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A FLORISTIC COMPOSITION AND STRUCTURAL ANALYSIS OF DENKORO FOREST, SOUTH WELLO

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ABSTRACT

The floristic composition and structure of Denkoro forest between altitudes 2300 to 3400 m were described. Sample plots of 25 m X 25 m were taken for woody species and 1 m X 1 m for herbaceous species. A total of 95 sample plots were analyzed. The cover-abundance values for trees, shrubs and herbs within the sample plots were estimated. All trees and shrubs with diameter at breast height (DBH), i.e. 1.3 m from the ground and ≥ 2 cm DBH were measured for height and diameter. A total of 174 species of vascular plants representing 66 families were recorded. 109 of the species collected from sample plots were used for floristic and structural analysis. The rest 64 were collected out of sample plots but from the forest and used to describe the complete floristic list. Polythetic divisive procedure was followed to classify the vegetation data Six clusters were recognized and designated as local plant community types. Each type was given names after one or two dominating and/or characteristic species. The community types are: Erica arborea - Hypericum revolutum, Myrsine melanophloeos - Dombeya torrida, Myrsine africana – Maesa lanceolata – Prunus africana, Olinia rochetiana – Olea europaea, Olinia rochetiana – Allophylus abyssinicus – Apodytes dimidiata and Maytenus gracilipes – Teclea nobilis. The structural analysis of the forest showed that there was a high density of small sized trees. This was ensured by the comparison of trees based on DBH and height classes. The density of trees > 10 cm DBH was almost two times more than that of DBH >20 cm. There was also high proportion (> 65%) of woody individuals in the low height classes (i.e. < 12 m), which was similar to the trend in DBH measurements. Analysis of species population structure showed five patterns, which almost represented species dynamics in the forest. The floristic and structural analysis; and comparison of Denkoro forest with similar Afromontane forests of Ethiopia

indicated that the forest is similar to the montane forests of the Central Plateau of Shewa(Tamrat, 1993). .

1. INTRODUCTION

A substantial proportion of the land area in highland Ethiopia was once believed to have been covered by forests having wide coverage than at present. However it was and it still is difficult to establish the precise coverage of the past as well as the present forest vegetation in Ethiopia (Friis, 1986). It was believed that even the best statistics do not distinguish between the present natural high forest, secondary forest and other serial stages in forest regrowth. And any estimation of the past coverage is even more beyond our present possibilities, as it has so far to rest on estimates based on the distribution of rainfall and forest relic patches. Logan (1946) estimated that high forest covered about 5% of the area of highlands. According to this author highlands of Ethiopia were once generally forest covered, but have gradually been cleared.

Friis (1986) also suggested on the extent to which the highlands were once forested by the numerous isolated mature forest trees or patches of forest or woodland of approximately the same species composition as in the remaining areas with closed forest. Tamrat Bekele, (1993) remarked on this point that the occurrence of isolated mature trees in farm lands and the patches of forests that are seen around church-yards and religious burial grounds indicate the presence of vast expanse of forests earlier.

These and other recent sources like FaWCDA (1982) and Birhane Habte and Mebrat Mihretu, (1990) showed much of the country might have been covered by closed forest and dense woodlands before they were cleared by human activities. However, the figure was reduced to 15% by 1955 to 3.6% in the early 1980's (FaWCDA, 1982).

The reduction of the forest vegetation was due to climatic changes and human activities (Hamilton, 1974). In thje latter case, clearing for cultivation, burning to create pasture lands, and improper cutting practices for fuel and lumber have reduced the forest area to a small fraction of the area of the country. According to a report by Eckholm, (1976; cited in Hailu Sharew 1982) the rate of destruction has increased since the mid-century. This team estimated the rate of disappearance of the natural forests and woodlands to be 1000 km^2/yr. This has resulted not only in the reduction of forests but also in a decrease in their effectiveness in conserving soil and water. Under natural conditions, i.e. free from human activities, soil is usually covered by vegetation. In other words, soils and vegetations are naturally kept in balance and therefore the imbalance is caused as a result of human interference such as removal of the vegetation cover for various needs. The Ethiopian highlands annually loose a total of between 1.9 to 3.5 billion tons of topsoil as a result of erosion (EFAP, 1994). The loss in soil fertility is due in part to the use of animal dung and crop residues as fuel, which otherwise could have been used as manure to improve the fertility of the soil.

The depletion of the natural vegetation in many parts of the country has also led to the threat and decline in number and area of distribution of many plant species (Tesfaye Bekele, 2000). According to Ensermu *et. al.,* (1992) 120 threatened endemic plant species are known from Ethiopia. Out of these, 35 species were from the Dry Afromentane forest.

Destruction of forest in the Afromontane zone of Wello, northeastern 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 shrubland and grassland (Pichi-Sermolli, 1957 ; Kebrom *et. al*., 1997).

If the present trend of exploiting the remaining scarce forest resources and their conversion into agricultural land continues, there will be little hope of having any forest worth mentioning after a few years (Hedberg, 1979; Sebsebe Demissew, 1998). The trend can only be reversed if appropriate measures are taken to halt them.

In order to maintain the ecological equilibrium and to meet the forest resource requirements of the population, scientific information on the composition, structure and distribution of species is the basis for forestry development.

According to Kershaw (1973), the object of vegetation description is to enable people build a mental picture of an area and its vegetation and to allow the comparison and ultimate classification of different units of vegetation. He also added about the necessity of vegetation description as it is essential to know what species are present, what their distribution is and what the relative degree of abundance of each species is before any serious or detailed work can be commenced in an area. On the same point, another author Oosting (1956) remarked that it is illogical to proceed with explanations when the subject itself is indefinite or unknown. Therefore, the first objective in ecological work according to this author is to learn the composition and structure of the community under consideration. Then follows a research for causes, experimentation and interpretations based upon a firm foundation. Thus the floristic composition (simply expressed as a list of species), life form composition and structure of vegetation are a necessary basis of all ecological work.

Various attempts to study the forests of Ethiopia have already been made. Beals (1969), Hailu Sharew (1982), Sebsebe Demissew (1980), Lisanework Nigatu (1987) and Tamrat Bekele (1993), are some of the examples.

The flora and vegetation of South Wello was also studied among others by Sebsebe Demissew (1998), Kebrom Tekle (1998), Tesfaye Bekele (2000), and Eyayu Molla (1996).

However, so far there has been no study carried out on the vegetation structure and composition of Denkoro forest. This has become a serious handicap to the management and rational utilization of the forest resources of the area. Therefore species documentation, classification and description of the forest are necessary. Thus, this study gives information about the floristic composition and structure of the forest.

Objectives of the study

i. To analyze the floristic composition and structure of Denkoro forest
ii. To classify the forest into community types
iii. To compare the floristic composition and structure of the forest with other similar forests of Ethiopia.
iv. To recommend solutions for management and conservation problems.

2. LITERATURE REVIEW

2.1. Vegetation Survey In Ethiopia

Pichi-Sermolli (1957), Breitenbach (1963), Mesfin Wolde Mariam (1972), Wilson (1977), Friis *et. al*., (1982), Tewolde Berhan Gebre Egziabher (1986), Friis (1992), and others have a considerable significance in the classification and description of Ethiopian vegetation mostly on physiognomic basis. Of these physiognomic studies, Pichi-Sermolli's is the most intensive. He recognized 24 physiognomic units to establish a geo-botanical map of Eritrea, Ethiopia and Somalia. At present, the Ethiopian vegetation is broadly divided into nine major types (Sebsebe Demissew, 1998): The Afroalpine and subafroalpine, the dry ever green montane forest and grassland, moist evergreen montane forest, evergreen scrub, *Combretum-Terminalia* (broad-leaved) deciduous woodland, *Acacia - Commiphora* (small-leaved) deciduous woodland, lowland semi-ever green forest, the desert and semidesert scrubland, and riparian and swamp vegetation. Of these, the dry energreen montane forest and grassland and the subafroalpine vegetation are represented in the study area.

Afroalpine and subafroalpine vegetation

This zone consists of areas that are on the average, higher than 3,200 m. The rain fall is between 600 & 1500 mm and the average annual temprature is 14 –18 ^{0}C (Teweledeberhan G. E., 1986). The rocks are volcanic (mostly basalts and trachytes)(McDugall *et. al.,* 1975; cited in Zerihun Woldu, 1999). The soil is very cold (near freezing point of water) and often thin. Plants are exposed for so high radiation that they lose much water than they absorb. Due to steepness of the terrain, the zone is vulnerable to water erosion. But on the other hand, it is a very important source of water for the permanent streams and rivers.

The *Erica* forest, typical for this zone, is the shelter as well as the source of food for the spectacular endemic mammals, Walia Ibex (*Capara ibex Walia* L.) Nyala (*Tragelaphus buxtoni* Lydekker), and Ethiopian Wolf [*Canis (Simenia) simensis* Ruppell]. Due to the slow growth rate and low productivity of crops in this zone the density of human population is low. Therefore the rational use of this environment is sheep grazing in addition to barley cultivation.

The vegetation of this zone is characterized by *Erica arborea* L., *Kniphofia* spp., *Helichrysum* spp., *Bartsia petitiana, Alchemilla* spp., *Crassula* spp., *Lobelia rynchopetalum* and *Phillipia trimera* Engl., Grasses are mainly of species of *Festuca, Poa*, and *Agrostis.*

The areas of thicker soil in the subafroalpire zone support more species of woody plants, like *Hypericum revolutum, Gnidia glauca* and *Myrsine (Rapanea) Melanophloeos* with the deepest well drained soils at the lower altitudinal limits supporting *Hagenia abyssinica* trees as well as many species of herbs.

Dry Evergreen Montane Vegetation

The altitudinal range of this complex vegetation type is 1500m to 3200m. Most part of the plateau on which this vegetation occurs consists of volcanic rocks, which are not uniform either to vegetation or to soil; sedimentary rocks ranging from sandstone to lime stone; and Precambrian rocks which form heterogeneous substrata for plant growth.

The economy of this area is based on mixed cereal agriculture common in northern and eastern parts and mixed root crop agriculture in western parts of south and central Ethiopia.

Degradation in this zone is very high and even severe in the northeastern Ethiopia. Forests have virtually disappeared, as a result most of the mountains sides are bare, valleys have been gullied, and springs and streams, which used to have water the whole year round are now mainly dry in the dry season.

According to Teweldeberhan G. E. (1986), the vegetation is characterized by *Olea europaea* ssp. *cuspidata* (DC.) Ciffieri, *Juniperous procera* Endl., *Celtis kraussiana* Bernh., *Euphorbia ampliphylla* Pax, *Dracaena spp., Carissa edulis* Vahl, *Rosa abyssinica* Lindley, *Mimusops kummel* Bruce ex DC, and *Ekebergia capensis* Sparrm. This vegetation type is associated with highland bamboo (*Arudinaria alpina* K. Schum.) and extensive areas of grassland rich in species. The most important genera are *Hyparrhenia, Eragrostis, Panicum, Sporobolus, Eleusine,* and *Pennisetum*. Many legumes are associated with this vegetation type, among these are the genera *Trifolium, Eriosema*, and *Crotalaria.* Epiphytes including orchids, mosses and lichens are common.

2.2. Techniques of Vegetation Data Analysis

Plant community data consist of lists of species in each sample or records of the amount of each species in each sample, forming a two-way table or matrix with “n” rows and “m” columns. This complete data set cannot be easily interpreted unless summarized retaining the information in inter-unit relationships (Anderson, 1971). Thus, multivariate techniques are employed to study the complex nature of plant communities, with the general objectives of summarizing large complex data sets obtained from community samples, aiding in the interpretation of the data and the generation of hypothesis about community structure and variation (Lambert and Dale 1964 and Greig-Smith 1964). These multivariate methods have shown an enormous increase in development and application since the last few decades. Among these multivariate methods employed to study the complex nature of communities, classificatory techniques are employed to analyze the vegetation data of Denkoro forest.

Classification involves the arrangement of samples into classes the members of which have one or more common characteristics, which can distinguish them from the members of other classes. Various techniques of vegetation classification have been discussed by several authors such as Whittaker (1962), Pielou (1969), Shimwell (1971), Mueller-Dombois and Ellenberg (1974), Greig-Smith (1964, Gold-Smith and Harrison (1976), Gauch (1982), and Digby and Kempton (1994). According to Gauch (1982) classification techniques are subdivided into three groups: Table arrangement, non-hierarchical classification and hierarchical classification. Detail description of table arrangement was given by Mueller-Dombois and Ellenberg (1974), and Westhoff and Maarel (1978). It is the earliest classification technique in community ecology. It has an advantage in that it exhibits at once both the general features and full detail of the data set. The Braun Blanquet table work pursues to order the sample-by-species data matrix into the order that could reveal the inherent structure of the data (Mueller-Dombois and Ellerberg, 1974). The aim is to arrange the species in the sequence that brings species together that are similar in their distribution and also, to arrange the samples in the sequence that brings samples together that are similar in composition. Besides its advantage, it has certain drawbacks. Some of these are: the result is relatively subjective (Kershaw, 1973 Gauch, 1983) and the application to unfamiliar species and unknown vegetation is difficult (Westhoft and Maarel, 1978).

