptic value.

Floristic comparison between the vegetation of Denkoro and other nine forests from Ethiopia was made based on the presence/absence of tree and shrub species. The similarity index used is Sorenson's similarity coefficient: 2c/(a+b); where "c'' is the number of species shared by the forests compared, "a'' is the number of species in one forest, "b'' is the number of species in the other forest.

The structure of the forest was described through the analyses of tree density, girth diame-

ter, height, and basal area. Tree density and basal area values were computed and described on a hectare basis. The diameter at breast height (DBH) was classified into six DBH classes (*i.e.*, 10–20 cm, 20–50 cm, 50–80 cm, 80–110 cm, 110–140 cm, >140 cm), and the percentage distribution of individuals in each class was calculated. Tree height was also classified into nine classes (*i.e.*, 6–9 m, 9–12 m, 12–15 m, 15–18 m, 18–21 m, 21–24 m, 24–27 m, 27–30 m, >30 m), and percentage distribution of individuals in each class was calculated. The vegetation of Denkoro forest was later compared with selected Afromontane forests of the central plateau based on the above structural attributes.

RESULTS

Floristic composition

A total of 174 species of vascular plants representing 66 families were recorded from the forest (a complete species list can be provided upon request). The floristic and structural analysis was based on 109 species that were collected from within the quadrats. Of the species collected, 62.4% were herbs, 14.5% trees, 3.5% trees/shrubs and 19.6% were shrubs. Of the total species, dicots constituted 80.9%, monocots 17.9%, and Pteridophytes 1.2%.

Six climber species were recorded from the families Asclepiadaceae, Ranunculaceae, Convolvulaceae, Cucurbitaceae, Phytolaccaceae, and Urticaceae. A species from a lichen genus, *Usnea*, has also been recorded.

Vegetation classification

Six plant associations, designated as 'community types', were recognized from the vegetation analysis. A list of the community types along with the synoptic cover-abundance values of the species is given in Table 1. One releve, which did not fit into any cluster was considered to represent a fragmentary development, and was excluded from subsequent analysis. The following is a description of the community types identified from the forest.

1. *Erica arborea-Hypericum revolutum* type

The *Erica arborea-Hypericum revolutum* type is found from 2990 to 3340 m.a.s.l. The characteristic species in the tree layer is *Erica arborea*. *Hypericum revolutum* and *Myrsine melanophloeos* are the other tree species in this layer. *Discopodium penninervium* is the character species in the shrub layer. *Achyranthes aspera* is the dominant species in the herb layer. *Alchemilla abyssinica*, *Festuca abyssinica*, and *Thymus schimperi* are the characteristic species in the field layer. Associated species in the field layer include *Sporobolus pyramidalis, Satureja simensis, Festuca macrophylla, Cerastium octandrum, Luzula abyssinica* and *Carex steudneri.* All *Erica arborea* individuals had been noted to possess a high coverage of the epiphytic lichen of the genus *Usnea.*

2. *Dombeya torrida- Myrsine melanophloeos* type

This community type is distributed between 2740 and 3165 m.a.s.l. *Myrsine melanophloeos* is the dominant species in the tree layer. *Dombeya torrida* is the character species and *Hypericum revolutum* and *Hagenia abyssinica* are the associated tree species in this layer. There was no prominent species in the shrub layer but a few individuals of *Myrsine africana* have been encountered. *Streblochaete logiarista* is the characteristic species in the field layer. *Achyranthes aspera* is the dominant species while *Carex steudneri, Cynoglossum coeruleum, Geranium arabicum, Ranunculus oreophytus, Rubus steudneri, Sanicula elata, Stachys alpigna, Stachys aculeolata, Solanum margintum* and *Carex steudneri* constitute the associated species in the field layer.

3. *Maesa lanceolata-Prunus africana* type

This community type was distributed from 2770 to 2860 m.a.s.l. The dominant tree species in this type is *Myrsine melanophloeos. Maesa lanceolata* and *Prunus africana* are the characteristic tree species. *Nuxia congesta* and *Bersama abyssinica* are the associated trees species in this community type. *Allophylus abyssinica* and *Juniperus procera* have been recorded in this type but in smaller numbers. *Myrsine africana* is the characteristic species in the shrub layer. The field layer is dominated by *Achyranthes aspera*.

