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AN ECOLOGICAL STUDY OF THE FOREST VEGETATION OF SOUTHWESTERN ETHIOPIA

KUMELACHEW YESHITELA

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TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

Abstract

The floristic composition and structure of the forest vegetation of southwestern Ethiopia between altitudes 1050 to 2500 m are described. Sample plots of 30 m x 30 m were taken for woody plants and 2 m x 2 m for herbaceous and bamboo plants. A total of 101 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 of ≥ 2 cm were measured for height and diameter. The leaf size of all tree species with heights ≥ 6 m was measured. The presence of epiphytes on each woody individuals and the presence of woody climbers (lianas) in the sample plot was noted. Altitude, slope, and exposure were measured and soil samples from surface and sub-surface were taken and analyzed for pH, electrical conductivity, soil colour, texture, organic carbon, total nitrogen, available phosphorus, exchangeable bases, and cation exchange capacity.

A total of 139 species of vascular plants, 15 species of vascular epiphytes, and 12 species of woody climbers (lianas) were recorded. Average linkage clustering procedure was followed to classify the vegetation data and 9 clusters were recognized and the clusters were identified as local plant community types and given names after one or two dominating and/or characteristic species. The community types are: *Arundinaria alpina*, *Manilikara butugi-Coffea arabica*, *Syzygium guineense-Maytenus gracilipes*, *Ilex mitis-Galiniera saxifraga*, *Celtis africana-Dracaena afromontana*, *Allophylus abyssinicus-Justicia schimperiana*, *Aningeria adolfi-friederici-Chionanthes mildbraedii*, *Syzygium guineense-Dracaena afromontana*, and *Olea welwitschii-Chionanthes mildbraedii*.

Analysis of variance (ANOVA) was performed to see if there is any significant variation among the community types with respect to any one environmental parameter. The result obtained shows that the community types significantly vary for all the environmental parameters except for slope, exposure, exchangeable sodium and potassium, cation exchange capacity and available phosphorus for subsoil (20-60 cm). Altitude is the environmental parameter that differentiate most of the community types. Some of the environmental perimeter are significantly correlated.

The structural analysis of the community types showed that the density of trees in the > 10 cm DBH class is significantly higher than density in the > 20 cm DBH class. Forty-seven per cent of the trees in *Manilikara butugi-Coffea arabica* community type, and more than 60% of the trees in the remaining types belong to the lowest diameter class (5-20 cm). More than 50% of the trees in *Manilikara butugi-Coffea arabica* and *Syzygium guineense-Maytenus gracilipes* community type and over 70% of the trees in the remaining community types fall into the lowest height classes (6-9 & 9-12 m). Mosses are the most abundant epiphytes in all community types and *Landolphia buchananii* is the abundant liana in all community types except in *Allophylus abyssinicus-Justicia schimperiana* type. The predominant leaf size class in all community types is mesophyll (4500-18,225 mm^2), while microphylls (225-2025 mm^2), notophylls (2025-4500 mm^2), macrophylls (18,225-164,025 mm^2), and megaphylls (> 164,025 mm^2) leaf sizes are shared by less than 20% of the species. Only mesophylls are present in *Arundinaria alpina* community type.

1 INTRODUCTION

1.1 Status of the Ethiopian Forest Vegetation

The land area of Ethiopia was once believed to have been covered by forests having wide coverage than at present. However, these forest resources have mostly disappeared in the recent past. The occurrence of isolated mature trees in farmlands and the patches of forests that are seen around churchyards and religious burial grounds indicate the presence of vast expanse of forests earlier (Tamrat Bekele, 1993). Logan (1946), for example, quotes local sources from Jimma area, as stating that the forest in 1900 reached almost to Jimma town. In 1946, the forest was little nearer than Saddaro and Belete some 25 to 35 km away from Jimma. At present, the natural forests southwest of Jimma are reduced to very small patches.

Various estimates are given of the extent of forest cover in the past and at present (Logan, 1946; Breitenbach, 1963; E.M.A., 1988; EFAP, 1994). According to the report of EFAP (1994), in the early 1950's, 16 per cent of the land area was covered with forests. In the early 1980's, the forest coverage was reported at 3.6 per cent, and in 1989 it was estimated at only 2.7 per cent. The causes for the reduction of the forest are: uncontrolled exploitation; forest fires; the expansion of permanently cultivated areas, shifting cultivation, human settlement and population growth. If the present trend of deforestation continues, the remaining forests will disappear in the very near future (Demel Teketay, 1992).

The depletion and degradation of forest resources have affected the country's environment. Deforestation has resulted in the loss of habitat for wildlife, the loss of reliable water supply, soil erosion and the loss of soil fertility. The Ethiopian highlands annually loose a total of 1.9 to 3.5 billion tons of soil 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. It is estimated that the present burning of animal dung and crop residues for energy represents a loss in crop production of 700,000 tons of grain (EEAP, 1994). Reduced forest cover and the associated impact on land degradation has also resulted in the loss of biodiversity.

At present it is only in the southern (Bale & Sidamo) and southwestern (Illubabor and Keffa) parts of the country that most of the remaining forests are found, although pressure of agricultural development and resettlement are rapidly diminishing these.

Due to climatic and anthropogenic factors, the natural environment of Ethiopia has been severely altered and as a result a few relict patches of the natural vegetation remain. This calls for urgent study and documentation of the vegetation of Ethiopia.

Few attempts to classify the forests of Ethiopia have already been made. Beals (1969, "Vegetation of the Erer-Gota Plain"), Hailu Sharew (1982, "Jemjem forest, Sidamo"), Sebsebe Demmisew (1980, "Menagesha state forest, Shewa"), Lissanework Nigatu (1987, "Harenna forest, Bale") and Tamrat Bekele (1993, "remnant Afromontane forests on the central plateau of Shewa"), have contributed to this end.

The physiognomy, altitudinal gradient and classification of the forest in Bale have particularly been studied by, among others, Friis (1986a), Hillman (1986), Mesfin Tadesse (1986), Uhling (1986), Zerihun Woldu *et al.* (1989) and Miehe & Miehe (1993).

The flora and vegetation of the forests of southwestern Ethiopia have been studied by Logan (1946), Chaffey (1979), Friis *et al.* (1982), and Friis (1992). Among these works, only Friis *et al.* (1982) utilized complete floristic analysis, the other works particularly focused on forest trees. Neither of the works, however, elucidated the ecological relationship of the forest communities. This has become a serious handicap to the management and rational utilization of the forest resources of the region.