Non-hierarchical clustering techniques partition samples into a number of clusters. The clusters are defined separately and the links between them have the form of a network rather than a tree (Pielou, 1984). In hierarchical methods, on the other hand, the emphasis is on the extraction of groups at successive levels, i.e., classes at any level are subclasses of a class at higher level, and permit the construction of a tree diagram or dendrogram to show the sequences through which the divisions or unions of the groups were made.

Hierarchical techniques may be subdivided into an agglomerative method which progresses by successive fusions (Williams, 1971; Goodall, 1978), beginning with individuals that may be grouped until all individuals are finally fused into a single group, building a hierarchy from the bottom (Greig-Smigh, 1980); and a divisive method which proceeds by progressive divisions, beginning with the whole set of data and decomposing it into individuals or at least into subgroups on the basis of an appropriate criterion to produce hierarchy (Pelou, 1969; Williams, 1971; Greig-Smith; 1980). The former increases heterogeneity as the union proceeds upward, while the latter increases homogeneity as the division proceeds downwards.

According to Williams (1971), the reason why agglomerative techniques are not completely replaced by divisive procedures lies in a monothetic and polythetic distinction.

Monothetic classificatory methods identify groups based on a single attribute, that is partition ed into subgroups is made on the presence or absence of a single character-usually species in the case of community samples (Gauch and Whittaker, 1981). The course of analysis in this method of classification can be affected by a chance occurrence of a rare species in the particular subset of stands being considered or the chance absence of a species common in the subset.

Polythetic classificatory techniques partition sample based on more than one attribute (all species). These are not wasteful of information. The theoretical advantage of polytheic systems is that the classification obtained is usually more stable and by its nature more informative (Lambert and Dale, 1964).

A drawback of the hierarchical approach (Lambert and Williams, 1966) is that the decision made is irrevocale. If the rules of the clustering algorism, at a particular point in the process, lead to a certain division or a certain fusing of groups, this can never by corrected by subsequent actions within the strictly hierarchic procedure. This is worse for monothetic than for polythetic techniques (Everitt, 1980) and led some ecologists to amend it by allowing for the possibility of fusion among clusters that have been separated and have become associated with different branches of the dendrogram (Goodall, 1953; Crawford and Wishart, 1968).

The variety of hierarchical classification techniques may be summed up in three groups as polythetic agglomerative Monothetic divisive, and polythetic divisive, (Williams *et al.,* 1966, Williams 1971, Gold-Smith and Harrison 1976, Everitt 1980, Greig-Smith 1980, 1983, Gauch 1982).

Polythetic agglomerative classification techniques also use information on all species. However, these begin with each sample allotted to a cluster with a single member and agglomerate these in a hierarchy of larger and larger clusters until finally a single cluster contain all the samples (Lance and Williams, 1966; Orloci, 1967; Pritchard and Anderson 1971, Gauch and Whittaker, 1981, Digby and Kempton 1994). These methods cluster on the basis of overall similarities. Because of this, they are in general less likely to lead to misclassification (Greg-Smith, 1983).

According to Williams and Lambert (1959) Monothetic divisive classification techniques begin with all the samples in a single group and divide them hierarchically into progressively smaller groups on the basis of the presence and absence of single species. This procedure has the disadvantage that it is liable to misclassification (Kershaw 1961, Gitting, 1965, Hill *et al.,* 1975) and it is also followed by computational difficulties (Digby and Kempton, 1994).

Polythetic divisive systems use information on all species (Hill, 1979) and begin with all samples together in a single cluster and successively divide them into smaller clusters, which finally contain only one sample or smaller number of samples. The present study employed this system of classification to classify the vegetation data into clusters.

3. MATERIALS AND METHODS

3.1 The Study Area

3.1.1 Location, Topography, and Soil

The study was carried out in South Wello, between Debresina and Saint woredas 10^0 35' – 11^0 15'N and 38^0 30' – 39^0 07'E (Fig.1). The study area is generally characterized by rough topography with mountains, deeply incised valleys, escarpments and plateau. South Wello, which ranges from 1500 to 3500 m.a.s.l (MPED 1993), is in most parts covered by volcanic rocks mainly basalts of Tertiary age (Anon. 1988 cited; in Tesfaye Bekele, 2000).

Cambisols, Arenosols, Lithosols and Vertisols are the major soil types in South Wello (MPED 1993; Anon. 1988; cited in Tesfaye Bekele 1993). Almost 80% of the area has a soil depth less than 20 cm due to excessive erosion which brings about low soil productivity and low water holding capacity during periods of irregular rainfall (Henrickson *et al.,* 1983; Barber, 1984; Constable and Belashaw, 1989; Hurni, 1988).

Figure 1. Location map of the study area

3.1.2 Natural Vegetation

The natural vegetation of the study area was broadly classified as *Juniperus procera* forest or "dry evergreen montane forest forest" with *J. procera* and/or *Olea europaea ssp. cuspidata* as dominant species (Friis, 1992, Mesfin Tadesse, 1990). At higher elevations remnants of the original Afromontane forest occur as secondary forest with *Juniperus procera*, *Olea europaea ssp. cuspidata* and *Podocarpus falcatus* among the dominant trees. Kebrom *et al.,* (1997) also described various types of serial communities. These include shrub-lands with regenerating pioneer species such as *Dodonaea angustifolia* and *Euclea racemosa* and other species such as *Rhus natalensis*, *Dovyalis verrucosa* and *Acacia sieberiana*. Grasslands also occur, which are grazed or cut for fodder. Very degraded sites have little cover of herbaceous species (*Arenaria leptoclados, Justicia sp.* and *Hypoestes forsskaolii*) and are characterized by shallow soil or stony out crops (Kebrom *et al.,* 1997).

3.1.3 Human Population

According to the 1994 Census (CSA 1995), South Wello Administrative Zone had 2.1 million inhabitants. Of this, 161843 inhabitants are living in Debresina woreda. The population increases from 1970 to 1994 by about 81% (CSO 1974, CSA 1995). This clearly shows the pressure on the natural vegetation, since 90% of the people live in rural areas and are engaged in rain fed agriculture and animal husbandry. The seriousness of this situation in the highlands of Ethiopia was emphasized by Messerli *et al.,* (1990).

3.1.4 Land use

According to South Wello Department of Agriculture, Landuse and Environment Protection Section (S.W.D.A L.E.P.S, 1990), the land area of South Wello is about 1, 773, 681.25 ha. It is a region of great geographical diversity. 35.31% of the land is currently cultivated. This cultivated land is divided into three categories based on its inclination (slope).

- ♦ Total cropland: Land cultivated intensively from flat plane to mountainous slopes, i.e. from 0% to 50% slope.
- ♦ Marginal to moderate productive cropland: land cultivated very intensively from flat plainto hilly slopes i.e. 0% - 15%.

- Productive cropland: land cultivated moderately on flat and gentile slopes and fulfill, by virtue of its nature or appropriate management, what a potential land deserves. There is hardly any such a cropland in South Wello.

All the types of lands mentioned above are cultivated for annual, perennial and homestead field crops. However, according to USDA land capacity classification, 15-30%, 30%-50% and > 50% slopes of land are grouped under non-arable classes. This is because of the nature of the terrain and the effect of erosion, croplands of those range of slopes are being changed to frequent outcrops of bare rocks. Had it not been for high population pressure that cause widespread rural poverty, those lands wouldn't have been cultivated. The current land use in South Wello and Debresina Woreda can be classified into 11 types. The area and proportion of each land use, which was compiled in 1990, is indicated in Table 1 and 2 respectively.

Table 1. Current land use system in South Wello

Land use pattern	Proportion %	Area in ha.
Cultivated land	35.31	626349
Forest land	0.88	15650
Wooded shrubland	4.74	84141
Wooded grassland	3.01	53345
Shrub or Bushland	22.52	399345
Riverine Forest	0.23	4121
Grazing land	9.14	162203
Plantation	2.3	40855
Wasteland	15.14	268488
Water body	0.46	8093
Settlement area	6.25	11108.95

Source: (S.W.D. A. L. E. P. S, 1990)

Table 2. Land use Pattern in Debresina Woreda

Land use pattern	Proportion in %	Area in ha.
Cultivated land	42.42	41421.26
Water body	0.08	77
Forest land	2.2	2187
Wooded shrubland	9.5	8241
Wooded grassland	6	5826
Grazing land	8.6	8356.14
Shrub or bushland	18.8	18329
Wasteland	4.4	4262
Riverine forest	1.0	990
Settlement area	5.6	5486.83
Plantation	1.6	1511

Source: S.W. D. A. C. E. P. S, 1990)

3.1.5 Water Resource

Rivers

The physiognomic make up of South Wello Administrative Zone is suitable to have the well-known drainage system in Ethiopia. Blue Nile and Awash having a catchment area of 14, 649 km^2 and 3,088 km^2 are the two drainage basins in the region (S.W.D. A. C. E. P. S, 1990).

The major tributaries of Blue Nile from this region are Woleka, Yeshume, Derame and Beshillo and of Awash are Borkena, upper Millie and Cheleka rivers. Many intermittent streams and rivers which feed for these drainages are also known.

Because mountains are extensive and the landform is highly dissected, rivers are flowing in deep gorges except for Borkena, Cheleka and Upper Millie. This irregular landscape accompanied by deforestation increases the speed of waterflow, which also increases the eroding and transporting capacity of rivers in the region. It is estimated that these drainage systems have different potentials for irrigation. About 9260 ha. of land is expected to be cultivated by both drainages. Of this 75.86% (7025 ha.) is found in Blue Nile basin where as 24.14% (2235 ha) is in the Awash`s

Lakes

There are four lakes in the region: Lake Hayk, Ardibo, Maybaar and Golbo. Lake Hayk and Ardibo are located in close proximity to each other. Among all the Lakes, Lake Golbo is the smallest in size and not as important as the others.

3.1.6 Wild life

According to the inventory performed by the South Wello Department of Agriculture, there are 44 species of mammals and 232 species of birds. Among these 4 species of mammals and 8 species of birds (Table 3) are endemic to Ethiopia. The endemic species found in Denkoro forest (Debresina Woreda), Lugo and Ardibo lakes (Tehuledera), Yegof forests (Dessie Zuria) are listed as follows:

Table 3. Endemic mammals and birds of Ethiopia

Endemic mammals	
1. Gelada Baboon (*Theropithecus gelada*)	3. Abyssinian Janet (*Genetta abyssinica*)
2. Menelik's Bush- buck (*Tragelaphus scriptus meneliki)*	4. Ethiopian Wolf *(Canis simensis*)
Endemic birds	
1. Golden backed wood-peckers (*Dendropicos abyssinicus*)	5. White - collared pigeon (*Columba albitorques*)
2. Ruppelt's chat (*Myrmecocichala melaena*)	6. .Abyssinian cat bird (*Parophasma galinieri)*
3. Yellow fronted parrot (*Poicephals flavifons*)	7. Banded Barbet (*Lybius undatus*)
4. Abyssianian long claw	8. Black-winged love bird

(*Macronyx flavicollis*)	(*Aqapornis taranta*)

3.1.7 Livestock

The livestock in the region is estimated to be 3, 614,014 of which the largest proportion (40.77%) constitutes cattle and the smallest (0.06%) camel (Table 4)

The average domestic animals possession of a household is

Cattle = 2.57 Horse = 0.13

Sheep = 2.57 Mule = 0.09

Goat = 1.45 Camel = 0.005

Donkey = 0.4

Total = 7.84 livestock/head.