4. *Olinia rochetiana-Olea europaea* type

This community type prevails between 2460 and 2765 m a.s.l. *Olinia rochetiana* and *Olea europaea* are the dominant tree species in the tree layer. The associated tree species in this community type include *Apodytes dimidiata, Bersama abyssinica* and *Nuxia congesta. Discopodium penninervium, Dovyalis abyssinica, Maytenus arbutifolia* were the species recorded from the shrub layer. *Achyranthes aspera* is the dominant species in the herb layer, while *Kalanchoe petitiana* and *Mimulopsis solmsii* are the associated species in the field layer.

5. *Olinia rochetiana–Allophylus abyssinicus-Apodytes dimidiata* type

This community type is distributed at the altitudes ranging from 2350 to 2660 m a.s.l. The dominant tree species in this type are *Olinia rochetiana* and *Apodytes dimidiata. Allophylus abyssinicus* is a characteristic tree species in this community type, while *Bersama abyssinica, Olea europaea ssp. cuspidata,* and *Nuxia congesta* are the associated species. *Ekebergia capensis, Myrsine melanophloeos, Myrica salicifolia, Prunus africana,* and *Scolopia theifolia* were rare in this community. Cl*erodendron alatum* is the characteristic shrub species. *Maytenus gracilipes* ssp. *arguta, Rosa abyssinica* and *Dovyalis abyssinica* were rare in occurrence in the shrub layer. *Achyrospermum schimperi* is a characteristic herb species in the field layer whereas *Achyranthes aspera* is the associated species.

6. Maytenus gracilipes-Teclea nobilis type

This community type is distributed from 2330 to 2445 m a.s.l. The characteristic tree species in this community is *Teclea nobilis.* The shrub layer is dominated by *Maytenus gracilipes*. *Cyperus dichroostachys* and *Snowdenia petitiana* are the characteristic species in the herb layer whereas *Achyranthes aspera* is the dominant one. Associated species in the field layer include *Mimulopsis solmsii* and *Kalanchoe petitina.*

Vegetation structure

Density

The density of all trees in Denkoro forest was 526 individuals per hectare for individuals with DBH >10 cm, and 285 individuals per hectare for individuals with DBH >20 cm. The ratio of DBH > 10 cm to DBH > 20 cm was very high (*i.e.*, 1.9), indicating a prevalence of small sized individuals in the forest. As indicated by Grubb *et al.* (1963), this ratio, described as a/b, is taken as a measure of the size class distribution.

A comparison of the density of trees in Denkoro forest with that of other dry Afromontane forests of the central plateau of Ethiopia is given in Table 2. Denkoro forest has the highest tree density for individuals with DBH > 20 cm, and ranks second for individuals with DBH > 10 cm DBH. On the other hand, Chilimo forest had the highest tree density for individuals with DBH > 10 cm.

Table 1. Synoptic cover-abundance values for species having a value of >1.0 in at least one community type.

	Type	I	II	III	IV	V	VI
	Size	8	19	8	21	23	15
Erica arborea		**6.3**	0.0	0.0	0.0	0.0	0.0
Hypericum revolutum		**4.6**	1.6	0.0	0.0	0.0	0.0
Alchemilla abyssinica		2.3	0.0	0.0	0.0	0.0	0.0
Festuca abyssinica		1.6	0.0	0.0	0.0	0.0	0.0
Discopodium penninervium		1.1	0.0	0.0	0.0	0.0	0.0
Thymus schimperi		1.1	0.0	0.0	0.0	0.0	0.0
Myrsine melanophloes		3.6	**6.1**	6.3	0.0	0.0	0.0
Achyranthes aspera		4.0	4.0	6.7	7.0	2.4	4.9
Streblochaete logiarista		0.0	3.5	0.0	0.0	0.0	0.0
Dombeya torrida		0.0	**1.8**	0.0	0.0	0.0	0.0
Maesa lanceolata		0.0	0.0	**4.9**	0.0	0.0	0.0
Prunus africana		0.0	0.0	**1.7**	0.0	0.0	0.0
Myrsine africana		0.0	0.0	1.0	0.0	0.0	0.0
Nuxia congesta		0.0	0.0	1.3	3.8	2.0	0.0
Bersama abyssinica		0.0	0.0	2.4	1.6	2.3	0.0
Mimulopsis solmsii		0.0	0.0	0.0	1.2	0.0	1.3
Kalanchoe petitiana		0.0	0.0	0.0	1.1	0.0	2.3
Apodytes dimidiata		0.0	0.0	0.0	1.8	4.9	0.0
Olea europaea		0.0	0.0	0.0	**4.0**	1.9	0.0
Olinia rochetiana		0.0	0.0	0.0	**6.2**	**5.0**	0.0
Clerodendron alatum		0.0	0.0	0.0	0.0	**3.1**	0.0
Achyrospermum schimperi		0.0	0.0	0.0	0.0	2.4	0.0
Allophylus abyssinicus		0.0	0.0	0.0	0.0	**1.1**	0.0
Maytenus gracilipes		0.0	0.0	0.0	0.0	1.0	**3.5**
Teclea nobilis		0.0	0.0	0.0	0.0	0.0	**1.1**
Cyperus dichroostachys		0.0	0.0	0.0	0.0	0.0	2.9
Snowdenia petitiana		0.0	0.0	0.0	0.0	0.0	1.2