The future survival of the forests of southwestern Ethiopia depends particularly on developing sustainable management methods which can predict the consequences on the floristic composition of various exploitation practices. Therefore, qualitative and quantitative description and classification of the forests of southwestern Ethiopia is necessary. The objectives of this study are:

i. To study the floristic composition and structure of the forest vegetation of southwestern Ethiopia;

ii. To produce an ecologically significant classification;

iii. To relate the vegetation cover with some environmental parameters;

iv. To provide information that would suggest solutions to some problems of conservation of the forest vegetation of southwestern Ethiopia.

2 1 LITERATURE REVIEW

2.1 The Vegetation of Ethiopia

2.1.1 General Vegetation Survey

The vegetation of Ethiopia shows a wide variation caused by the varied topography and the unevenly distributed rainfall. These vegetation types have been described and classified by many authors. Among these are Pichi-Sermolli (1957), Breitenbach (1961, 1963), Mesfin Wolde Mariam (1972), Wilson (1977), Friis *et al.* (1982), Tewolde Berhan Gebre Egziabher (1986), and Friis (1992).

Most of these works put emphasise on the distribution of broad vegetation units which have been classified on a physiognomic basis. Of these physiognomic studies, Pichi-Sermolli's (1957) is the most intensive. He recognized 24 physiognomic units in order to establish a geobotanical map of Eritrea, Ethiopia and Somalia. Tewolde Berhan Gebre Egziabher (1986) proposed a much simpler scheme than that of Pichi-Sermolli by classifying the Ethiopian vegetation into broad zones constituting the following.

1. Afroalpine and sub afroalpine zone;
2. Dry evergreen montane forests and associated grassland;
3. Moist evergreen montane forests;
4. Broad-leaved deciduous woodlands;
5. Small-leaved deciduous woodlands;

6. Evergreen scrub;
7. Semi desert and desert vegetation.

The following description on the above vegetation types is based on Friis *et al.* (1982), and Tewolde Berhan Gebre Egziabher (1986).

The afroalpine zone covers areas which are higher than 3,400 meters above sea level on the northwestern and southeastern plateaux. The rocks are volcanic, being mostly basalts and trachytes. The soil is often shallow although very rich in undecomposed organic matter. The vegetation is characterized by *Erica arborea* L., *Kniphofia spp., Helichrysum spp., Bartisia petitiana, Alchemilla spp., Crassula spp.,* *Lobelia rynchopetalum* and *Phillipia trimera* Engl.; the later species being restricted to the southeastern part. Grasses are mainly of species of *Festuca, Poa*, and *Agrostis*. This vegetation type is the upper catchment for many important rivers of Ethiopia.

The dry evergreen montane forests occur scattered in the northern, eastern and southern parts of the northwestern plateau. In the mountains of Gojam, Shewa, Wello, and Tigray this vegetation types occurs at altitudes between 1900 and 3400 m. The annual rainfall is between >600 and 1500 mm and the average annual temperature is 14-18 °c. In Sidamo, Bale, and Hararghe this vegetation type occurs at altitudes between 1500 and 3200 m. At the lower limits, the annual rainfall is ca. 500-700 mm and the average annual temperature is between 20 and 25 °c. The vegetation is characterised by *Olea europea 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 *(Arundinaria alpina* K. Schum.) and extensive areas of grassland rich in species. The most important genera are *Hyparrhenia, Eragrostis, Panicum, Sporobulus, Eleusine*, and *Pennisetum*. Many legumes are associated with this vegetation type, among these are the genera *Trifolium, Eriosema*, and *Crotalaria*. This is the zone where sedentary cereal-based mixed agriculture has gone on for the longest time. In most cases these forests have been replaced by bushlands on the stepper slopes with thin soil.

The moist evergreen montane forests occur mainly in the southwestern parts of the Ethiopian plateau. The zone occurs at altitudes between 800 and 2500 m. This vegetation type is characterized by *Aningeria adolfi-friederici* (Engl.) Robyns & Gilbert, *Podocarpus falcatus (Thaunb.) Mirb., Trilepisium madagascariense* Dc., *Albizia gummifera* (J.F.Gmel.) C.A. Smith, *Celtis afircana* Burm.f., *Polyscias fulva* (Hiern) Harms, *Schefflera abyssinica* (Hochst. ex A. Rich.)Harms, *Bersama abyssinica* Fresen., *Olea hochstetteri* Bak., *Prunus africana* (Hook. f.) Kalkm. and *Syzygium guineense* (Willd.) Dc..The understorey often includes *Coffea arabica* L.

The broad-leaved deciduous woodlands occur in the northwestern and western parts and in the southwest along the Ethio-Sudan boundary between 500-1900 m a.s.l. This vegetation is characterised by *Combretum spp., Terminallia spp., Oxytenanthera abyssinica* (A. Rich.) Munro, *Boswellia papyrifera* (Del.) Hochst., *Lannea schimperi* (A. Rich.) Engl., *Anogeisus leiocarpus* (Dc.) Guill. & Perr, and *Stereospermum kunthianum* Cham.. The understorey is a combination of herbs and grasses.

The small-leaved deciduous woodlands occur mainly in the southern and eastern parts of the country and in the Rift valley between altitudes of 900 and 1900 m. This vegetation type is characterized by *Acacia tortilis* (Forssk.) Hayne, *A. mellifera* (Vahl) Benth., *Balinites aegyptiaca* (L.) Del., and species of *Aerva, Acalypha, Barleria,* and *Capparis*. The understorey is a combination of suffrutescents and grasses.

The evergreen scrub is a complex vegetation type on lower slopes surrounding the escarpments of the northwestern and southeastern plateau. Trees include *Teclea nobilis* Del., *Croton macrostachyus* Del., *Bersama abyssinica, Olea europaea ssp. cuspidata, Juniperus procera* and *Euphorbia abyssinica* Gmel. Shrubs occurring in this vegetation type include *Acokanthera schimperi* (A. Dc.) Schweinf., *Carissa edulis, Euclea schimperi* (A. Dc.) Dandy, *Rhamnus staddo* A. Rich., *Myrsine africana* L. L., *Rhus* spp., *Dodonaea angustifolia* L. f., *Calpurnia aurea* (Ait.) Benth., *Jasminium abyssinicum* Hochst. ex Dc., *Osyris quadripartiata* Decn., *Ximenia americana* L., and *Protea gaguedi J. F. Gmel.*. None of these species in this vegetation type implies a characteristic feature of the vegetation.