Table 4. Livestock population of South Wello by agro-ecological zone based on 1990 census

Agroecology	Cattle	Sheep	Goat	Poultry	Camel	Equine
Kolla	390825	81832	283476	1826.92	1263	32778
Dega	425279	703858	82424	449189	-	145138
Weina Dega	630424	388078	302873	538975	821.39	105720
Wurich	5148	10232	815	2512	-	1050
Total	1473656	1184000	669588	1173368	2084	284686

Source: (S.W.D. A. C. E. P. S, 1990)

3.1.8 Economy

About 89.43% of the population earns their living directly from the land, mainly as subsistence farmers. Therefore, Agriculture is directly or indirectly the backbone of the region. Percentage of income from different sources looks as follows. 0.62% of the population is living on daily labor, 4.04% on crops, 89.14% on agro-pasturalism, 2.1% on arts, 3.26% on trade, 0.75 on wage and 0.09% on others (S. W.D. A. C. E. P. S, 1990). The types of crops cultivated in the region are

Cereals**:** Teff, Barley, Wheat, Maize, Sorghum, Finger Millet, Oats and Rice

Pulses**:** Horse beans, Field Peas, Haricot beans Chick Peas, Lentils,

Oil Seeds**:** Niger seed, linseed (flax), rapeseed, sunflower, sesame, groundnuts, caster bean

3.1.9 Soil and water conservation

The broken and rugged nature of topography together with adverse interference of humans on the environment has brought about severe soil erosion in South Wello. As natural balance is disturbed by human activities especially for fuelwood and for more cultivated lands, the process of erosion is speeded up many folds. In the past decades it has been observed that most part of the region natural vegetation has been depleted to the maximum because of the reasons mentioned above. As a result, South Wello zone currently is not rich in forest resources. Based on Ethiopian Forestry Action Program (EFAP, 1994) the total forest cover (natural vegetation) of the region is estimated as 597,460 ha. On the other hand, volume of wood to be harvested from this vegetation (i.e. woodland, bush/shrubland below 50% slope) is estimated as 639,409.6m^3/yr where wood and bush /shrub land above 50% slope and natural forests left for conservation. The current fuel demand is also assumed to be 2,647,519m^3 & 149797.46 m^3/yr for rural and urban population respectively. EFAP (1994) finally came up for the rate of fuel wood consumption per capita per annum of a household to be 1.19m3 & 0.94 m^3 for rural and urban (more than 5000 dwellers) inhabitants respectively.

Therefore, the deficit is calculated to be 2157907 m^3/yr. This has brought about the removal of topsoil from the Blue Nile basin in the region having an area of 14,649 km^2, which is as much as 51 million tones every year and deposited in Sudan and Egypt depressions and plains.

To mitigate this eminent danger, there has been a tremendous endeavor for soil and water conservation programmes launched by the previous Derg regime and the current government. A profound experience and awareness have been created and developed in the past 20 years. To the contrary, unwise policy or practice on land use, inadequate SWC technologies, wrong implementation approaches, the ways and means used to implement a SWC technique on the ground couldn't sustain the effort.

3.1.10 Climate

The distribution of rainfall in South Wello is characterized by wet seasons that mostly occur from June to September (big rain season), locally known as “Kiremt”), and February to May (small rain season), locally known as “Belg”. The small rainy season is erratic and highly variable. There is a long dry period from the end of September to February, and a short dry spell in June. Altitude has a decisive influence on temperature and rainfall. Rainfall generally increases and temperature decreases with altitude (Abebe Asrat, 1977), (Daniel Gamachu 1990). The climatic diagram of Debresina Woreda Mekane Selam station is presented in (Figure .2)

MekaneSelam(2600)

[10] 16.1^{o} 933

Figure 2. Climatic diagram for the Denkoro forest – town of Mekane Selam, 2600 m a.s.l. (following Walter 1979).

Source: National Metrological Service Agency

3.2. Data Collection

A reconnaissance survey of Denkoro forest was made between November 10 and 12/ 2002 in order to obtain an impression of the structure and physiognomy of the vegetation. Then, the field data were collected from November 13 to December 6/ 2002. During this period sample plots were selected (subjective sampling) in such a way that the various conditions encountered were represented by at least one sample.

3.2.1 Floristic data

At each sampling site, altitude was measured using Pretzel digital altimeter and aspect using Sunto M-3D Leader Compass (Appendix 1). 95, 25m x 25m sampling sites were considered to sample trees and shrubs. The same number of subplots (1m x 1m) laid within the larger plots to analyze herbaceous and graminoid species. From each plot a complete list of trees, shrubs and herbs was made. Appendix 2 shows all the plants recorded in the stands. Arial cover of each species was described using a 1-9 modified Braun-Blanquet (1932) scale (Maarel, 1979). These are:

Scale 1: rare, generally one individual.

2: sporadic, with less than 5% cover of the total area.

3: abundant, with less than 5% cover of the total area

4: very abundant, with less than 5% cover of the total area

5: 5-12% cover of the total area.

6: 12-25% cover of the total area

7: 25-50% cover of the total area

8: 50-75% cover of the total area

9: 75-100% cover of the total area

Additional plant species out of the plots but in the forest were recorded. Besides the floristic analysis, the total number of dead standing trees, stumps and logs in the plots were counted. Occurrence of vascular epiphytes, bryophytes, and lichens were noted.

3.2.2 Structural data

The height and diameter at breast height (DBH), i.e. 1.3 m, of all trees and shrubs were measured. Individuals with a DBH less than 2 cm and height less than 2 m were counted. Height measurement was done with Sunnto Height meter and DBH with measuring caliper and meter tape. The latter instrument measured circumference, which was changed into diameter. 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.

Finally plant specimens collected from each quadrat were recorded with their vernacular names and pressed for latter identification. Identification was made in the National Herbarium

(ETH) by comparing the specimen with already identified specimens and by referring to the flora of Ethiopia (Hedberg and Edwards, 1989, 1995; Edwards et al., 1995; 1997, 2000) Voucher specimens are kept in the National Herbarium (ETH).

3.3. Data Analysis

3.3.1 Floristic data analysis

Releve's were grouped into clusters with the aid of the program TWINSPAN (Hill, 1979). The community types distinguished were further refined in a synoptic table where each column represents a community type and species occurrences were summarized by synoptic cover-abundance values. These synoptic values are the products of the species' frequency and average cover-abundance values (van der Maarel *et al*. 1987).

Finally, the types were named after one to three of the dominant and/or characteristic species. Floristic comparison between Denkoro and other eight forests of Ethiopia was made based on Sorenson's similarity coefficients 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.

3.3.2 Structural data

The structure of the forest was analyzed in terms of tree density, girth diameter, height and basal area per hectare   Tree density and basal area were computed from the plots of a hectare basis. The diameter at breast height (DBH) was classified into six DBH-classes (10-20 cm, 20-50 cm, 50-80 cm, 80-110 cm, 110-140 cm, >140 cm) and the percentage distribution of trees in each class was computed. Tree height was also classified into nine classes (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). The percentage distribution of trees in each class was calculated.

Structural comparison between Denkoro and the Afromontane forests of the central plateau (Tamrat, 1993) was made.

4. RESULTS

4.1 Floristic Composition

A total of 174 species of vascular plants representing 66 families were recorded from the forest (see Appendix 2). 109 of the species collected were used in floristic and structural analysis. The rest were collected out side the sample plots but within the forest and used to make the complete floristic list of the forest. From all the species collected 62.4% were herbs, 14.5% trees, 3.5% trees/shrubs and 19.6% were shrubs. 92.4% of the families were dicots, 6.6% were monocots and 1.5 were pteridophytes. 80.9% of the species were dicots, 17.9% were monocots and 1.2% were Pteridophytes. The proportion of families represented only by one species each, were 56%, 2-5 species 31.5%, 6-10 species 6% and with >10 species were 4.5%

One species from the Family Crassulaceae, a Lichen genus, *Usnea*, and *a* Moss were recorded as epiphytes. Six climber species were recorded from the families Asclepiadaceae, Ranunculaceae, Convolvulaceae, Cucurbitaceae, Phytolaccaceae and Uriticaceae.

The distribution of 62% (106) of the species collected were identified based on the available reference (Appendix 3). 50% of the species were not previously reported from Wello

A total of 11 endemic species are known from the area (Annon, 2002). These include:

1. *Kniphofia foliosa*
2. *Conyza spinosa*
3. *Laggera tomentosa*
4. *Cynoglossum coeruleum*
5. *Urtica simensis*
6. *Anthoxanthum aethiopicum*
7. *Festuca macrophylla*
8. *Kalanchoe petitiana*
9. *Satureja paradoxa*
10. *Stachys alpigna*
11. *Thymus shimperi*
12 *Acanthus sennii*

Eight Indicator species for forest disturbance have been identified. These were

1. *Cyathulla cylinderica*
2. *Sanicula elata*
3. *Kalanchoe petitiana*
4. *Commelina africana*
5. *Asparagus africanus (*indicator of 2ndry forest*)*
6. *Croton macrostachyus*
7. *Euphorbia ampliphylla*
8. *Phytolacca dodecandra*

4.2 Vegetation classification

Six clusters were recognized from the TWINSPAN out put. One releve, which did not fit any cluster was considered to represent a fragmentary development and was neglected in all further analysis. The clusters were designated as local plant community types and given names after two to three dominating and/or characteristic tree and shrub species selected by their synoptic value (Table 5).

The description of the plant community types based on the dominant and characteristic species with their altitudinal distribution is as follows.

I. *Erica arborea-Hypericum revolutum* type

The *Erica arborea-Hypericum revolutum* type is found from 2992 to 3339 m.a.s.l. The characteristic and dominant 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 of all community types. *Alchemilla abyssinica*, *Festuca abyssinica*, and *Thymus schimperi* are the characteristic species in the same field layer. Moss is the common species in almost all community types. *Sporobolus pyramidalis, Satureja simensis, Festuca macrophylla, Cerastium octandrum, Luzula abyssinica* and *Carex steudneri* were recorded from this type only with very low coverage. High coverage of epiphytes of the genus *Usnea* on all *Erica arborea* trees was recorded from this community type.

II. *Myrsine melanophloeos – Dombeya torrida* type

This community type is distributed between 2742 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* is the other tree species in the same layer. Few individuals of *Hagenia abyssinica* and the shrub *Myrsine africana* were incountered. *Asplenium adiantum-nigrum, Carex steudneri, Cynoglossum coeruleum, Geranium arabicum, Ranunculus oreophytus,* *Rubus steudneri, Sanicula elata, Stachys alpigna, Stachys aculeolata, Streblochaete logiarista, Solanum margintum* and *Carex steudneri* were recorded with lower abundance from the field layer.

III. *Myrsine africana - Maesa lanceolata - Prunus africana* type

This community type was distributed from 2771 to 2861 m.a.s.l. The dominant tree species in this type is *Myrsine melanophloeos. Maesa lanceolata and Prunus africana are* the characteristic trees and *Myrsine africana is* the characteristic shrub. *Nuxia congesta* and *Bersama abyssinica* are the associated trees species in this type. *Allophylus abyssinica,and Juniperus procera were recorded in smaller quantities.*

IV. *Olinia rochetiana-Olea europaea* type

This type prevails between 2457 and 2764 m a.s.l. *Olinia rochetiana* is the dominant tree species. Other tree species including *Olea europaea, Apodytes dimidiata, Bersama abyssinica* and *Nuxia congesta* were also recorded. *Discopodium penninervium, Dovyalis abyssinica, Maytenus arbutifolia* were recorded from the shrub layer. *Kalanchoe petitiana* and *Mimulopsis solmsii* were in the field layer. *Pennisetum thunbergii* was recorded only from this type.

V. Olinia rochetiana – Allophylus abyssinicus - Apodytes dimidiata type

This community type is distributed at the altitudes ranging from 2354 to 2660 m. The dominant tree species in this type are *Olinia rochetiana* and *Apodytes dimidiata. Allophylus abyssinicus* is the characteristic tree species. *Bersama abyssinica, Olea europaea ssp. cuspidata, Ekebergia capensis, Myrsine (Rapanea) melanophloeos, Myrica salicifolia, Nuxia congesta, 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 in smaller number in the shrub layer. *Achyrospermum shimperi* is the characteristic herb species where as *Achyrospermum schimperi, Anthoxanthum aethopicum*, *Cynoglossum coeruleum, Geranium arabicum, Kalanchoe petitiana, Mimulopsis solmsii, Sanicula elata and Thalictrum rhyncocarpumhave have a lower cover-abundance.*

VI. Maytenus gracilipes- Teclea nobilis type

Maytenus gracilipes community type is distributed from 2338 to 2445 m a.s.l. The character tree species in this community is *Teclea nobilis* while the dominant shrub species in the same layer was *Maytenus gracilipes*. *Cyprus dichroostachys* and *Snowdenia petitiana* were characteristic species in the herb layer. *Mimulopsis solmsii* and *Kalanchoe petitina* were the other herbs record in the field layer. *Allophylus abyssinica, Apodytes dimidiata, Ekebergia capensis, Scolopia theifolia, Olea europaea* ssp. cuspidata, *Prunus africana*, *Acacia pilispina*, *Albizia schimperiana Euphorbia ampliphylla, Podocarpus falcatus* and *Ficus sur* from the tree, *Carissa edulis, Acanthus sennii* and *Calpurnia aurea* from the shrub and *Asparagus* *africanus, Anthoxanthum aethopicum*, *Cyperus dichroostachyus, Geranium arabicum, Girardinia bullosa, Mimulopsis solmsii, Plantago lanceolata, Snowdenia petitiana* and *Streblochaete logiarista Streblochaete logiarista* from the field layer were recorded in smaller quantities.