* Values in bold refer to occurrences as characteristic/dominant species.

Table 2. Comparison of tree density (no./ha) of Denkoro forest with other dry Afromontane forests of the Central Plateau of Ethiopia.

Forest	DBH > 10cm(a)	DBH > 20cm(b)	a/b
Denkoro	526	285	1.9
Chilimo*	638	250	2.6
Menagesha*	484	208	2.3
Wof-Washa*	329	215	1.5

Note: * Source of information is Tamrat Bekele (1993).

Tree height and diameter

The distribution of individuals in different height classes is shown in Fig. 3. A significant proportion of the individuals in Denkoro forest (*i.e.*, > 65%) is found in the height classes 6–12 m. Only a very small proportion of the individuals (*i.e.*, 3%) attain heights of 21 m. The percentage distribution of individuals among the DBH classes is presented in Fig. 4. Most of the individuals, *i.e.*, about 97%, were in the DBH class < 50 cm, and a very small proportion (*i.e.*, 0.6%) attained DBH greater than 110 cm.

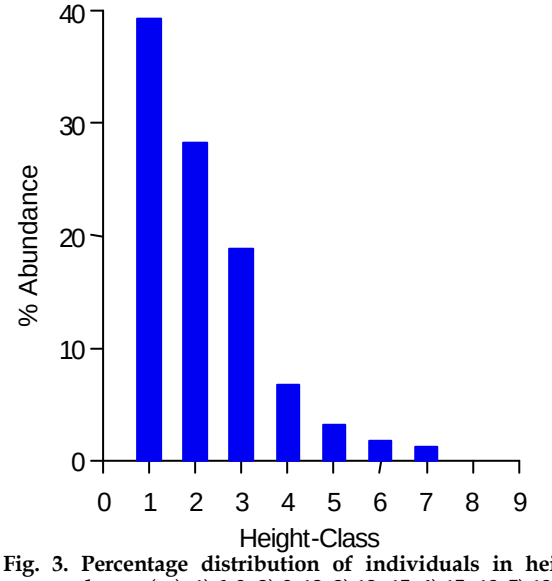

Fig. 3. Percentage distribution of individuals in height classes (m): 1) 6–9, 2) 9–12, 3) 12–15, 4) 15–18, 5) 18–21, 6) 21–24, 7) 24–27, 8) 27–30.

but their contribution to the total basal area is significant.

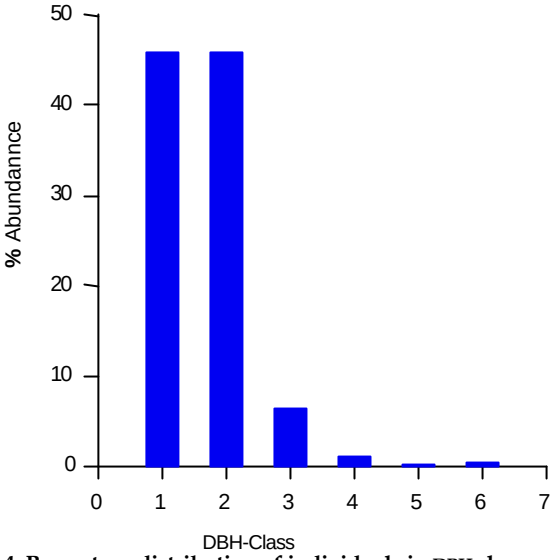

Fig. 4. Percentage distribution of individuals in DBH classes: 1) 10–20 cm, 2) 20–50 cm, 3) 50–80 cm, 4) 80–110 cm, 5) 110–140 cm, 6) >140 cm.