The semi desert and desert vegetation occupy the extreme lowland portion of Ethiopia and is found in the Afar depression, and along the southern border of Ethiopia. It occupies altitudes from ca. 130 m below sea level to 600 m. above sea level. The vegetation type is characterized by *Euphorbia scordifolia* Jacq., *Dactyloctenium aegyptium, Panicum turgidum* Forssk., species of *Acacia, Commelina, Commiphora, Zizyphus, Maerva, Cadaba, Boscia*, and *Aloe*.

2.1.2 The Forest Vegetation of Ethiopia

White (1983) defined forest as a continuous stand of trees. The canopy varies in height from 10 to 50 m or more, and usually consists of several layers or storeys. The crowns of individual trees interdigitate or overlap each other and are often interlanced with lianas. A shrub layer is normally present. It is usually densest in those types of forest with a more open canopy. The ground layer is often sparce and may be absent or consist only of bryophytes. Epiphytes, including ferns, orchids and large mosses are characteristic of the moister tropical and subtropical types. Large epiphytic lichens, especially *Usnea* are often conspicuous, especially in the upland types.

The forest vegetation of Ethiopia has been surveyed by Logan (1946), Pichi-Sermolli (1957), Breitenbach (1963), Friis *et al.*(1982), and Friis (1986b, 1992). Friis (1992), in his monograph of the forests and forest trees of Northeast Tropical Africa, outlines the following natural forest types as occurring in Ethiopia. The descriptive summary that follows is taken from the monograph. Map of Ethiopia showing the distribution of these forest types is presented in Fig.1.

i. Dry peripheral semi-deciduous Guineo-Congolian forest

This forest type is restricted to the Baro Lowlands of western Ethiopia. The altitudinal range of the parts of this forest is 450-600 m. The mean annual maximum temperature is 35-38 °c and mean annual minimum temperature is 18-20 °c. The annual rainfall is between 1300 and 1800 m. The forest occurs mainly on rocky or sandy and well-drained soils, and is semi-deciduous, with a 15-20 m tall, more or less continuous canopy of *Baphia abyssinica* Brummitt, mixed with less common species such as *Celtis toka* (Forssk.) Hepper & Wood, *Diospyros abyssinica* (Hiern) F.White, *Malacantha alnifolia* (Bak.) Pierre and *Zanha golungensis* Hiern. Some species emerge high above the main canopy: *Alstonia boonei* De Wildem., *Antiaris toxicara* Lesch., *Celtis gomphophylla* Bak. and *Milicia excelsa* (Welw.) C. C. Berg. The shrub layer is sometimes dense, and includes *Alchornea laxiflora* (Benth.) Pax & Haffm., *Argomuellera macrophylla* Pax, *Oxyanthus speciosus* Dc. and *Whitfieldia elongata* (P. Beauv.) De Wildem. & Th. Dur..Tall lianas are not prominent, but the lower strata of the forest are often densely mixed with woody climbers. The ground is mostly covered by thick litter, and there are apparently very few species of forest floor herbs.

ii. Transitional rain forests

The Transitional rain forests occupy extensive areas on the southwestern slopes of the Northwestern Highlands especially in western Illubabor and western Kefa. The forests occur between 500 and 1500 m, partly in river valleys, partly in areas presumed to have a high water table. The average annual temperature ranges from 20-25 ^{o}c. The species which occur in the transitional rain forest include *Aningeria altissima* (A. Chev.) Aubrev. & Pellegr, *Anthocleista schweinfurthii* Gilg, *Celtis zenkeri* Engl., *Celtis philippensis* Blanco, *Campylospermum bukobense* (Gilg) Farron, *Croton sylvaticus* Krauss, *Dracaena fragrans* (L.) Ker-Gawler, *Ficus exasperecta* Vahl, *Manilkara butugi* Chiov. and *Trichilia drgeana* Sand.

iii. Afromontane rain forests

At elevations between about 1500 and 2600 m in the southwestern part of the NW Highlands especially on the southwest plateau and in the southwestern part of the SE Highlands, the natural vegetation is Afromontane rainforest (Friis, 1992). The average annual temperature in the forest is 15-20 ^{o}c and annual rainfall 700-1500 mm, most falling between April and September. These forests characteristically contain a mixture of *Podocarpus* and broad-leaved species in the canopy, but *Podocarpus* is never predominant and become gradually more infrequent towards the west in Kefa and is almost absent in Illubabor, while *Aningeria adolfi-friederici* becomes more prominent in the same direction.

The canopy consists of medium sized trees, 10-30 m tall: *Croton macrostachyus, Ilex mitis* (L.) Radlk., *Olea hochstetteri, Podocarpus falcatus*, and *Schefflera abyssinica.* Smaller trees and large shrubs include: *Allophylus abyssinicus* (Hochst.) Radlk., *Bersama abyssinica, Brucea antidysentrica, Calpurnia aurea, Clausena anisata* (Willd.) Benth, and *Discopodium penninvervium* Hochst.. A few species of lianas are present, and the epiphytes include ferns, orchides, and *Peperomia* spp. The ground cover is comparatively lush, and rich in ferns, grasses, and herbaceous dicotyledons.

At higher altitudes, near 2650 m, the composition is some what altered, and the canopy includes many large specimens of *Hagenia abyssinica* (Bruce) J. F. Gmel., *Hypericum revolutum* Vahl, and *Schefflera volkensii* (Engl.) Harms. Smaller trees include *Agauria salcifolia* (Lam.) Oliv., *Galiniera saxifraga* (Hochst.) Bridson, *Lepidotrichilia volkensii* (Gurke) Leroy, *Nuxia congesta* Fresen., and *Rapanea melanophloeos* (L.) Mez.

On the gentler slopes, at elevations of about 2400 m and above and where the rainfall is highest, bamboo thicket occurs. This is composed of *Arundinaria alpina*, either virtually pure or in mixture with scattered trees, or open woodland. There are extensive areas of bamboo thicket on the high ground between Masha and Gecha

In the highland region of southern central Sidamo, Friis (1993) observed isolated specimens of *Aningeria adolfi-friederici* at altitudes up to 1900 or 2000 m, isolated or grouped specimens of *Syzygium guineense* ssp. *afromontanum* and *Hagenia abyssinica* at altitudes above 2300 m.