Table 5. Synoptic cover-abundance values for species reaching a value of >1.0 in at least one community type. Values in bold refers to occurrences as characteristic species.

Type	I	II	III	IV	V	VI
Size	8	19	8	21	23	15
Usnea sp.	**9.0**	0.0	0.0	0.0	0.0	0.0
Erica arborea	**6.3**	0.0	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
Achyranthes aspera	4.0	4.0	6.7	7.0	2.4	4.9
Hypericum revolutum	**4.6**	1.6	0.0	0.0	0.0	0.0
Myrsine melanophloes	3.6	6.1	6.3	0.0	0.0	0.0
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**
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**
Teclea nobilis	0.0	0.0	0.0	0.0	0.0	**1.1**

4.3 Vegetation Structure

4.3.1 Tree density

The density of all trees in Denkoro forest based on DBH (Diameter at Breast Height) >10 cm was 526 individuals per hectare while it was 285 indi. /ha. on DBH > 20 cm. The ratio of DBH > 10 cm to DBH > 20 cm was very high (1.9). As indicated by Grubb *et al.,* (1963), the ratio of tree density > 10 cm DBH to > 20 cm DBH is taken as a measure of the size classes. Therefore, the a/b ratio in Denkoro forest indicates the predominance of small sized tree individuals which indicates the forest was under heany degradation and in a stage of secondry development..

Denkoro forest was compared with the dry Afromontane forests of the central plateau of Shewa (Tamrat, 1993) (Table 6). It was the 2^{nd} in tree density > 10 cm DBH (a) and the first in the DBH > 20 cm (b). Like Chilmo and Menagesha forests the ratio of (a/b) is very high. Therefore, the a/b ratio in Denkoro indicates the predominance of small sized individuals like it was happened in the two forests mentioned above.

Table 6. Tree density of Denkoro forest and dry forests of the Central Plateau of Shewa (Tamrat, 1993) with DBH > 10cm and > 20cm.

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

4.3.2 Tree height and diameter

The distribution of trees in different height classes is shown in Table 7. Denkoro forest has high proportion (> 65%) of individuals in the low height classes (i.e. 6 – 12 m). Less than 3% of the individuals in the same forest attain heights more than 21 meters.

Table 8 shows percentage distribution of trees DBH classes which has a similar trend to the percentage distribution height in Table 7. Most trees, i.e. 97% of the trees in the forest, were in the DBH class < 50 cm and 3.6% of them were above the middle class DBH (80 - 110 cm)

Table 7. Percentage distribution of trees in height classes in m

Height class in m	**%**
6-9	39.3
9-12	28.3
12-15	18.9
15-18	6.7
18-21	3.2
21-24	1.7
24-27	1.2
27-30	< 1
> 30	-

Table 8. Percenttage distribution of trees in DBH - classes (cm)

DBH – class in cm	%
10-20	46
20-50	46
50-80	6.3
80-110	1.1
110-140	0.2
> 140	0.4

The density of trees based on DBH and height class distribution was similar among the three dry forests under comparison (Table 9&10). Percentage of trees < 50 cm DBH were 97, 92, and 90 in Chilmo, Denkoro and Menagesh forests respectively. The same rank was observed for Denkoro forest above the middle class DBH (80-110 cm). It was 3.6%, 2%, and none in Menagesha Denkoro and Chilmo respectively. Height class comparison (Table 10) also shows the same trend as the DBH class distribution.

Table 9. Percenttage distribution of DBH class (cm) of trees in four forests

DBH – class in cm	Chilmo	Menagasha	Wof-Washa	Denkoro
10-20	60.8	56.9	32.6	46
20-50	36.5	32.8	31.7	46
50-80	2.6	6.5	14.6	6.3
80-110	-	2.5	11.7	1.1

Table 10. Percenttage distribution of trees in height classes of the four forests

Height class in m	**Chilmo**	**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	-

4.3.3 Basal area

The total basal area of Denkoro forest was 45 m^2/ha and its basal area >10 cm DBH was 43.6 m^2/ha. Fig. 3 presents block diagrams of the numbers of trees in 30 cm DBH classes (above the horizontal line) and basal area in m^2 (below the line). There is a considerable decrease in number of individuals with increasing DBH. Most of the trees are small sized as shown by the peak in basal area in the lowest DBH classes (< 50 cm). The trees belonging to higher DBH classes are fewer but contribute higher to the total basal area. Denkoro forest has more than half its total number of individuals in the smallest DBH class (< 20 cm). The contribution of these individuals to the basal area is less than the ones in higher DBH classes. Many individuals in the lowest DBH classes are of a small stature; hence the basal area by these classes is small (Tamrat 1993). The basal area contribution by the lowest and the highest DBH classes is very low as compared to the contribution of the intermediate classes.

The basal area and density distribution of six species (selected among 25 tree species based on their important value Index) of Denkoro forest is shown in table 11. Appendix 4 shows the important values of the tree species. These species contribute more than 50% of the total basal area and 70% of the tree density of the forest. None of the six major species shows an overriding dominance over the others interms of basal area.

The density distribution of the six most important species does not follow the same trend as that of the basal area. Species with higher basal area per hectare does not always have higher density, indicating size differences between the species (e.g., *Apodytes dimidiata* and *Erica arborea*). Therefore, contribution of these trees to the density is more than their contribution to the basal area of the forest.

Figure 3. Frequency distribution of trees in DBH classes (all trees included) in Denkoro forest.

Blocks above the 0 – line: figures based on relative DBH (%); blocks below the 0 - line: figures based on relative basal area (%) (1 = < 20 cm, 2 = 20 - 50 cm, 3 = 50 - 80 cm, 4 = 80 - 110 cm, 5 = 110 - 140 cm, 6 = >140 cm)

Table 11. Basal area and density of the six most important species of Denkoro forest.

Species	**Basal area**		**Density**	
	m^2/ha	**%**	**Stem/ha**	**%**
Myrsine melanophloeos	5	11.07	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	11.86	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	55.23	715.9	70.4

4.3.4 Species population structure

The population structure of 25 species from Denkoro forest communities were analyzed. Fig.4 shows the structure of five representative trees of the whole community types. This is because the patterns of species population structure indicate the variation in population dynamics in the forest (Popma *et al,* 1988; cited in Tamrat, 1993). Five general patterns of population structure were seen in the six community types.

The first pattern (Fig. 4A) is formed by the species with the least frequency in DBH class 1 and 6, average frequency from 2 - 5 and high frequency in class 7. This pattern suggests, with an exception of class 6, a poor reproduction and a good recruitment. Two species, *Scolopia theifolia* and *Euphorbia ampliphylla* both from type VI form this group. No seedling and coppices of these species were recorded from the forest.

The second type (Fig. 4B) includes species with the least frequency in DBH class 1 to 6 and with the ones which have the highest frequency in the higher DBH classes (7 and 8) and then the frequency gradually declines. Species in this group include: *Apodytes dimidiata* (Type IV& **V**), *Nuxia congesta* (Types III, IV & V), *Olea europaea and Olinia rochetaina* both fromTypes IV & V, *Dombeya torrida* from (Type II), and *Allophylus abyssinicus* (Type V). This pattern indicates poor reproduction and recruitment

The third (Fig. 4C) shows a pattern where the frequencies are highest in the lowest DBH classes, and then decrease towards the higher class. Species in this group include only *Erica arborea* (Type I). This pattern indicates good reproduction and recruitment but excess cutting above the intermediate classes

The fourth pattern (Fig. 4D) shows the highest frequently in the lowest DBH classes followed by gradual decline towards the highest DBH class. *Bersama abyssinica* (types III, IV & V), *Prunus africana* (Type III), *Ficus sur* (Type VI) and *Myrsine (Rapanea) melanophloeos*

(Types I, II & III) belong to this group. This pattern might be the results of selective cutting on medium - sized and old individuals.

The fifth type (Fig. 4E) shows a pattern where individuals are frequent only in the highest DBH classes. This indicates very big trees, and no longer reproducing. This pattern is shown by *Hagenia abyssinica* (Types I & II) and *Podocarpus falcatus* (Type VI).

Few species like *Galiniera saxifrage* (Types II & III), *Acacia pilispina, Croton macrostachyus and Albizia schimperiana* from Type VI, *Maesa lanceolata* (Types III, V, & VI), *Hypericum revolutum* (Types I & II) and *Ekebergia capensis* (Types V & VI) show intermediate trends among the patterns shown above.

Figure 4. Five representative patterns of frequency distribution of tree density value over DBH classes in the Denkoro forest represented by A. *Scolopia theifolia* (types VI); B. *Apodytes dimidiata* (Types IV & V); C. *Erica arborea* (Type I): D. *(Myrsine* (*Rapanea) melanophloes* (Types I, II & III); E. *Hagenia abyssinia* (Types I & II). 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 > 110 cm.

5. DISCUSSION

5.1 A Floristic and Structural Description on Denkoro Forest

5.1.1 Floristic

According to EFAP (1994), the land area of Denkoro forest is 8000 ha. which makes it the smallest forest among the NFPA's in Ethiopia. Nevertheless, it has higher species diversity (66 families consisting of 174 species) in comparison to other Afromontane forests. The presence of high species diversity (a characteristic of moist evergreen forest) in the forest could be the result of the surrounding high peaked mountain (3600 m.a.s.l) and the Blue Nile river which increase the humidity of the forest. The existence of high species diversity together with the characteristic tree for moist forest (*Prunus africana*) and Moss (on almost all trees of community types 2, 3, 4, &5) indicate the forest has some characteristics of moist forest.

The forest also contains 11 endemic species, which are in IUCN Red List categories of which the distribution of 5 species in the study area were not recorded in the flora of Ethiopia. Moreover, 8 indicator species for forest disturbance were noted.

The appearance of high species diversity and some endemic species as well as the existence of indicator species for forest disturbance could initiate further study and better management on the forest.

Denkoro forest was compared with other nine forests of Ethiopia (Table 12). A similarity analysis was carried out to evaluate the relationship between Denkoro and other forests based on the presence of tree and shrub species. The similarity index used is Sorensen's similarity coefficients 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 forests of Chilmo and Menagesha show the highest similarity to Denkoro forest. This might be according to Tamrat (1993) due to the geographic proximity of these forests to each other and similar human influences they have been exposed to. Denkoro has also close similarity with Wof Washa, Jibat and Harenna forests but the least with Southwestern Ethiopia forests.

Table 12. Floristic similarities between Denkoro (with 58 sp.) and 9 forests of Ethiopia: South western forests of Ethiopia (Kumlachew Yeshitila, 1999), Harenna forest (Lisanework Nigatu, 1987), Jemjem forest (Hailu Sharew, 1982), Shrub land of south western Shewa (Zerihun and Backeus, 1991). Tree shrub layer of South Wello (Kebrom *et al.,* 1997), Afromontane forests of the Central Plateau of Shewa-Menagesha, Wof Washa, Chilmo and Jibat (Tamrat Bekele, 1993).

Forest	**Total number of species**	**Common species**	**Similarity index**
South Western Eth. forest	88	18	.24
Harenna forest	85	30	.42
Jemjem forest	67	21	.33
Shrub land of South west Shewa	55	21	.37
Tree Shrub layer of South Wello	43	21	.41
Jibat	52	26	.47
Chilmo	31	26	.58
Menagesha	31	26	.58
Wof Washa	29	21	.48

The six clusters designated as plant community types described in section 4.2 were *Erica arborea Hypericum revolutum, , Myrsine melanophloeos - Dombeya torrida, Myrsine africana - Maesa lanceolata - Prunus africana*, *Olinia rochetiana* - *Olea europaea ssp. cuspidata, Olinia rochetiana* - *Allophylus abyssinica - Apodytes dimidiata, Maytenus gracilipes – Teclea nobilis.*

The *Erica arborea - Hypericum revolutum* type prevails on the sloppy upper edge of the forest. It is relatively nearer to the human settlement areas, which made it subjected to high human interference. The local informants told that people from the surrounding village took their domestic animals to the forest in every evening for grazing and returned at midnight holding clusters of firewood. A lot of browsed *Hypericum* seedlings were encountered during the fieldwork, which confirmed the information. A large number of *Erica arborea, Myrsine melanophloeos* and some *Hypericum revolutum* stumps were also noted. According to the information from the surrounding people, most of the cuttings particularly on *Erica arborea* took place during the civil war by the political prisoners who were made to live in a cave found in this community type. *Myrsine melanophloeos, Hypericum revolutum* and *Discopodium penninervum* were also used for house construction and farm instruments, which aggravated the deforestation process. On the other hand very abundant seedlings of the first two species and some seedlings of *Discopodium* and *Erica* were observed. Obviously, this showed the community has a regenerating potential provided that it is well protected.