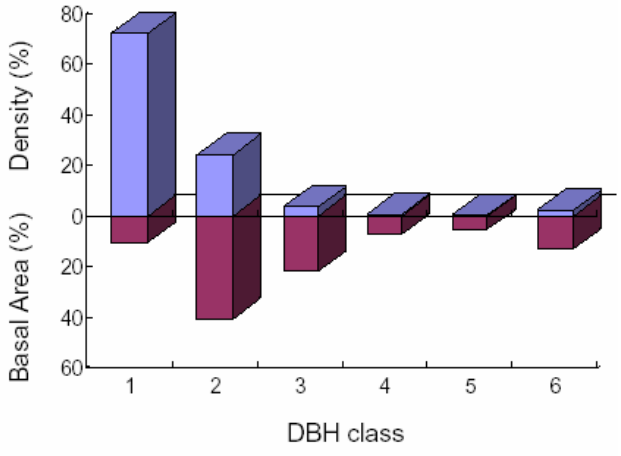

Fig. 5. Frequency distribution of individuals in DBH classes (all trees included) in Denkoro forest. 1, < 20 cm, 2, 20–50 cm, 3, 50–80 cm, 4, 80 110 cm, 5, 110–140 cm, 6, >140 cm). Blocks above the 0-line: figures based on relative DBH (%); blocks below the 0-line: figures based on relative basal area (%).

Basal area

The total basal area calculated for Denkoro forest is 45 m²/ha. Block diagrams depicting frequency distribution of trees among DBH classes are presented in Fig. 5. Most of the trees are small sized as shown by the peak in basal area in the lowest DBH classes (*i.e.*, < 50 cm). Individuals that belong to higher DBH classes are few in number,

The basal area and density distribution of six species, selected based on the basis of a high importance value index (IVI) is shown in Table 3. These species contribute to more than 50% of the total basal area, and 70% of the tree density of the forest. However, none of the six major species shows an overriding dominance over the others in terms of basal area.

Table 3. Basal area and density of the six most important tree species in Denkoro forest.

Species	Basal area		Density	
	m^2/ha	%	Stem/ha	%
Myrsine melanophloeos	5	11.1	350.8	34.5
Erica arborea	2	4.4	159.8	15.8
Olinia rochetaina	5.9	13.0	99.7	9.8
Apodytes dimidiata	5.3	11.9	28.8	2.8
Olea europaea	4.41	9.8	30.7	3
Nuxia congesta	2.3	5.1	46.1	4.5
Total	24.91	55.2	715.9	70.4

Species population structure

Five generalized patterns emerge from the analysis of the population structure of 25 selected species. An inverted 'J' type curve representing good reproduction and recruitment (*e.g., Erica arborea*) is shown by Type I curves (Fig. 6). Type II curves indicating a decline in the lowest size class, but good recruitment and establishment in other classes is portrayed by *Scolopia theifolia*. Type III curves represent intensive harvesting of small and medium sized individuals, and a dwindling population as shown by *Apodytes dimidiata*. Type IV curves indicate good reproduction and good recruitment, but selective cutting of individuals of intermediate sizes as observed in *Myrsine melanophloes*. Pattern V curves depicting poor reproduction and complete absence of individuals in intermediate classes, as exemplified by *Hagenia abyssinica* for instance, indicate a vanishing population.