A rather wetter types of Afromontane forest occur widely in the upland parts of southern Wellega, Illubabor and western Kefa. They are found in areas between 1500 and 2500 m, with an average rainfall between 1500 mm and 2200 mm, with rain all year round, but a maximum in April through October

There is only one emergent species from the 20-30 m high canopy: *Aningeria adolfi-friederici*. The 10-30 m main canopy consists of *Albizia gummifera, A. schimperiana* Oliv., *A. grandibracteata* Taub., *Cassipourea malosana* (Bak.) Alston, *Celtis africana, Croton macrostachyus, Ekebergia capensis, Ficus sur* Forssk., *F. ovata* Vahl, *F. thonningii* Blume, *Ilex mitis, Macaranga capensis* (Bail.) Sim, *Olea welwitschii* (Knobl.) Gilg. & Schellenb., *Shefflera abyssinica, Sapium ellipticum* (Hochst. ex Krauss.) Pax and *Syzigium guinnense ssp. afromontanum*. A discontinuous lower canopy of smaller trees includes *Allophylus abyssinicus, Apodytes dimidiata* E. Mey. ex Arn., *Bersama abyssinica, Brucea antidysentrica, Calpurnia* *aurea, Clausena anisata, Coffea arabica, Cyathea manniana* Hook., *Draceanea afromontana* Mildbr., *D. fragrans, D. steundeneri* Engl., *Ehretia cymosa* Thonn., *Galineria saxifraga, Millettia ferruginea* (Hochst.) Bak, *Nuxia congesta, Rothmannia urcelliformis* (Hiern) Roibyns, *Teclea nobilis, Treama orientalis* (L.) Bl., and *Vepris dainellii* (Pichui-Sermolli) Kowkwar.

The shrub stratum includes *Acanthus eminess* C. B. Clarke, *Mayetenus spp.*, *Phylanthus limunesis* Cufod. and *Whitfieldia elongata.* Lianas are common. Epiphytes include ferns, lycopodes, orchids, species of *Peperomia* and *Scadoxus nutans* (Friis & Bjornst.) Friis & Nordal. The ground cover is very rich where light is sufficient. Broad-leaved forest grasses, especially belonging to the genera *Setaria* and *Panicum* may be present.

iv. Undifferentiated Afromotane forests

These are *Juniperus-Podocarpus* forests, or predominantly *Podocarpus* forests, both with an element of broad-leaved species. They occur in the northwestern and southeastern highlands at altitudes from 1500 to 2700 m, with average annual temperatures between 14 and 20 °c and annual rainfall between 700 and 1100 mm. The *Podocarpus-Juniperus* forest in the southern part of the southwestern plateau is composed of the following floristic composition. The canopy consists of *Juniperus procera* mixed with *Podocarpus falcatus*, both more than 20-30 m high. There is a rather well-developed stratum of small to medium-sized tress, consisting of *Allophylus abyssinicus, Apodytes dimidiata, Cassipourea malosana, Celtis africana, Dovyalis abyssinica* (A. Rich.) Warb., *Ekebergia capensis, Prunus africana, Olea europea* ssp. *cuspidata*, and *Teclea nobilis*. Other small trees & shrubs are *Carissa edulis, Croton macrostachyus, Myrsine africana, Solanecio gigas* (Vatke) C. Jeffrey and *Spiniluma oxyacantha* (Baill.) Aubrèv. Scrambling species of *Rubus* are common together with true lianas. Epiphytes include species of *Peperomia, Sedum* and a few orchids. The ground cover is rich in ferns, grasses, sedges, and small herbaceous dicotyledons.

v. Dry single-dominant Afromontane forest of the Ethiopian Highlands.

These occur in the northwestern and southeastern Ethiopian highlands at altitudes from (1600-)2200 to ca. 3200 (3300) m, at annual average temperatures from 12-18 $^{\circ}$c and annual rainfall between 500 and 1500 mm. The typical dominant species in the upper storey of these forest is *Juniperus procera*, with *Olea europaea* ssp. *cuspidata* and a number of other species in the lower storeys.

vi. Dry single-dominant Afromontane forest of the escarpments and transition between single-dominant Afromontane forest and East African evergreen and semi-evergreen bushland.

This category includes a range of physiognomic types, from typical forest to evergreen scrub with dispersed trees, but floristically the whole range is connected. The forest-like types exist on the eastern escarpment of the northwestern highlands, and on the northern escarpment of the southeastern highlands; the bushland-like types with trees occur scattered in previous areas and on the southeast slope of the southeastern highlands. Throughout the range of the type it occurs on rocky ground with unimpeded drainage from an altitude of ca. 1500 m to ca. 2400 m. The annual rainfall is probably between 400 and 700 mm, the average annual temperature varies from 15-20 °c. The dry juniper forests of Sidamo occur at altitudes between 1500 and 2000(-2200) m, with an average temperature of 18-25 °c and an average rainfall of 400-700 mm. These forests, on the southeast slope of the southeastern highlands, form the southern extension of this type. The canopy is 10-15 m high, and consists mainly of *Juniperus procera*, often covered with lichens of the genus *Usnea*. Other trees in the forest are *Barbeya oleoides* Schweinf., *Olea europea* ssp. *cuspidata*, and *Schrebera alata* (Hochst.) Welw. Small trees and shrubs are *Acokanthera schimperi, Carissa edulis, Dodonaea angustifolia, Euclea divinorum* Hiern, *Monotheca buxifolia* (Flaconer) A. Dc. and *Zanthoxylum* spp. The dry montane forest of Sidamo is often associated with a type of fringing woodland or evergreen bushland with much *Cussonia holstii* Harms ex Engl. The undergrowth consists of evergreen bushes with open grassy glades in between.

vii. Riverine forest.

The riverine forest vegetation of Ethiopia is very variable, and the floristic composition is dependent on altitude and geographical location. The riverine forest in the Ethiopian Highlands include the following species: *Breonadia salicifolia* , *Ficus capreafolia* Del., *F. vallis-choudae* Del., *Tamarindus indica* L.and *Trichilia emetica* Vahl. In the Southwestern part of the Ethiopian Highlands, *Phoenix reclinata* Jacq. is frequent.