Myrsine melanophloeos - Dombeya torrida community type consisting of some elements of the previous 'type' emerged at the foot of the slope inhabited by *Erica arborea*. The community was characterized by medium sized trees with more or less interlocked canopies. Some trees were covered by climbers. Moss was a common epiphyte starting from this community and gradually disappeared at the lower altitude where the fifth community terminates. The ground layer was bare with a thick layer of decayed litters, some stumps, a large number of uprooted logs and dead stands of trees were common which showed less human interferences. This was because all the community types except the first one are found in a deep valley where it was difficult for people to use the forest products. According to the local people the other reason for the less human interference was, the surrounding people do not want to cut the forest since they use it for animal husbandry. As a result the logs together with the large pile of litter had been decayed which made the forest floor spongy and fertile.

This created a suitable condition for fast circulation of nutrients between the soil and the vegetation. On the other hand, domestic animals had damaged seedlings and saplings, which caused the government to protect the forest strictly. *Myrsine melanophloeos* and *Hypericum revolutum* showed better reproduction in this community, but it is the former, which showed a better recruitment. This was partly because it has regeneration potential under tree canopies and unpalatable for herbivores. *Hagenia abyssinica* and *Dombeya torrida* were not regenerated. Only medium sized and old trees of these two types were encountered. This community type is in a stage of secondary development eliminating the none-regenerating ones.

The third community (*Myrsine africana - Maesa lanceolata - Prunus africana*) type showed more or less the same characteristics as community type II. The 'type' was composed of seven trees, three shrubs and four herbal species. Some stumps, logs and dead stands of all types of trees were observed. *Myrsine melanophloeos* in this 'type' also showed high regeneration followed by *Maesa lanceolata*. Some seedlings of *Myrsine africana* and *Bersama abyssinica* were also encountered. To the contrary no young trees of *Dombeya torrida, Prunus africana, Nuxia congesta* and *Hagenia abyssinica* were observed. There was a very low field layer as the canopy was more or less closed. This community was also in a stage of secondary development.

The other community came next to the third one was *Olinia rochetiana - Olea europaea* type. This was also composed of 17 trees, 7 shrubs, and < 5 herbaceous species. Some stumps, few logs and dead stands of *Erica arborea*, *Olinia rochetiana, Juniperus procera, Olea europaea* ssp. *cuspidata* and *Hagenia abyssinica* were noted. *Myrsine melanophloeos, Discopodium* *penninervium* and *Bersama abyssinica* showed high regeneration where as *Myrsine africana*, *Maytenus arbutifolia*, *Dovyalis abyssinica, Scolopia theifolia, Ekebergia capensis* and *Clerodendron alatum* were producing some seedlings. On the other hand, *Olinia rochetiana*, *Juniperus procera*, *Olea europaea ssp. cuspidata*, *Hagenia abyssinica*, *Nuxia congesta* and *Prunus africana* showed no sign of regeneration. A few herbs and a thick decayed litter was observed on the ground layer. Those trees that were in a good stage of regeneration were in a stage of secondary development.

The fifth community is *Olinia rochetiana – Allophylus abyssinicus - Apodytes dimidiata* type which shares most characterstics of the preceeding community. Trees in this community like *Bersama abyssinica Clerodenderon alatun, Myrsine melanophloeos and Maytenus gracilipes showed dood regeneration where as only one species (Scolopia theifolia) with poor regeneration. On the other hand Apodytes dimidiata, Olinia rochetiana, Hagenia abyssinica, Nuxia congesta and Olea europaea* were not regenerated.

The last community type based on its altitude was *Maytenus gracilipes - Teclea nobilis*. This community consisted of all types of tree species appeared in the other community types except those in the Ericaceous zone. It has 20 trees, nine shrubs and many herbaceous species. The community was dominated by *Maytenus gracilipes ssp. arguta*. The field layer was relatively rich in herbs except those that were completely covered by the scrambling shrubs and closed canopies. The ground has less decayed litter mainly because of the decline in altitude. Moreover, the vegetation was dominated by shrubs with open canopy. Some old and many saplings of *Podocarpus falcatus* were observed in this community. However, the bark of this rare tree species in the forest had been taken away for medicinal purposes, which facilitated the disappearance of the species from the forest.

Human interference in this community was small but in one section of the community a large number of topped *Maytenus gracilipes* were observed. According to the local people, that was because, once new settlers came and tried to clear the vegetation for agriculture but immediately chased away by the surrounding people.

5.1.2 Structural

The predominance of small sized woody species in Denkoro forest might be the result of excessive cutting, which took place in the forest a long time ago. This was witnessed by the subsequent structural analysis based on tree height and DBH classes distribution as shown in Tables 6 & 7 respectively. Both results show high proportion of individuals in the lower and the least in the higher classes.

Correlation of basal area to density of trees based on DBH classes described in Fig. 3 shows the same trend as the preceding disccription based on height and DBH classes. The forest has more than half its total number of individuals in the lowest DBH classes (< 20 cm) and very few in the highest DBH classes. The contribution of small sized individuals to the basal area is very small. This is because many individuals in the lowest DBH classes are of smaller stature. The large density of small sized woody individuals and the least number of large trees in the forest did not contribute much to the total basal area of the forest (45 $m^{2/}$ha) as the intermediate classes.

Basal area comparison made Denkoro forest (45 m^2/ha) similar to Menagesha (36.1 m^2/ha) and Chilmo (30.1m^2/ha) forests (both in Tamrat, 1993) in structure than Wof-Washa (101.8 m^2/ha) (Tamrat, 1993) which was relatively not much, degraded.

Denkoro forest was compared with the dry Afromontane forests of the central plateau of Shewa (Chilmo, Menagesha and Wof-Washa) (Tamrat, 1993) based on tree density in different classes and basal area of woody species.

The ratio of DBH > 10 cm over DBH > 20 cm of woody species in Denkoro forest is very close to the ratio in Chilmo and Menagesha forests (Table 9). Table 10 and 11 also show the same result in the comparison of trees based on height and DBH classes, which indicated the predominance of small sized woody species in all the three forests.

The structural analysis discussed so far indicate Denkoro forest is in a stage of secondary development and has closer characteristics to that of Chilmo and Menagesha forests. These two forests were described by Tamrat (1993) as both were subjected to excessive cutting, which took place a long time ago and were in a stage of secondary development. This conclusion agrees with the suggestion given in the introduction that Denkoro has been subjected to combined forces of exploitation and forest degradation.

The patterns of species population structure (Fig. 4) suggest two major types of woody species.

(1) species able to regenerate in the forest under storey *(Myrsine melanophloeos, Hypericum revolutum, Ekebergia capensis, Discopodium penninervum, Myrsine africana, Maesa lanceolata*, and *Bersama abyssinica*). (2) Large and old trees with difficulties to reproduce in the understorey environment (*Hagenia abyssinica, Juniperus procera* and *Olea europaea*). Several species like *Hypericum revolutum* and *Ekebergia capensis* which were consumed by grazers have a good regeneration but most of the seedlings do not exist long to grow into mature trees. These species were suitable for browsing.

The patterns in the population structure of some species are suggestive of the past occurrence of disturbance. In cases of trees with inverted J-Shaped population structure (e.g. Fig. 4D) medium and large-sized individuals have probably been cut. The elimination of older individuals could also be possible by other more successful species (Tamrat, 1993).

Hagenia abyssinica, Juniperus procera, Dombeya torrida, Nuxia congesta, Prunus africana, Olinia rochetiana, Apodytes dimidiata and *Olea europaea* where their pattern is represented by Fig 4B and E did not show good regeneration. The old trees of *Hagenia abyssinica* for example, have started to die back and even some were completely dried and uprooted.

5.2 Phyto-geographical Description

The altitudinal range of Denkoro forest is from 2300 to 3500 m a. s. l., which is almost closer to Wof-Washa forest. Altitude has a decisive role on the distribution of vegetation on East

African Mountains (O. Hedberg, 1951; Lind and Morrison, 1974; Tewolde, 1989). Three vegetation belts were described as characteristic for East African mountains based on altitude (O. Hedberg, 1951). These are the Montane forest belt, the Ericaceous belt and the Alpine belt. The montane forest belt, and the Ericaceous belt are represented in Denkoro forest. However, the Afroalpine belt starts immediately above the Ericaceous zone out of Denkoro forest at an altitude of ca. 3600 m. It extends about 200 km up to "Guguftu" a small town 40 km away from Dessie and covers most parts of Werehimenu (the former province of South Wello). This Afroalpine vegetation in the study area has not been investigated or mentioned in literatures.

The *Erica arborea* type prevails at the highest elevation (> 2900 m a.s.l.). The *Erica* individuals decrease in size towards the upper limit of their occurrence and merge with the Afroalpine vegetation at about 3500 m a.s.l. *Erica arborea* in Denkoro forest formed a distinct community towards the upper edge of the forest.

The Montane forest belt is further subdivided into three zones (O. Hedberg, 1951), the Montane rain forest zone, the Bamboo zone and the *Hagenia – Hypericum* zone. The *Hagenia – Hypericum* zone was described in Denkoro forest. The zone is not distinct although the species assemblage is represented in the forest.

Among the seven forest types described by Friis (1992), Denkoro forest represents the undifferentiated Afromontane ones. According to this author the forest represents both transitional rain forest and undifferentiated Afromotane forest consisting of dominant tree species like *Juniperus procera*, *Olea europaea ssp. cuspidata*, *Croton macrostachyus*, *Ficus* *sur*, and *Maesa lanceolata.* It was also noted that *Ekebergia capensis* and *Acacia abyssinica* existed as relics in a dispersed manner adjacent of the forest. From the present analysis however, it was understood that the forest has some elements of Afromontane rain forest and more species of the undifferentiated ones. Only one of the species (*Ficus sur*) is Guineo-Congolian floral element. According to Tamrat (1993) *Ficus sur* is found in specialized habitat such as along river courses (on marshy plain in Denkoro forest relatively at lower altitude 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 at lower altitude in the forest. The forest is sharply demarcated by a large cliff from the lowland.

Prunus africana typical of moist montane forest (Lind and Morrison, 1974) was also recorded. On the other hand Denkoro forest includes Afromontane endemics such as *Juniperus procera, Olea europaea ssp. cuspidata, Hagenia abyssinica, Podocarpus falcatus, Apodytes dimidiata, Ilex mitis, Myrsine melanophloeos* and *Olinia rochetiana.* Of these *Myrsine melanophloeos, Olinia rochetiana, Apodytes dimidiata* and *Olea europaea ssp. Cuspidate* are the current dominant species in the forest.The ones mentioned as dominant tree species by the above authors are now rare in the forest except *Olea europaea ssp. cuspidata* and *Maesa lanceolata*. This was not because of successation or forest disturbance. For the former reason only 16 years has been elapsed since the study was conducted. In these few years a dominant species wouldn't be disappeared by succession. For the latter case, there was no sign of cuttings such as stumps and logs of the species. Thus, the so called dominant species by Friis (1992) were naturally rare in the forest.

In addition to the Afromontane endemics other species belonging to connecting elements have also 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 are found in disturbed habitats along forest edges (distributed in most communities Denkoro forest).

Some of the montane forest species listed from Denkoro forest have also been recorded from shrub land vegetation of the central plateau of Ethiopia (Zerihun and Backeus, (1991). This species include *Erica arborea, Juniperus procera, Olea europaea, Pittosporum viridiflorum, Prunus africana, Maytenus arbutifolia, Myrsine africana* and *Scolopia theifolia*. This shrub land type has been described as a secondary community that has expanded from lower altitudes and drier sites as the forest gradually disappeared (Zerihun and Backeus, 1991).

6. CONCLUSIONS AND RECOMMENDATION

The floristic description indicated the presence of high species diversity (66 families represented by 174 species) in the forest. Of which 11 endemic species, which are already, getting in the red list of IUCN, 8 indicator species for forest disturbance, the distribution of 56 species in the study area which have not been recorded in the flora of Ethiopia were identified. The eight indicator species showed the forest was under degradation and hadn't got emphasis by the scientific community and the concerned department that should manage the forest.

Description of the six community types also implied three important points. The first was the existence of degradation took that place in all community types. This was because of human interference, which was increasing from time to time due to the scarcity of other forest reserves in the region. A conflict of interest was observed between the local people and the Regional government. On one hand the local people wanted freedom to use the forest, on the other hand the government had strictly protected the forest without the participation of the local people. As a result, illegal usage of the forest had been intensified that aggravated the degradation process.