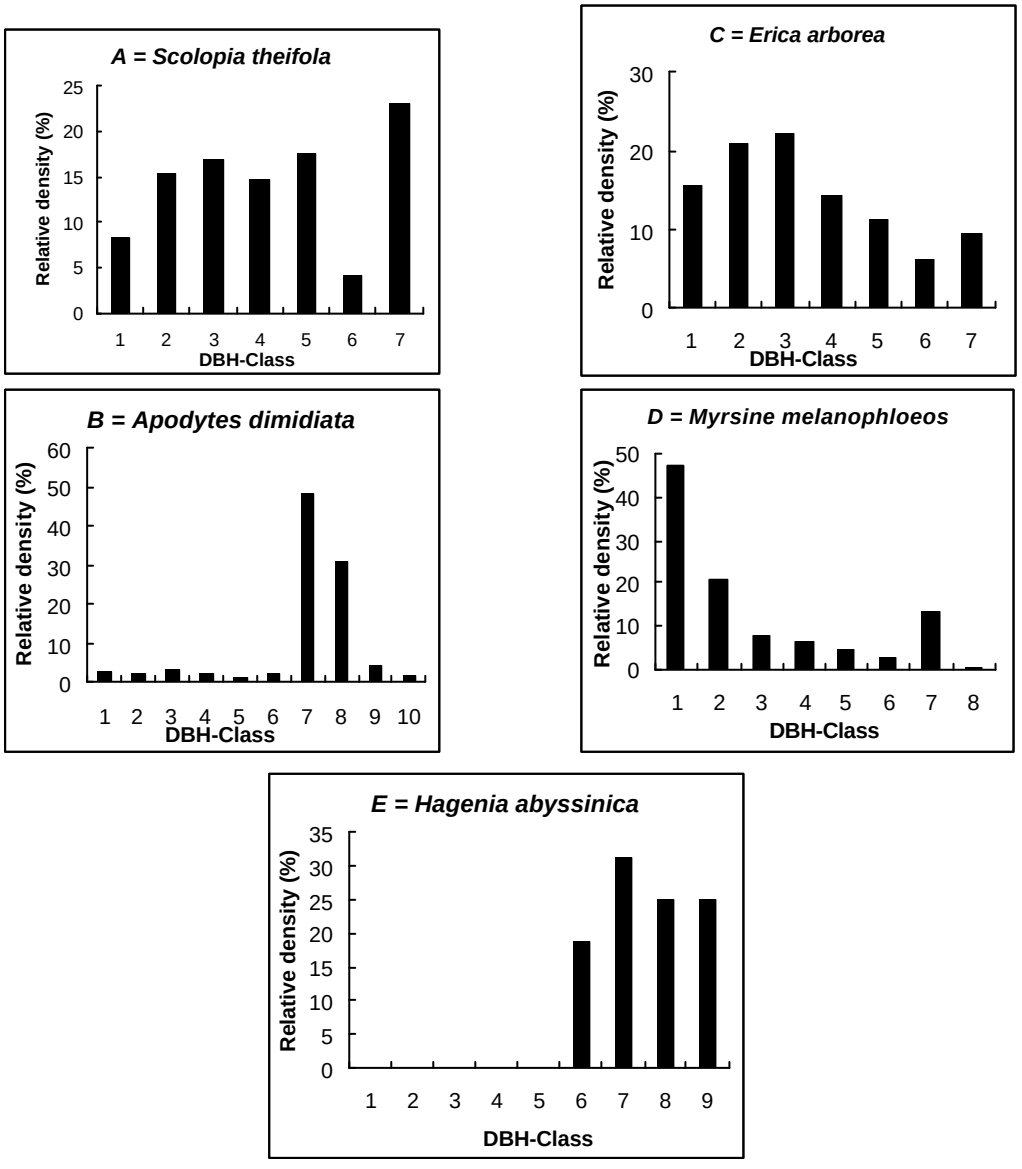

Fig. 6. Five representative patterns of frequency distribution of tree density values over DBH classes in the Denkoro forest. DBH class 1, 2–5 cm; 2, 5–8 cm; 3, 8–11 cm; 4, 11–14 cm; 5, 14 - 17 cm; 6, 17–20 cm; 7, 20–50 cm; 8, 50–80 cm; 9, 80–110 cm; 10, >110cm.

DISCUSSION

Floristic description

Out of the 174 species identified in the present study, 41 are new records not previously reported from Wello. The forest contains 12 endemic species which are in the IUCN Red List categories. These are *Acanthus sennii, Anthoxanthum aethiopicum, Conyza spinosa, Cynoglossum coeruleum, Festuca macrophylla, Kalanchoe petitiana, Kniphofia foliosa, Laggera tomentosa, Satureja paradoxa, Stachys alpigena, Thymus schimperi,* and *Urtica simensis*.

Eight indicator species for forest disturbance have been recorded from the forest. These include *Asparagus africanus, Commelina africana, Croton macrostachyus, Cyathula cylindrica, Euphorbia ampliphylla, Kalanchoe petitiana, Phytolacca dodecandra,* and *Sanicula elata*.

The *Erica arborea–Hypericum revolutum* community type prevails at very high elevations forming a distinct community towards the upper edge of the forest. Individuals of *Erica arborea* diminish in stature towards the upper limit of their distribution, and merge with the Afroalpine vegetation at about 3500 m a.s.l.