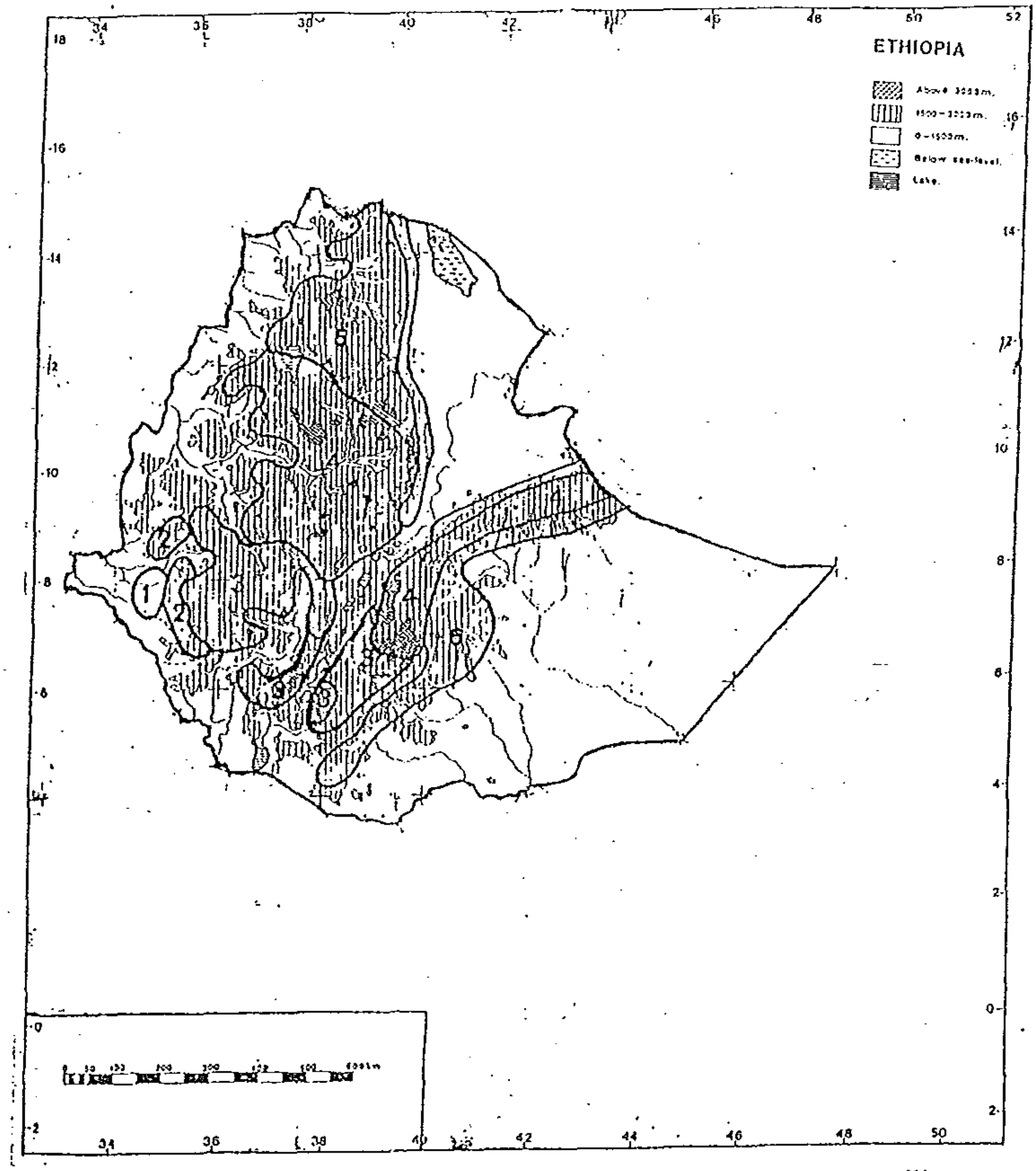

Fig. 1 Ethiopian forest types: (1) Lowland dry peripheral semi-evergreen Guineo-Congolian type forest; (2) Transitional rain forest, (3) Broad-leaved Afromontane rain forest; (4) Undifferentiated Afromontane forest, including various types of upland forests with *Podocarpus*; (5) Dry single-dominant Afromontane forest, with *Juniperus procera* in the canopy and *Olea europea* ssp. *cuspidata* in the under storey; (6) Transition between single-dominant Afromontane forest and East African evergreen and semi-evergreen bushland and thicket. Riverine forest (7) not shown here. From Friis (1993) with slight modification.

2.1.3 Human Impact

Ethiopia, with a projected total population of 53.6 million in 1993 (Sileshi Teferra, 1994), is the second most populous country in Sub-Saharan Africa. The population of Ethiopia, estimated at 11.8 million in 1900, increased to 23.6 million and 47.3 million in 1960 and 1988 respectively (CSA, 1991). Thus it took the country 60 years to double between 1900 and 1960 and 28 years between 1960 and 1988. The population growth rate at the beginning of the century was estimated at 0.3 per cent per annum and currently the population is growing by over 3 per cent per annum (CSA, 1991). The projected time for the population to double between 1988 and 2010 is 22 years.

Compared to other East African countries, human impact on the vegetation in Ethiopia started early (Bonnefille & Hamilton, 1986). According to these authors, in the Arssi Mountains of Ethiopia, the onset of major disturbance, including montane forest

destruction, occurred around 1850 B.P. Forest destruction was also relatively early on the Bale Mountains. On Mt Elgon and Mt Kenya there is very little evidence of human impact within the montane forest belt until much more recent times and indeed these two mountains still carry extensive montane forest today, a contrast with the largely deforested highlands of Ethiopia (Bonnefille& Hamilton, 1986).

There is great human pressure on all natural and semi-natural vegetation types in Ethiopia (Hamilton, 1982). Forest is being heavily exploited, woodland is deteriorating rapidly, and high altitude scrub is being replaced by grassland. Cultivation is practised on very steep slopes. Most of the land which would naturally be occupied by Gymnosperm forest is today taken up by grassland or montane scrub (Hamilton, 1982). Under the influence of man, virtually all the dry evergreen montane forests and highland grasslands, and most of the moist evergreen montane forests have changed to farmlands and grasslands (Tewolde Berhan Gebre Egziabher, 1989). The *Acacia* Woodlands have also given way to farmlands. The Bare hills and small patches of forest and overgrazed grasslands are characteristic features of Ethiopian landscape, especially that of the Central Plateau (Zerihun Woldu *et al, 1989)*.

2.2 Sampling in Vegetation Studies

Almost all problems in vegetation ecology are approached by sampling, selecting a small subset of the vegetation one is interested in (Okland, 1990). The method of sampling will determine in large measure the description of the vegetation. Different description will result from different patterns of sampling, different types of samples, and different sizes of samples (Spurr, 1962).