The other point was the appearance of two types of woody species in all community types: Those that were regenerating and disappearing. The woody species, which showed high regeneration potential, were *Myrsine melanophloeos* (almost in all communities), *Hypericum revolutum*, *Discopodium Penninervium*, *Maesa lanceolata*, *Bersama abyssinica* and *Clerodenderon alatun.* Those, which showed least regeneration, were *Erica arborea, Myrsine* *africana, Maytenus arbutifolia, Dovialis abyssinica*, *Scolopia theifolia* and *Ekebergia capensis*. The non-regenerating ones were *Hagenia absssinica, Dombeya torrida, Prunus africana Nuxia congesta, Olinia rochetiana, Juniperus procera, Olea europaea ssp. cuspidata* and *Apodytes dimidiata*. Three of these species (*Olinia rochetiana, Apodytes dimidiata* and *Olea europaea ssp. cuspidata*) were the dominant species in the forest. All these non-regenerating species need a better emphasis before they are displaced by the regenerating ones and used by the surrounding people.

Structural description on Denkoro forest based on tree density and basal area, implied the predominance of small sized individuals and the rare occurrence of large and woody species. This indicated the forest had been under heavy exploitation and degradation and is in a stage of secondary development. The structural and floristic comparison made in the nine Afromontane forest of Ethiopia ensured Denkoro forest to have a similar structural characteristics with Chilmo and Menagesha forests which were already identified by Tamrat (1993) as degraded and in a stage of secondary development.

Analysis of population structure pointed out the variability of population dynamics in the forest. It confirmed at least the existence of two major types of woody species: species able to regenerate in the forest under storey; and large and old trees with difficulties to reproduce in the under storey environment. *Hagenia abyssinica*, which has started to die back, *Juniperus procera and Olea europaea ssp. cuspidata*, were grouped in the latter case.

The phytogeographic description indicated the following major points. The first is the floristic comparison of Denkoro forest with the nine forests of Ethiopia revealed the forest is very close to the floristic composition of Menagesha and Chilmo forests (Tamrat, 1993). This was because the forests are found in similar altitude and climatic conditions. Denkoro had also better similarities with Wof Washa, Harenna and Jibat forests. Its similarity with the latter two forests could be because the forest has some moist forest characteristics and high species diversity. The highest similarity, among Menagesha, Chilmo and Denkoro forests confirmed all were under heavy degradation. The 2^{nd} is the dominant tree species of Denkoro forest suggested by Friis (1992) are disappearing and being replaced by another ones *(Olinia rochetiana, Myrsine melanophloeos, Olea europaea ssp. cuspidata, Apodytes dimidiata* and *Maytenus gracilipes*. The same authors also confirmed that Anabe and Mekonnen Lemlem forests were the only natural forest left in Wello. But it was Denkoro forest now and at that time the only natural forest left in the region. The two forests mentioned by the above author consisted mainly of plantation (particularly Mekonnen Lemlem) than natural vegetation.

The other point mentioned in the phytogeographic description is the presence of Ericaceous zone ca. 200 ha. at the upper edge of the forest and the appearance of large Afroalpine vegetation extending from the Ericaceous zone and cover a considerable portion of South Wello (one woreda of Worehimenu). This Afroalpine vegetation has not been studied still now and call for future investigation. Finally from the floristic comparison between Denkoro and the forest types of Hedberg (1951) and Friis (1992), Denkoro represents undifferentiated Afromontane forest, and sub-Afroalpine vegetation.

Forest regulates microclimate, protect water resources, provide forest products and are homes to plant and animal species. The forest under discussion might probably be the last remaining montane forest in Amhara region with distinct vegetation zones that could be used to carry more scientific studies. It provides habitat for a number of unique animals, which are already mentioned in the study area. It could also be considered as gene reserve and natural regeneration area for several economically important plant species. However, from the forgoing discussion it can be seen that the forest requires better management so that its resources could be effectively utilized on a sustainable bases. Therefore, the following recommendations are made to meet these requirements

- Creating awareness on the various uses of the forest resources so as to utilize them wisely.
- Agro forestry practice should be encouraged so that people can use the forest for forage, construction, farm materials and firewood.
- Extension program including forest management should be extended so as to increase awareness on people for better utilization of the forest.
- Timber cutting from the forest should be stopped if possible at least controlled.
- Animal husbandry (a common practice in the forest) should be reduced so that regeneration of the species in the forest could be facilitated.
- Any forest planning and development activities should include the active participation of local communities. However, the conservation program implemented in the study area has discouraged the local people. It was implemented by the regional government leaving the surrounding people aside. Obviously, this calls for better forest management as a means to avoid conflicts of interest between the future utilization of the forest and other development activity.
- The planning and management of forests should be based on research works and therefore, more basic research should be continued

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APPENDICES

Appendix 1. Releve Characteristics of Denkoro forest

Releve No.	Aspect	Altitude	Locality
1	N-w	3416	Tikur Gora
2	Plain	3339	" "
3	" "'	3292	Godgoadit
4	N-E	3294	Laygnaw Gosh Beret
5	N-W	3240	Tachignaw " "
6	Plain	3165	Kassa gizaw Ager
7	S-W	3164	Arogew Zeda
8	N-W	3238	Keyu Dingay
9	Plain	3058	Derse Beret
10	N-E	3051	Endeshaw Beret
11	N	3066	Goblale
12	Plain	3000	Tachignaw Goblale
13	Plain	3014	Mehal Goblale
14	Plain	2977	Goblale Tig
15	Plain	2935	Haro Tig
16	Plain	2959	Mehal Haro
17	N	3009	Haro Tig
18	Plain	2964	Mehal Haro
19	Plain	3002	Alebachew Washa Tig
20	Plain	2948	Tilku Haro Awasagn
21	Plain	2918	Haro
22	Plain	2918	Haro Afaf
23	Plain	2955	Haro
24	N-w	2940	Tilku haro Awasagn
25	N-w	2742	Yedesalew Beret
26	W	2787	Keyu Dingay
27	S-W	2861	Desalew Beret
28	Plain	2926	Zebate Haro
29	N-E	2861	Fertate
30	N-W	2812	Fertate
31	Plain	2801	"
32	N-E	2795	Kintro Awasagn
33	N-W	2821	Sekedireshet
34	N-E	2773	Jigra Wogeb
35	Plain	2771	Yegezahegn Wurma
36	N-E	2763	Jibu Wotmed
37	N-W	2760	Sekedereba
38	Plain	2764	"
39	Plain	2706	Kelawatira
40	N-W	2702	"
41	N-W	2667	"
42	N-W	2693	"
43	Plain	2717	"
44	N-E	2709	Jemaw Sar
45	N-E	2707	"
46	N-E	2670	Mehal Menged
47	Plain	2646	" "
48	N-W	2655	" "

…Appendix 1 contd.

49	N-W	2637	Ketane
50	N-W	2613	"
51	N-W	2647	Gefefo
52	S-W	2632	"
53	N-W	2582	"
54	N-E	2594	Gurtu
55	N-E	2600	"
56	Plain	2628	"
57	Plain	2646	Gishewa
58	Plain	2634	Gurtu
59	N-=W	2555	Gurtu
60	Plain	2398	Gishewa-Zebate
61	Plain	2439	" "
62	N-E	2430	Zebate
63	N-W	2518	Gishewa
64	N-W	2611	"
65	Plain	2650	Gishewa Mariam
66	N-E	2633	Gishewa
67	Plain	2649	"
68	S-W	2607	"
69	S-W	2586	"
70	Plain	2585	"
71	N-W	2614	Gishewa
72	Plain	2642	"
73	Plain	2634	"
74	N-W	2660	Kintro Afaf
75	N-W	2665	Gishewa
76	Plain	2425	Sinkir Kebir
77	Plain	2457	Buke
78	Plain	2418	Sinkir Kebir
79	S	2354	Buke
80	Plain	2338	"
81	Plain	2345	Mehal Buke
82	Plain	2362	Buke
83	Plain	2353	Mognoch Afaf
84	Plain	2370	" "
85	Plain	2371	Buke
86	Plain	2415	"
87	Plain	2916	Buke Abaselam
88	Plain	2420	BukeGedam
89	Plain	2446	" "
90	Plain	2416	" "
91	Plain	2445	" "
92	Plain	2674	" "
93	Plain	2647	Gurtu
94	Plain	2618	Gurtu Tig
95	Plain	2629	Gishewa Tig

Appendix 2. List of plants recorded in the stands sampled

Botanical name	Family name	Vernacular name (Amheric)	Life form	Coll. No
Acacia pilispina Pic.Serm.	Fabaceae	Girar	T	7604
Acanthus sennii Chiov.	Acanthaceae	Shekori	S	F.O.R
Achyranthes aspera L.	Amaranthaceae	Yedergu sar	H	357
Achyrospermum schimperi T.C.E. Fries	Lamiaceae	Yemogn kimem	H	5798
Acritochaeta volkensii Pilg.	Poaceae	Shenbeko sar	G	4026
Aeschynomene abyssinica (A. Rich.) Vatke	Fabaceae		H	F.O.R
Agrocharis melanantha Hochst.	Apiaceae	Dog	H	F.O.R
Agrocharis sp.	Apiaceae	Chegogot	H	7253
Albizia schimperiana Oliv.	Fabaceae	Sesiy	T	7126
Alchemilla abyssinica Fresen**.**	Rosaceae	Yemdir Kosso	H	228
Allophylus abyssinica (Hochst.) Radlk.	Sapindaceae	Bar Embis	T	7397
Andropogon abyssinica R. Br. ex. Fresen.	Poaceae	Balami	G	4373

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Andropogon lima (Hack) Stapf.	Poaceae	-	G	F.O.R
Anthoxanthum aethopicum I. Hedberg	Poaceae	Yekok sar	G	F.O.R
Anthriscus sylvestris (L) Hoffm.	Apiaceae		H	F.O.R
Apodytes dimidiata E. Mey. ex Arn.	Icacinaceae	Dong	T	3809
Arisaema shimperianum Schott.	Araceae	Amoch	H	F.O.R
Asparagus africanus Lam.	Asparagaceae	Yeset kest	S	7274
Asplenium adiantum-nigrum L. Del. R.Viane	Aspleniaceae	Joro asfi	F	228
Asplenium aethopicum (Burm. f.) Becherer.	Aspleniaceae	Amsa Anketkit	F	227
Athrixia rosmarinifolia (Walp.) Oilv. and Hiern	Asteraceae		H	F.O.R
Arudinara alpina K. Schum.	Poaceae	Kerkeha	B	F.O.R
Bersama abyssinica Fres.	Melianthaceae	Azamir	T/S	3370

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Bromus pectinatus Thunb	Poaceae	Shenbeko sar	G	F.O.R
Buddelja polystachya Fresen.	Loganiaceae	Nech Anfar	S	F.O.R
Calpurnia aurea (Ait.) Benth.	Fabaceae	Digita	S	5879
Campanula edulis Forssk.	Campanulaceae		H	382
Cappris tomentosa Lam.	Capparidaceae	Gumero	S	7298
Carduus sp.	Asteraceae	Yeahya Eshoh	H	789
Cardamine africana L.	Brassicaceae		H	F.O.R
Cardamine trichocarpa Hochst. ex. A. Rich.	Brassicaceae	Fetosar	H	376
Carex conferta Hochst. ex A. Rich.	Cyperaceae		G	F.O.R
Carex steudneri Bock	Cyperaceae	Filla	G	F.O.R
Carissa edulis (Forssk.) Vahl	Apocynaceae	Agam	S	7239
Celtis africana Burm. f.	Ulmaceae	Kawot.	T	F.O.R
Cerastium octandrum A. Rich.	Caryophyllaceae	Chegof Sar	H	356

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Clematis simensis Fresen.	Ranunculaceae	Azo Areg	H	F.O.R
Clerodendron alatum Gurke	Verbenaceae	Buyte	S	7744
Commelina diffusa Brum. f.	Commelinaceae		H	F.O.R
Commelina africana L.	Commelinaceae		H	F.O.R
Convolvulus kilimandschari Engl.	Convolvulaceae	Yeayt Areg	H	1661
Conyza spinosa Sch.-Bip. ex. Oliv. & Hiern	Asteraceae	Yedega Chifrg	H	F.O.R
Conzya hypoleuca A. Rich.	Asteraceae	Qulsh	S	934
Croton macrostachyus Del.	Euphorbiaceae	Bisana	T	7289
Cynoglossum coeruleum Steud. ex DC.	Boraginaceae	Chegog ot	H	254
Cynoglossum sp.	Boraginaceae		H	F.O.R
Cyanotis barbata D. Don	Commelinaceae		H	F.O.R
Cyathula cylindrica Moq.	Amaranthaceae	Kundosa r	H	F.O.R
Cyperus dichroostachyus A. Rich.	Cyperaceae	Giramta	G	1326