The vicinity of this plant community to human settlements has subjected it to high anthropogenic influences. It is customary for people from the surrounding villages to take cattle into the forest every evening for grazing, and return late at night holding clusters of firewood to serve as torch. The most preferred species for this are *Erica arborea* and *Hypericum revolutum.* According to local informants, most of the harvesting, particularly of *Erica arborea,* took place during the government transition in 1991 when prisoners, that were kept captive inside a large cave located in the forest, used the species extensively for fire wood.

The prevalence of abundant seedlings of *Myrsine melanophloeos, Hypericum revolutum,* and *Erica arborea* in this community obviously indicates that this community is regenerating and may persist in the future, provided appropriately managed.

The *Myrsine melanophloeos - Dombeya torrida* community type was characterized by medium sized trees with more or less interlocked canopies. Climbers covered some trees, and the community is dotted with some stumps, a large number of uprooted logs, and dead stands of trees, indicative of the magnitude of disturbance. The ground layer is covered with a thick layer of litter that is in different stages of decay. This will create a suitable condition for the rapid circulation of nutrients between the soil and the vegetation.

Myrsine melanophloeos and *Hypericum revolutum* showed better reproduction in this community, but it is the former, which showed a better recruitment. This is partly due to its good regeneration potential under tree canopies, and its un-palatability to herbivores. Only medium sized and old individuals of *Hagenia abyssinica* and *Dombeya torrida* were present, indicating that they are critically endangered. This is especially true for the former, whose floral parts are widely used in traditional medicine to eliminate tapeworm in humans.

Myrsine melanophloeos and *Maesa lanceolata* showed very good regeneration in the third community type (*i.e., Maesa lanceolata - Myrsine africana - Prunus africana* community type). Some seedlings of *Myrsine africana* and *Bersama abyssinica* were also encountered. On the other hand, no young trees of *Dombeya torrida*, *Prunus africana*, *Nuxia congesta* and *Hagenia abyssinica* were observed.

Species of *Myrsine melanophloeos, Discopodium penninervium* and *Bersama abyssinica* were regenerating abundantly in the *Olinia rochetiana - Olea europaea* community type. On the other hand, *Myrsine africana*, *Maytenus arbutifolia*, *Dovyalis abyssinica, Scolopia theifolia, Ekebergia capensis* and *Clerodendron alatum* showed poor regeneration, while *Olinia rochetiana*, *Juniperus procera*, *Olea europaea ssp. cuspidata*, *Hagenia abyssinica*, *Nuxia congesta* and *Prunus africana* showed no sign of regeneration at all.

This could be due to either the species' inability to regenerate under the parent plant, or because of total failure in regeneration. If the former is the case, this implies that the species requires special conditions to facilitate its germination. If it is the latter, for instance, as in the case of *Hagenia abyssinica*, then it would mean that the species' future is bleak, indicating possible extinction from the community. Some stumps, few logs and dead but standing individuals of *Erica arborea*, *Olinia rochetiana, Juniperus procera, Olea europaea* ssp. *cuspidata* and *Hagenia abyssinica* were notable.

Species such as *Bersama abyssinica*, *Clerodenderon alatun*, *Myrsine melanophloeos* and *Maytenus gracilipes* showed good regeneration in the *Olinia rochetiana - Allophylus abyssinicus - Apodytes dimidiata* community type. The fact that Apodytes dimidiata, currently one of the dominant species in the community, is poorly regenerating indicates that its ecological influence (*i.e.,* impact on the community's structure and dynamics) will be bleak in the future.

Some old individuals and several saplings of *Podocarpus falcatus* were observed in the *Maytenus*

gracilipes - Teclea nobilis community type at lower altitudes. However, the bark of this rare tree species in the forest is being harvested for its medicinal use (as communicated by the local people), thus calling for an appropriate management plan to ensure its sustainable use in the future.

Results of similarity analyses (Table 4) indicate Denkoro forest to have the highest affinity with the forests of Chilmo and Menagesha, and lesser resemblance to the forests of Wof Washa, Jibat, (all four located in the central plateau of Ethiopia), and Harenna (situated in the south eastern highlands). Denkoro forest shows the least resemblance to the south western forests of Ethiopia as it is found in a different climate regime compared to the south western forests: the former is classified as a dry afromontane forest while the later is a humid broad leaved forest. Variability in the amount of annual precipitation accounts for the floristic differences observed in these forests.

Table 4. Floristic similarities between Denkoro forest (with 58 species) and 9 other forests from Ethiopia.