Various sampling methods that are useful for a variety of vegetation types have been treated by, among others, Cain and Castro (1959), Spurr (1962), Kershaw (1973), Mueller-Dombois & Ellenberg (1974), Orlòci (1978), Greig-Smith (1983), Goldsmith & Harrison (1986) and Okland (1990).

According to Greig-Smith (1983), the objectives in making quantitative estimates of vegetation, with few exceptions, fall into one or another of the following three categories:

a) an estimate of the overall composition of the vegetation within certain boundaries, with a view to comparison with other areas or with the same area at another time;

b) the investigation of variation within one area; or

c) correlation of vegetation differences with differences in environmental factors.

The choice of sampling procedure involves many considerations. Homogeneity of the vegetation is the first important feature in the choice of a sample stand for description (Shimwell, 1971). The sample stand should be homogenous in composition and structure if the aim is to represent community types by samples or to relate vegetation to environment. Assuming that there is a reasonable degree of uniformity, three decisions have to be made before sampling is begun. These concern the size and shape of quadrat, and the number of samples to be used. Spurr (1962) elaborates these points as follows.

Size of sample is affected by both the size and number of the sample plots. A single plot of small size will obviously include only a few of the species to be found in the entire community and only a narrow range of the variation in size and other attributes of the individuals of these few species. By increasing either the size of the individual plots, or alternatively by increasing the number of plots taken within a population, more and more species will be recorded together with a greater range in size of the individual plants. The plot size must be large enough to sample adequately that portion of the community for which an estimate is desired. In other words, there is a desirable minimal area of plot size.

Various authors give different meanings to minimal area. Cain and Castro (1959) defined the minimal area of a community as the smallest area on which the community can develop its characteristic composition and structure. Mueller-Dombois & Ellenberg (1974) suggest the following sample sizes for temperate zone vegetation: 200-500 m^2 for forests (including tree stratum) and 50-200 m^2 (undergrowth vegetation only); 50-100 m^2 for dry-grassland; 10-25 m^2 for dwarf-shrub heath; 10-25 m^2 for hay meadow; 5-10 m^2 for fertilized pasture; 25-100 m^2 for agricultural weed communities; 1-4 m^2 for moss communities and 0.1-1 m^2 for lichen communities.

Sprangers & Balasubramanian (1978) used relevés covering up to 40 m^2 to analyze tropical semi-evergreen forest in India. Hommel (1990) used relevès up to 100 m^2 for a phytosociological study of a forest in the humid tropics of Indonesia. Westhoff & van der Maarel (1978) mention relevès of 200-1000 m^2 as satisfactory for tropical secondary rain forest.

Tewolde Berhan Gebre Egziabher (1975), Sebsebe Demmisew (1980), Hailu Sharew (1982), Lissanework Nigatu (1987) and Zerihun Woldu *et al.* (1989) employed a relevè of 400 m^2, whereas Tamrat Bekele (1993) used a relevè of 900 m^2 to study woody vegetation in Ethiopia.

Sample plots can assume any regular shape. They are commonly square, circular, rectangular or strips. In some cases one form is more efficient than another. The number of sample units that constitute a sample will vary according to the characteristics of the community, the objectives of the investigation, and the time that is available (Cain & Castro, 1959).

Within a selected area, samples might be placed in three ways: by selecting typical sites of the area as a whole (preferential sampling); by placing samples randomly or by placing samples systematically in some regular pattern or some combination of the latter two methods (Kershaw, 1973).

Selection of typical sites for samples is not suitable for a quantitative approach since their choice is dependent on the observer's preconceived ideas of the character of the vegetation. When the purpose of a study is description of selected stands as in phytosociology, preferential sampling is a natural choice (Okland, 1990). Random and systematic sampling are representative and unbiased and provide information on the entire population. If samples are taken at random an estimate of the mean value and of the precision of this mean can be found. If sampling is systematic an estimate of the mean is available but there is no indication of its precision. Nevertheless, systematic sampling has been preferred on the grounds that it is more representative of variations over the area and hence likely to give a better estimate than random samples, and that it is easier to carry out efficiently in the field (Greig-Smith, 1983).

The type of sampling employed to describe and measure plant communities is variable. Spurr (1962) discussed the following types of sampling.

Point sampling. This is the simplest method of sampling; it involves the record of what is present at a point in the vegetation.

Line sampling. Transects provide a means of rapidly surveying the vegetation that is intercepted by a line laid out through the vegetation. Typically, the line is marked with a string or tape. The vegetation cover can be estimated from the relative distances occupied by different plants above this line.

Plot sampling. Most vegetation surveys involve plot sampling. A plot is laid out on the ground and the vegetation on it is either described, enumerated, or mapped. Plots may be temporary or permanent. Temporary plots are used to evaluate the current vegetation while permanent plots are so established that they can be visited from time to time for the purpose of recording changes in the vegetation over a time.

2.3 Vegetation Description

Vegetation can be described by using its various characters. Structural characters and floristic composition are used to describe vegetation (Werger & Sprangers, 1982).

2.3.1 Structural Approach

Kershaw (1973) defined the structure of vegetation by three components: the vertical arrangement of species (stratification); the horizontal arrangement of species (spatial distribution of individuals); and the abundance of each species. A number of authors (e.g. Richards *et al.*, 1940; Richards, 1964; Richards, 1983) have emphasized the validity of structural characters for vegetation analysis aimed at ecologically interpretable results. Various structural characters can be used in describing vegetation. Grubb *et al.* (1963) considered tree density, height and diameter, leaf size and profile diagrams for structural analysis of montane and lowland rain forests in

Ecuador. Christopher (1981) used tree density, basal area, height, and profile diagram for the study of the structure of the Amazon Basin of Venezuela. Werger & Sprangers (1982) used the following structural-physiognomic characters in the classification of a tropical dry semi-evergreen forest and thicket vegetation in southeastern India: life form; growth form; degree and form of branching; phenology; leaf and crown characteristics; and liana and epiphyte characteristics. Bongers *et al.* (1988) considered tree density, basal area, species population structure, gap dynamics, leaf deciduousness and compoundness and leaf size spectra in the study of the structure of the lowland rain forest of Los Tuxtlas, Mexico. Popma *et al.* (1988) used profile diagrams, tree density, basal area, crown cover, leaf size, leaf deciduousness and compoundness in their study of the vertical structure of a tropical rain forest at Los Tuxtlas, Mexico. Tamrat Bekele (1993) emphasized on tree density, tree height and diameter, basal area, species population structure and stratification in the analysis of vegetation structure of the Afromontane forests of the central plateau of Shewa in Ethiopia.