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Cyperus fischerianus A. Rich.	Cyperaceae	Giramta	G	7256
Cyperus sesquiflorus (Torr.) Mattf. Kuk. subsp. *cylindercus* (Nees) Koyama	Cyperaceae	Yewrma ketema	G	F.O.R
Deliphinium dasycaulon Fresen.	Ranunuclaceae	Sete yemdir kosso	H	F.O.R
Desmodium repandum (Vahl) DC.	Fabaceae	Yeayt Misir	H	F.O.R
Dichrocephala integrifolia (L. f) O. Kuntze	Asteraceae		H	F.O.R
Discopodium penninervium Hochst.	Solanaceae	Ameraro	S	347
Dombeya torrida (J. F. Gmel.) P. Bamps	Sterculiaceae	Wulkfa	T	1801
Dovyalis abyssinica (A. Rich.) Warb.	Flacourtiaceae	Koshim	S/T	6558
Drouguetina iners (Forssk.) Schweinf.	Uriticaceae		H	F.O.R
Ekebergia capensis Sparrm.	Meliaceae	Sembo	T	5773

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Embelia schimperi Vatke	Myrsinaceae	Enkoko	S	F.O.R
Erica arborea L.	Ericaceae	Asta	T/S	1
Euphorbia ampliphylla Pax	Euphorbiaceae	Kulkual	T	5630
Euphorbia shimperiana Scheele	Euphorbiaceae	Antrfa	H	F.O.R
Festuca abyssinica Hochst. ex A. Rich.	Poaceae	Angedgid	G	359
Festuca macrophyla Hochst. ex A. Rich.	Poaceae	Goassa	G	F.O.R
Ficus sur Forssk	Moraceae	Sholla	T	7692
Galiniera saxifraga (Hochst. ex. A. Rich.) Bridson	Rubiaceae	Wude	T	2911
Galium asparinoides Forssk.	Rubiaceae	Ashket	H	234
Geranium arabicum Forssk.	Geraniaceae		H	256
Girardinia bullosa (Steud.) Wedd.	Urticaceae	Dobi	H	5792

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Gladiolus abyssinica (Borngn. ex Lemaire) Goldblatt & de Vos	Iridaceae		H	F.O.R
Guizotia scabra (Vis.) Chiov.	Asteraceae	Mech	H	F.O.R
Hageniaia abyssinica (Bruce) J. F. Gmel.	Rosaceae	Kosso	T	1645
Haplocarpha rueppellii (Sch.- Bip.) Beauv.	Asteraceae	Yewha Getin	H	F.O.R
Holothrix arachnoidea (A. Rich.) Rchb. f.	Orchidaceae	Yewsha Kintrosh	H	234
Hypericum peplidfolium A. Rich.	Hypericaceae	Yemdir Kosso	H	7315
Hypericum quartinianum A. Rich.	Hypericaceae	Amja	S	F.O.R
Hypericum revolutum Vahl	Hypericaceae	Amja	T/S	2774
Isodon ramosissimus (Hook. f.) Codd	Lamiaceae		T	F.O.R
Jasminum abyssinicum Hochst. ex DC.	Oleaceae	Enchlbe	S	F.O.R
Juniperus procera L.	Cuppressaceae	Tid	T	3648

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Kalanchoe petitiana A. Rich.	Crassulaceae	Andawlla	H	2646
Kniphofia foliosa Hochst.	Asphodelaceae	Ashengado	H	F.O.R
Lactuca capensis Thunb.	Asteraceae		H	235
Lactuca serriola L.	Asteraceae	Amedmede	H	378
Laggera crispata (Vahl) Hepper & Wood	Asteraceae		H	F.O.R
Laggera pterodonta (DC.) Sch. -Bip.	Asteraceae		H	F.O.R
Laggera tomentosa Sch.- Bip.	Asteraceae	Alashume	S	F.O.R
Laggera braunii Vatke	Asteraceae		H	F.O.R
Lotus discolor E. Mey.	Fabaceae	Yechaka Tosign	H	F.O.R
Luzula abyssinica Parl.	Juncaceae		G	246
Maesa eanceolata Forssk.	Myrsinaceae	Akelawe	TP	2310
Maytenus arbutifolia (Hochst. ex. A. Rich) Wilczex	Celastraceae	Kombel	S	2823
Maytenus gracilipes (Welw. ex Oliv.) Exell ssp. a*rguta* (Loes.) Sebsebe	Celastraceae	Atat	S	4046

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Mimulopsis solmsii Schweinf.	Acanthaceae	Dergu	H	5614
Monopsis stelarioides (Presl.) Urban	Campanulaceae		H	382
Myrica salicifolia A. Rich.	Myricaceae	Shinet	T	4031
Myrsine (Rapanea) melanophloeos (L.) R. Br.	Myrsinaceae	Gewra	T	693
Myrsine africana L.	Myrsinaceae	Kechemo	S	1336
Nuxia congesta R. Br. ex Fresen.	Loganiaceae	Asquar	T	6125
Olea europaea L. ssp. cuspidate (Wall. ex DC.) Cifferri	Oleaceae	Woira	T	4462
Olinia rochetiana A. Juss.	Oliniaceae	Tife	T/S	4327
Olea hochstetteri Baker	Oleaceae	DerekWoira	T	F.O.R
Osyris quadripartita Decne	Santaleceae	Keret	T/S	4330
Otostegia integrifolia Benth.	Lamiaceae		H	F.O.R
Pennisetum thunbergii Kunth	Poaceae	Yewsha sindedo	G	F.O.R
Pentaschistis pictigluma (Steud.) Pilg.	Poaceae	Tef sar	G	364

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Peperomia abyssinica Miq.	Piperaceae		H	F.O.R
Periploca linearifolia A. Rich. & Quartin-Dillon	Asclepiadaceae		H	F.O.R
Peucedanum winkleri Wolff	Apiaceae		H	5729
Phoenix reclinata Jacq.	Arecaceae	Selen	S	F.O.R
Phytolacca dodecandra L'Herit	Phytolaccaceae	Endod	S	F.O.R
Pittosporum virdiflorum Sims	Pittosporaceae	Solae	T	4235
Plantago lanceolata L.	Plantaginaceae	Gorteb	H	7257
Plantago palmata Hook. f	Plantaginaceae	Yewurma Gorteb	H	F.O.R
Plectranthus assurgens (Baker) J. K. Morton	Lamiaceae		H	F.O.R
Plectranthus punctatus (L.) L` Herit	Lamiaceae	Solelat	H	3263
Poa shimperiana Hochst. ex A. Rich.	Poaceae	Labuche	G	403
Podocarpus (Afrocarpus) falcatus (Thunb.) Mirb.	Podocarpceae	Zigba	T	8066

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Polygala steudneri Chod	Polygalaceae	Yabeba Fire	H	F.O.R
Primula verticillata Forssk.	Primulaceae		H	F.O.R
Prunus africana (Hook. f.) Kalkm	Rosaceae	Tikur Enchet	T	3974
Ranunculus oreophytus Del. var. *stolonifer* Ulbr.	Ranunculaceae	Gudiga	H	381
Rhabdotosperma scrophulariiafolia A. Rich.	Scrophulariacea e		H	F.O.R
Rhus abyssinica Oliv.	Anacardiaceae	Tatesa	S	F.O.R
Rhus glutinosa A. Rich.	Anacardiaceae	Embis	S	F.O.R
Romulea fischeri Pax	Iridaceae	Yeregna Kolo	H	655
Rosa abyssinica Lindley	Rosaceae	Kega	S	1282
Rubus apetalus Poir.	Rosaceae	Enjori	S	F.O.R
Rubus steudneri Schweinf.	Rosaceae	Gurarba	S	1130
Rubus volkensii Engl.	Rosaceae	Encholla	S	F.O.R
Rumex abyssinica Jacq.	Polygonaceae	Mekmeko	H	F.O.R
Rumex nepalensis Spreng.	Polygonaceae	Tult	H	7261
Rumex nervosus Vahl	Polygonaceae	Emboacho	S	F.O.R
Rytidosperma sp.	Poaceae	Ginchire	G	226

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Sanicula elata Buch. Ham. ex D. Don	Apiaceae	Gurarba Aynet Kitel	H	1532
Satureja paradoxa Vatke	Lamiaceae	Yewurma Kisnkis	H	F.O.R
Satureja pseudosimensis Brenan	Lamiaceae		H	F.O.R
Satureja punctata (Benth.) Briq.	Lamiaceae	Lomishetsar	H	1322
Satureja simensis (Benth.) Briq.	Lamiaceae	Lomishet	H	369
Scabiosa columbaria L.	Dipsacaceae	Ketetina Sar	H	365
Scolopia theifolia Gilg.	Flacourtiaceae	Wanaye	T	4721
Senecio ochrocarpus Oliv. & Hiern	Asteraceae		S	F.O.R
Senra incana Cav.	Malvaceae	Ne chillo	S	F.O.R
Sium sp.	Apiaceae		H	F.O.R
Snowdenia petitiana (A. Rich.) C. E. Hubb	Poaceae	Muja	G	F.O.R
Solanecio gigas (Vatke) C. Jeffrey	Asteraceae	Yeshikoko Gomen	S	7132

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Solanum benderianum Schimp. ex Engl.	Solanaceae	Enkulti	S	760
Solanum marginatum L. f.	Solanaceae	Zerch Emboay	S	7252
Sprobolous pyramidalis Beauv.	Poaceae	Gaja	G	F.O.R
Stachys aculeolata Hook. f.	Lamiaceae	Sama Sar	H	943
Stachys alpina T. C. E. Fries	Lamiaceae		H	2823
Stephania abyssinica (Dill. & A. Rich.) Walp.	Menispermaceae	Kelala	H	F.O.R
Stellaria senni Chiov.	Caryophyllaceae		H	F.O.R
Streblochaete logiarista (A.Rich.) Pilg.	Poaceae	Yesytan merfe	G	959
Swertia lugardae Bullock	Gentaniaceae		H	F.O.R
Tagetes minuta L.	Asteraceae		S	F.O.R
Teclea nobilis Del.	Rutaceae	Worer	T	5757

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Thalictrum rhyncocarpum Quartin – Dillon & A. Rich.	Ranunculaceae		H	F.O.R
Thymus schimperi Ronnign.	Lamiaceae	Tosign	H	219
Tacazzea conferta N. E. Br.	Asclepiadaceae	Kuande	S	F.O.R
Torillis arvensis (Huds.) Link	Apiaceae		H	F.O.R
Trachydium abyssinicum (Hochst.) Hiern	Apiaceae	Yesar Asherako	H	F.O.R
Trifolium burchellianum Ser.	Fabaceae	Maget	H	942
Trifolium semipilosum Fresen.	Fabaceae		H	942
Ubelinia kiwuensis T.C.E. Fries	Caryophyllaceae		H	F.O.R
Umbilicus botryoides A. Rich.	Crassulaceae	Yedingay Kitel	H	365
Urera hypselodendron (A. Rich.) Wedd.	Urticaceae	Lankuso	S	F.O.R

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

… Appendix 2 continued

Urtica simensis Steud.	Urticaceae	Sama	H	F.O.R
Usnea sp.	Lichen	Yeasta Shebeto	L	223
Vernonia bipontini Vatke	Asteraceae	Yetija limich	S	F.O.R
Veronica glandulosa Hochst. ex Benth.	Scropholariaceae		H	375
Viola abyssinica Oliv.	Violaceae	Yebere Chew	H	799
Zehneria minutiflora (Cogn.) C. Jefrey	Cucurbitaceae	Areg Resa	H	F.O.R

F.O.R Found Out of Releves; G Graminoid; T Tree; S Shrub; T/s Tree/Shrub; TP Pioneer Tree

Appendix 3.List of species which have not been previously reported from Wello zone

Acritochaeta volkensii	*Aeschynomene abyssinica*	*Andropogon abyssinica*
Andropogon lima	*Anthoxanthum aethopicum*	*Apodytes dimidiata*
Arisaema schimperianum	*Scolopia theifolia*	*Cardamine trichocarpa*
Carex conferta	*Carex steudneri*	*Commelina diffusa*
Convolvulus kilimandschari	*Cynoglossum coeruleum*	*Cyperus ficherianus*
Cyperus sesquiflorus	*Embelia schimperi*	*Festuca abyssinica*
Festuca macrophyla	*Galiniera saxifraga*	*Geranium arabicum*
Girardinia bullosa	*Holothrix arachnoidea*	*Laggera crispata*
Luzula abyssinica	*Maytenus gracilipes ssp. arguta*	*Myrsine melanophloeos*
Pentaschistis pictigluma	*Plantago lanceolata*	*Veronica glandulosa*
Poa schimperiana	*Prunus africana*	*Rhabdotosperma scrophulariiafolia*
Romulea fischeri	*Rubus volkensii*	*Rumex abyssinicus*
Satureja punctata	*Scolopia theifolia*	*Senra incana*
Solanum benderianum	*Streblochaete logiarista*	*Thalictrum rhyncocarpum*
Thymus schimperi	*Trifolium burchellianum*	*Uebelinia kiwuensis*
Umbilicus botryoides	*Urera hypselodendron*	*Urtica simensis*