Forest	a	b	SI
South Western Eth. Forest[1]	88	18	.24
Harenna forest[2]	85	30	.42
Jemjem forest[3]	67	21	.33
Shrub land of South west Shewa[4]	55	21	.37
Tree Shrub layer of South Wello[5]	43	21	.41
Jibat[6]	52	26	.47
Chilmo[6]	31	26	.58
Menagesha[6]	31	26	.58
Wof Washa[6]	29	21	.48

Note: 'a', number of species used for comparison, 'b', number of common species with Denkoro forest, and SI, similarity index.

Sources: [1] (Kumlachew Yeshitila and Tamrat Bekele, 2002); [2] (Lisanework Nigatu, 1987); [3] (Hailu Sharew, 1982); [4] (Zerihun Woldu and Backeus, 1991); [5] (Kebrom Tekle *et al.*, 1997); [6] (Tamrat Bekele, 1993).

Structural description

The results of the structural analyses of the natural vegetation of Denkoro forest reveal that it is in a stage of secondary development, with very close resemblance to the forests of Chilimo and Menagesha that have been described by Tamrat Bekele (1993). The ratio of individuals with DBH > 10 cm to DBH > 20 cm (*i.e.*, a/b ratio) in the forests of Denkoro, Chilimo and Menagesha resemble one another (see Table 2). Small sized woody species predominate in all the three forests as revealed by the high a/b ratio. That the forests had been exposed to a history of heavy deforestation is observable in the absence of large individuals. Distribution of individuals in different height classes also reveals a similar trend in these forests (Table 5).

The basal area for Denkoro forest (*i.e.*, 45 m^2/ha) showed more resemblance to figures reported for the forests of Menagesha and Chilimo than to Wof-Washa (see Tamrat Bekele, 1993; 1994). The basal area of these forests is 36.1 m^2/ha, 30.1m^2/ha and 101.8 m^2/ha, respectively.

Table 5. Comparison of percentage distribution of individuals in height classes in Denkoro and three other Afromontane forests.

Height class (m)	Chilimo	Menagesha	Wof-Washa	Denkoro
6–9	42.1	38.5	23.3	39.3
9–12	30.8	32.0	21.3	28.3
12–15	15.3	10.8	13.7	18.9
15–18	7.5	11.0	13.1	6.7
18–21	3.4	2.2	6.1	3.2
21–24	1.1	2.2	1.6	1.7
24–27	-	1.0	8.0	1.2
27–30	-	< 1	8.0	< 1
> 30	-	2.0	4.8	-

Two major groups of woody species can be recognized based on the patterns of species population structure. The first group consists of species that are capable of regenerating in the forest under-story. These include species such as *Myrsine melanophloeos, Hypericum revolutum, Ekebergia capensis, Discopodium penninervum, Myrsine africana, Maesa lanceolata*, and *Bersama abyssinica*. Species such as *Hypericum revolutum* and *Ekebergia capensis,* having a good regeneration were poorly represented in the seedling and sapling layer because they were preferred by grazers and were suitable for browsing too.

The second group includes those species that are very big and old trees with difficulty in regenerating in the forest under-storey. These include species such as *Hagenia abyssinica, Juniperus procera* and *Olea europaea*. As a result, these species are critically endangered and might face possible extinction in this forest. This is even more so especially for the species of *Hagenia abyssinica,* where the old trees have started to die back, and some individuals were completely dried and uprooted.

Phytogeographical description

The altitudinal range of Denkoro forest is from 2300 to 3500 m a. s. l., and it is known that altitude has a decisive role on the distribution of vegetation on East African Mountains (Hedberg, 1951; Lind

and Morrison, 1974; Tewolde Berhan Gebre Egziabher, 1989). Three vegetation belts were described as characteristic for East African mountains based on altitude (Hedberg, 1951). These are the Afromontane forest belt, the Ericaceous belt and the Alpine belt. The Afromontane forest belt, and the Ericaceous belt are represented in Denkoro forest. The Afromontane forest belt is further subdivided into three zones (Hedberg, 1951); the Afromontane rain forest zone, the Bamboo zone and the *Hagenia – Hypericum* zone. The *Hagenia – Hypericum* zone has been detected and described from Denkoro forest, while the former two are absent.

The Afroalpine belt has neither been investigated in the present study, nor cited in any other literature, but it is recognizable above the Ericaceous zone (sub-Afroalpine belt) in Denkoro forest. This vegetation merits future investigation, as it would enrich our current knowledge on the floristics of the belt in particular, and the ecosystem at large.