2.3.2 Floristic Approach

The floristic approach to characterize vegetation became popular since the beginning of the 20^{th} century (Werger & Sprangers 1982). This approach uses the species composition of the vegetation to describe it. Therefore, a good knowledge of the flora of a particular locality is very important to achieve this goal. The floristic data could be qualitative, *i.e.*, presence or absence of a species or quantitative, *i.e.*, the species list supported with some quantitative parameters as cover and abundance estimates.

The Braun-Blanquet approach (see Braun-Blanquet, 1965; Westhoff & van der Mareel, 1978) is the most widely applied method for vegatation description (Okland, 1990). The essence of the approach can be summarized in three ideas (Westhoff & van der Marrel, 1978):

i. Plant communities are conceived as types of vegetation, recognized by their floristic composition. The full species compositions of communities better express their relationships to one another and environment than any other characteristic.

ii. Amongst the species that make up the floristic composition of a community, some are more sensitive expressions of a given relationship than others. For practical considerations (and indication of environment) the approach seeks to use those species whose ecological relationships make them most effective indicators; these are diagnostic species (character species, differential species, and constant companions).

iii. Diagnostic species are used to organize communities into a hierarchical classification of which the association is the basic unit.

2.4 Techniques of Analyzing Vegetation Data

Ecological data are multidimensional and that the analysis of such kind of data is most profitably accomplished by means of multivariate methods. Such method of data analysis can provide information about variate interactions or correlations (Orlòci, 1978). Multivariate analysis of plant community data primarily involves classification and ordination with the general purposes of summarizing large data sets obtained from community samples, aiding in the interpretation of the data and the generation of hypotheses about community structure and variation (Gauch, 1982).

Classification and ordination approaches towards vegetation study are, in theory, quite distinct and based on fundamentally different concepts of the nature of plant communities. The classification approach is based on the community-unit theory (Clements, 1916: cited in Whittaker, 1962). According to this theory, vegetation consists of the community types into which it is classified. These community types are assumed to be well-defined natural units which are part of the structure of the vegetation and which generally contact one another along narrow boundaries. The ordination approach, on the other hand, is believed to have projected from the concept of vegetation as a continuum which is based on the principle of species individuality (Ramensky, 1924; Gleason, 1926: cited in Whittaker, 1962; Mueller-Dombois and Ellenberg, 1974; and McIntosh, 1967).

These view points on the nature of plant communities have influenced the basic objectives in vegetation science and these in turn have a strong bearing on the methods applied in field research (Mueller-Dombois & Ellenberg, 1974). There has been considerable controversy between those ecologists who prefer classificatory procedures and those who prefer ordinadtional techniques in the analysis of vegetation data (Anderson, 1965). It is now, however, generally recognized that both classification and ordination techniques could be appropriately applied to the same vegetation data, and that the choice between the two approaches depends on the objectives rather than on the preconception about the nature of vegetation (Anderson, 1965; Goodall, 1978; Spurr & Barnes, 1980; Greig-Smith, 1983).

2.4.1 Classification

Classification involves arranging stands in to classes, the member of each of which have in common a number of characteristics setting them apart from the members of other classes (Greig-Smith, 1983). Three objectives can be identified in the classification of vegetation (Greig-Smith, 1980) though, more than one objective may be covered by one procedure.

1. Classification may help as a basis of inventory and mapping, either as an objective in itself or as a basis of management.
2. Classification may aim to identify "real" entities with clear discontinuities between them.
3. Classification may be a tool in the exploration of correlations between vegetation and environment.

The various techniques of community classification have been treated by Mueller--Dombois & Ellenberg, 1974; Gauch (1982); Greig-Smith (1983) and Goldsmith & Harrison (1986).

According to Gauch (1982), the main classification techniques in community studies could be categorized into three groups: table arrangements, non-hierarchial classifications, and hierarchial classifications.

Table arrangement is the earliest classification technique in community ecology (Gauch, 1982). Its unique advantage is that it displays at once both the full details of the data set and the general features. The aim in table work is to arrange the species that brings together similar in their distribution in the samples and likewise, to arrange the samples in the sequence that brings samples similar in composition. The non-zero data matrix entities are thereby concentrated into blocks, and lines may be drawn in the matrix of sample and species clusters (Gauch, 1982).

Non-hierarchical classification procedure appropriates each sample or species to a cluster, placing similar samples or species together. The clusters are defined separately and the links between them have the form of a network rather than a dendrogram (Pielou, 1969). Non-hierarchial systems aim to produce the most efficient groupings regardless of the route by which they are derived (Greig-Smith, 1983). Maximal efficiency of groupings implies maximum homogeneity of groups within any constraints of size or number of groups. For those applications in which the homogeneity of groups is of prime importance, the non-hierarchical techniques are attractive. Gauch (1980) utilized non-hierarchical classification for rapid initial clustering of large data sets and developed a computer programme COMPCLUS for this rapid initial clustering.

Hierarchical classifications aim to subdivide the population successively by the most efficient steps. They are less cumbersome and they have the advantage of being more readily interpreted ecologically (Greig-Smith, 1983). In hierarchical classifications, the strategy of producing a classification may be either divisive or agglomerative. In a divisive strategy, the whole set of data may be successively divided into subsets based on appropriate criteria to produce a hierarchy. In an agglomerative strategy, individual stands may be grouped until all stands are finally fused into a single group. Classification can also be monothetic, based on a single criterion at each stage, i.e. presence or absence of a single species or polythetic, using many species as the criteria at each stage; i.e. assessment of overall similarity between stands.

Monothetic methods can only be divisive, but polythetic methods can be either divisive or agglomerative. Accordingly, the hierarchical classification methods are monothetic-divisive, polythetic-divisive, and polythetic-agglomerative (Williams *et al*, 1966; Greig-Smith,1983).

Monothetic-divisive hierarchical classification methods begin with all the samples in a single group and then divide them hierarchically into progressively smaller groups on the basis of the presence and absence of a single attribute. Association analysis (Williams & Lambert, 1959, 1960, 1961) is the first widely used divisive-monothetic procedure. It has been extensively used in the study of many different community types which range over the tropical savanna (Kershaw, 1967), tropical rainforest (Austin & Greig-Smith, 1968), a wooded grassland in Ethiopia (Tewolde Berhan Gebre egziabher , 1975), a montane forest in Ethiopia (Sebsebe Demmisew, 1980) and a montane grassland vegetation in Ethiopia (Zerihun Woldu, 1980).