Appendix 4. Important value index of trees in Denkoro forest

Species	Relative density	Relative Dominance	Relative frequency	Important value index
Acacia pilispina	1	.34	.61	1.95
Albizia schimperiana	.1	.31	.6	1.01
Allophylus abyssinica	1.6	.8	6.7	9.1
Apodytes dimidiata	2.9	12.3	7.87	22.17
Bersama abyssinica	7	1.8	9.5	18
Croton macrostachyus	.3	.16	.8	1.3
Dombeya torrida	1	3.45	2.42	6.87
Ekebergia capensis	.5	4	2.63	7.13
Erica arborea	16	4.5	3.2	23.7
Euphorbia ampliphylla	.9	1.56	1.42	3.9
Ficus sur	.7	.29	.4	1.4
Galiniera saxifraga	.9	.24	.8	1.9
Hageniaia abyssinica	.3	4.26	2.63	7.2
Hypericum revolutum	4.6	3.57	5.2	13.4
Juniperus procera	.2	7.45	1.6	9.27

…Appendix 4 continued

Maesa lanceolata	3.5	2.74	4.22	10.46
Myrica salicifolia	.5	2.7	1.8	5
Myrsine africana	30.5	11.38	9.2	51.08
Nuxia congesta	4.5	5.2	8.49	18.2
Olea europaea ssp. cuspidata	3.0	11.38	8.25	21.2
Olinia rochetiana	10	13.5	9.08	22.58
Podocarpus (Afrocarpus) falcatus	.1	5.1	.6	5.8
Prunus africana	1.2	2.38	4.6	8.25
Scolopia theifolia	2.3	.97	2.82	6.09
Teclea nobilis	1	.06	2.01	3.08

Figures of Denkoro Forest

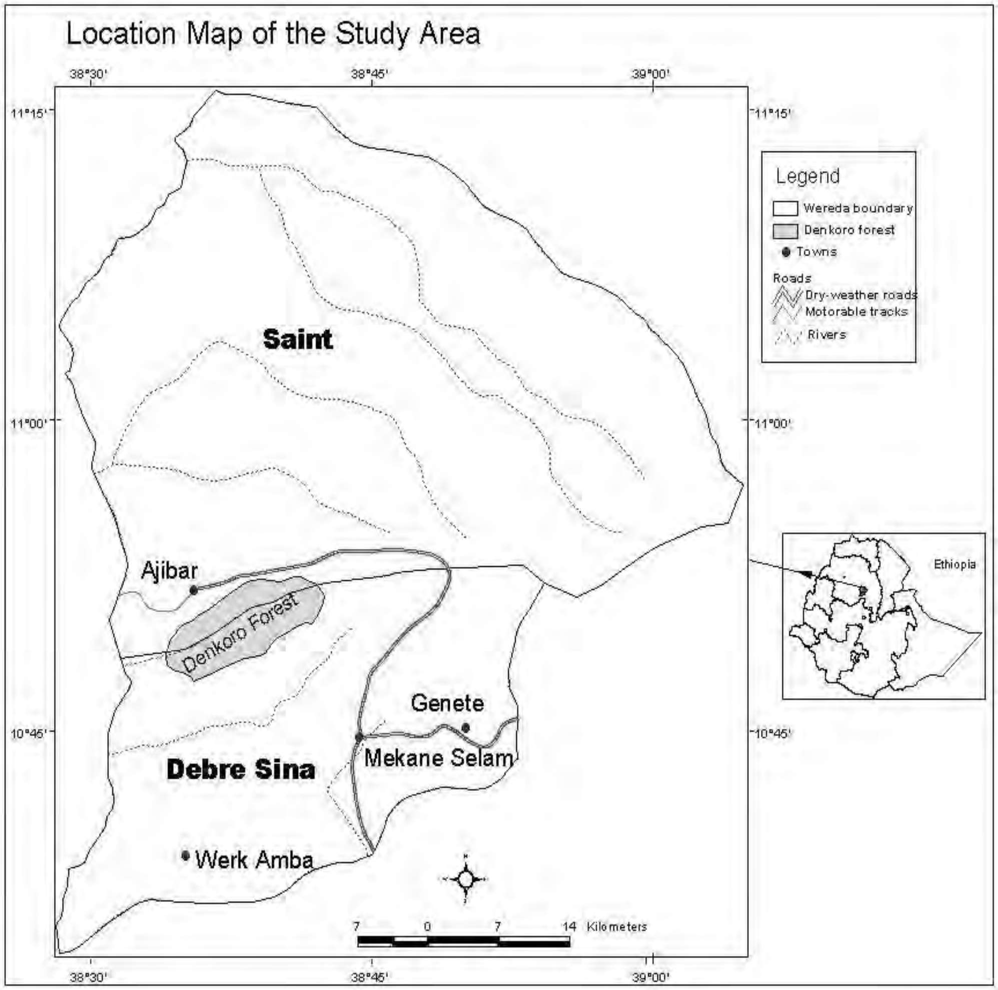


Figure 5. Location map of the study area

MekaneSelam(2600)

[10] 16.1^{o} 933

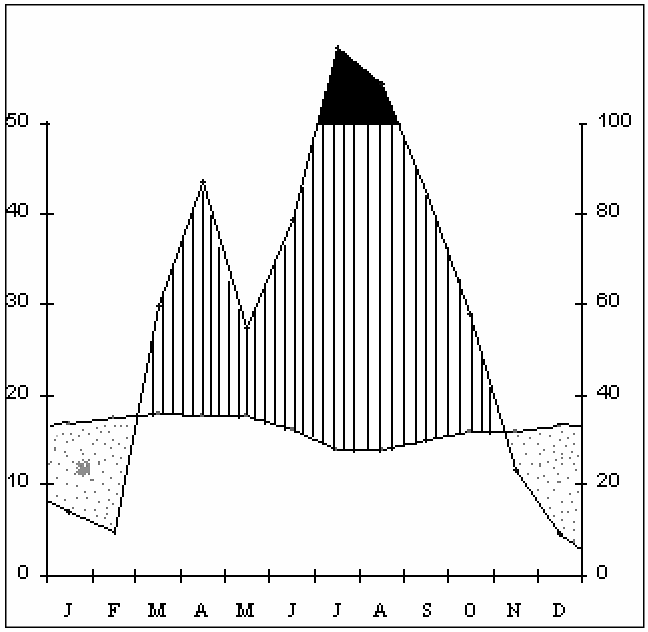


Figure 6. Climatic diagram for the Denkoro forest – town of Mekane Selam, 2600 m a.s.l. (following Walter 1979).

Source: National Metrological Service Agency

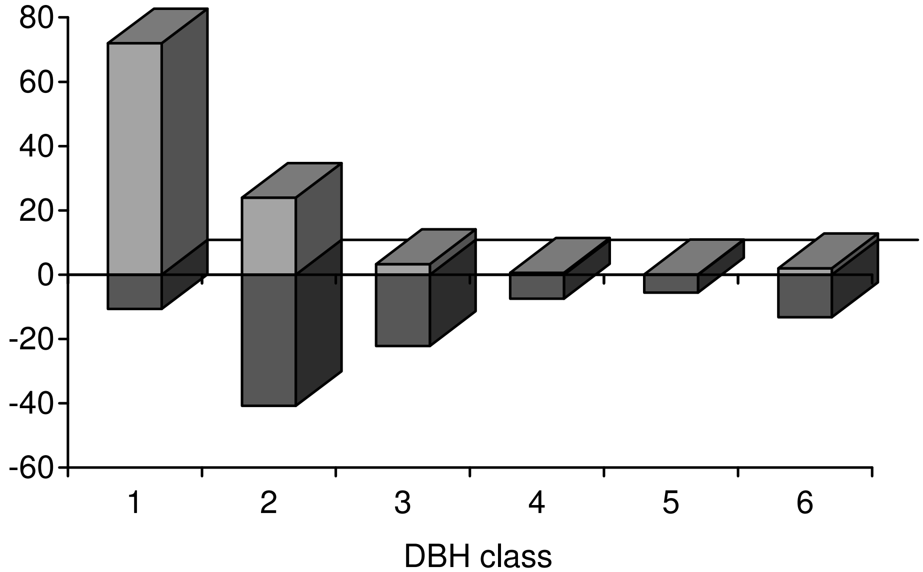
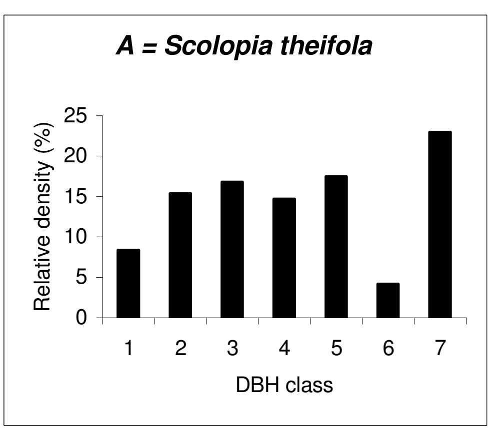
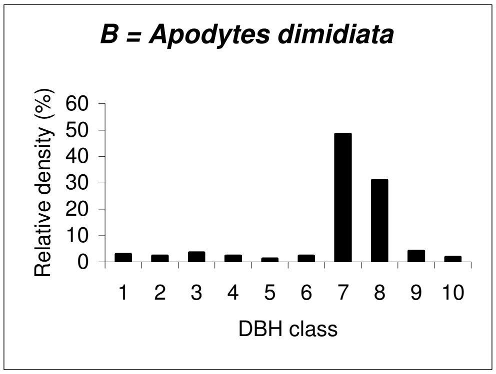
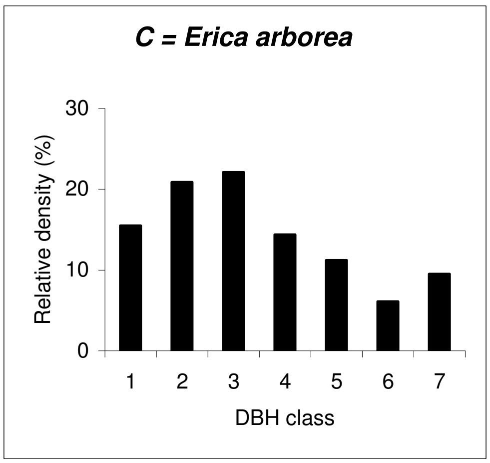


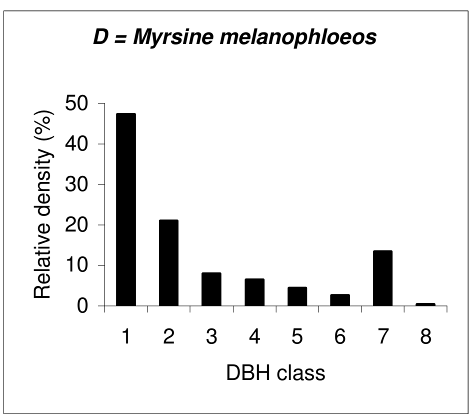
Figure 7. Frequency distribution of trees in DBH classes (all trees included) in Denkoro forest.

Blocks above the 0 – line: figures based on relative DBH (%); blocks below the 0 - line: figures based on relative basal area (%) (1 = < 20 cm, 2 = 20 - 50 cm, 3 = 50 - 80 cm, 4 = 80 - 110 cm, 5 = 110 - 140 cm, 6 = >140 cm)




B = Apodytes dimidiata
Relative density (%)
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10
DBH class


C = Erica arborea
Relative density (%)
30
20
10
0
1 2 3 4 5 6 7
DBH class


D = Myrsine melanophloeos
Relative density (%)
50
40
30
20
10
0
1 2 3 4 5 6 7 8
DBH class

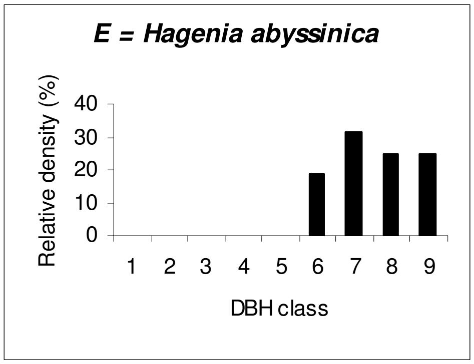


Figure 8. Five representative patterns of frequency distribution of tree density value over DBH classes in the Denkoro forestrepresented by A. *Scolopia theifolia* (types VI); B. *Apodytes dimidiata* (Types IV & V); C. *Erica arborea* (Type I): D. *(Myrsine* (*Rapanea) melanophloes* (Types I, II & III); E. *Hagenia abyssinia* (Types I & II). 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 > 110 cm