Among the seven forest types described from Ethiopia by Friis (1992), Denkoro forest fits the description given to the undifferentiated Afromontane forests. However, the forest contains elements of both transitional rain forest, and undifferentiated Afromotane forest as well, consisting of dominant tree species like *Juniperus procera*, *Olea europaea* ssp. *africana*, *Croton macrostachyus*, *Ficus sur* and *Maesa lanceolata.* Species characteristic of moist forests (*e.g., Prunus africana*), have also been identified. It was also noted that *Ekebergia capensis* and *Acacia abyssinica* existed as relics in a dispersed manner in areas adjacent to the forest.

From the present analysis, therefore, it can be concluded that the forest is characterized more by species of the undifferentiated ones, although some elements of Afromontane rain forests are present. Only one of the species (*Ficus sur*) is a Guineo-Congolian floral element. According to Tamrat Bekele (1993) *Ficus sur* is found in specialized habitats such as along river courses, and in Denkoro forest it has been observed as occurring in a marshy plain, at an altitude of 2300 m a.s.l. The presence of this species in Denkoro forest has to do with the close proximity of the forest to the lowland floral region, and the presence of suitable habitats for its growth at lower altitudes in the forest.

Prunus africana, typical of moist montane forests (Lind and Morrison, 1974), has been recorded from this forest. This marks the northern latitudinal limit so far described for the species in Ethiopia. On the other hand, Denkoro forest includes Afromontane endemics such as *Juniperus procera, Olea europaea* ssp. *africana, Hagenia abyssinica, Podocarpus falcatus, Apodytes dimidiata, Ilex mitis, Myrsine melanophloeos* and *Olinia rochetiana.* The species mentioned as dominant tree species by Lind and Morrison (1974), except *Olea europaea* ssp. *africana* and *Maesa lanceolata,* and Friis (1992) were rare in the forest.

In addition to the Afromontane endemics, other species belonging to connecting elements have been identified from Denkoro forest. These include the 'ecological transgressor' *Ekebergia capensis*, and 'forest pioneer connecting species' like *Maesa lanceolata* and *Bersama abyssinica.* The former can be found dispersed over a wider geographical area, while the latter two are found in disturbed habitats along forest edges.

Some of the montane forest species listed from Denkoro forest have also been recorded in shrub land vegetation of the central plateau of Ethiopia that had been described by Zerihun Woldu and Backeus (1991). These species include *Erica arborea, Juniperus procera, Olea europaea, Pittosporum viridiflorum, Prunus africana, Maytenus arbutifolia, Myrsine africana* and *Scolopia theifolia*. Zerihun Woldu and Backeus (1991) describe this shrub land type to be a secondary community which has replaced the forest vegetation that gradually disappeared from the highlands.

CONCLUSION AND RECOMMENDATIONS

The Floristic description of Denkoro forest reveals the presence of high species diversity. Of the species recorded from the forest, 11 species are endemics that have been recorded in the red data list of IUCN, and 8 species identified as indicator species for forest disturbance.

Identification and description of the six community types in the forest revealed signs of heavy degradation in all, implying that the forest had been exposed to a past history of heavy exploitation. In addition, structural description of the forest indicated the predominance of small sized individuals. These observations assert Denkoro forest to be in a stage of secondary development at present.

Analysis of species population structure indicated a high variation among species population dynamics within the forest. Two

generalized groups have been observed: species with a good capacity for regeneration, and species with a very poor regeneration or none at all.

Phytogeographic description of Denkoro forest asserts the presence of an undifferentiated Afromontane forest. A sub-Afroalpine vegetation that is represented with a clear Ericaceous belt, although not investigated in the present study, lies above the forest.

To ease the present human influence on the natural forest, and for a future management of the forest on a sustainable basis, the following recommendations are made:

- Participatory forest management programs should be introduced so that local communities assume responsibility for the management and conservation of the forest, and end up as the beneficiaries of economic benefits ensuing from these activities,
- Creating awareness, through extension programs, on the multiple use of forest resources and forest ecosystems,
- Agro forestry practices should be introduced and encouraged so that local communities can obtain multiple uses out of it,
- Natural regeneration of species in the forest can be facilitated through reduced grazing/-browsing pressure,
- Cattle rearing, a basic livelihood in the area, should be carried out commensurate with the carrying capacity of the environment,
- The planning and management of forests can be assisted with research findings, and therefore, more basic and applied research should be encouraged.

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