Polythetic-divisive procedures are based on information drawn from the whole of the data. They begin with all sample together in a single cluster and successively divide the samples into a hierarchy of smaller and smaller clusters until finally, each cluster contains only one sample or some specified small number of samples.

Polythetic-agglomerative classification techniques use information on all species to fuse subgroups into larger group(s). Depending on the choice of similarity or distance measure, and the strategy of fusion which determines the way the distance between a group and a single stand, or between two groups, is measured, various types of polythetic-agglomerative procedures are possible (Greig-Smith, 1983). Average linkage clustering is a polythetic-agglomerative classification procedure where individuals or groups are fused when their average similarity is greatest. In an average linkage, the distance between two clusters is the average distance between all possible pairs ofstands, one in each cluster. The procedure proceeds in the following way:

1. As the first step, quadrat similarity is calculated and this will be entered into a matrix.

2. The first operation on the matrix involves finding the highest similarity value and quadrats with the highest similarity will be fused.

3. A reduced similarity matrix will then be computed where the columns (rows) of the fused quadrats are replaced by a new column (row) of average similarities.

4. The average similarity between any quadrat and the fused group is computed. The quadrats with the highest similarity is fused. These steps are continued until all quadrats are fused into one group.

These classification techniques have been used by Orlòci (1967); Pritchard and Anderson (1971); Gauch & Whittaker (1981); Zerihun Woldu (1985), Lissanework Nigatu (1987), and Menassie Gashaw & Masresha Fetene (1996).

3 STUDY AREA

3.1 Location and description

The forests investigated in this study include Jiren forest, Yayu forest, Gebre Dima forest, Sele-Anderacha forest, Bonga forest, Sheko forest and Belete-Gera forest. These forests are located in the former provinces of Illubabor and Kefa, currently in Illubabor and Jimma zones of Oromia, and Kaffecho-Shekacho and Bench-Maji zones of Southern Nations Nationalities and Peoples regional states. The forest of Sele-Anderacha, which is the farthest from Addis Ababa, is 670 kms away while Belete-Gera forest lies the closest at 380 kms from Addis Ababa. The forests extend in elevation from 1050 m to 2600 m above sea level. The study area is located between 6° 53' to 8° 27'N latitudes and 35° 15' to 36° 50'E longitudes (see Fig.2).

Most of the forests investigated in this study have been included in the National Forest Priority Areas (EFAP, 1994). These forests have been listed in EFAP (1994) as slightly to heavily disturbed (see below).

Table 1 The National Forest Priority Areas within the study area

Forest	**Total area (ha)**	**Slightly disturbed (ha)**	**heavily disturbed (ha)**
Yayu	120,000	20,000	100,000
GebreDima	132,000	50,000	82,000
Sele-Anderacha	215,00	100,000	115,000
Bonga	17,000	7,000	10,000
Belete-Gera	111,700	76,500	35,200

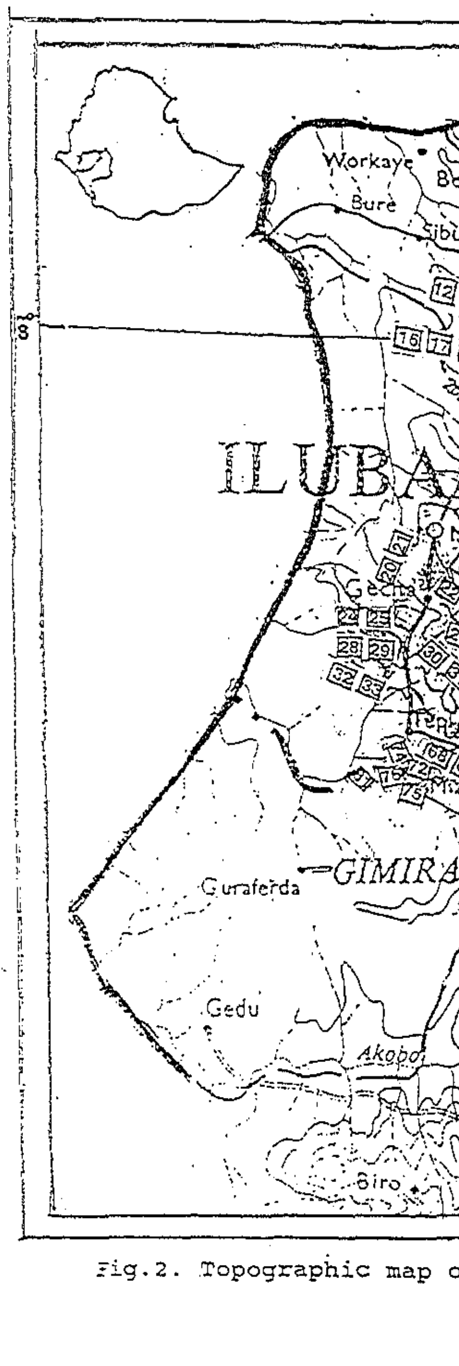

Fig.2. Topographic map o

3.2 Geology, Geomorphology and Soil.

3.2.1 Geology and Geomorphology

Precambrian rocks with various grades and types of schist and gnesis, as well as almost unaltered sedimentary rocks and igneous intrusions underlie all other rocks of Ethiopia and form an intensely folded and foliated metamorphic sediment (FAO, 1984). Much of the Ethiopian plateau lie above 2000 m altitude and comprise extensive areas of structurally horizontal table-land. This is an expression of the flat lying nature of the peneplained precambrian basement rocks (Mohr, 1971).

In Southwestern Ethiopia, Tertiary lavas lie directly on the crystalline basement, minor exceptions being where small remnants of Permian sedimentary rocks are preserved. Crystalline basement rocks are exposed in Illubabor and southwest Kefa (Davidson, 1983).

The northeast-southwest trending Great Rift System of Africa bifurcates the Afar lowlands of Ethiopia with major escarpments trending north and east respectively after the point of separation. The original land mass resulting from the enormous, uplifted swell has thus been divided into two extensive plateau units by the Rift system: the Ethiopia plateau (the northwestern Highlands) to the west and the Somalian plateau (the southeastern Highlands) to the east (FAO, 1984). Despite the dominance of tectonics on the large scale physiography of Ethiopia, on a smaller scale denuditional, depositional, and volcanic processes have been significant in shaping the surface of the country (FAO, 1984).

3.2.2 Soils

The very wide range of climate, topography, parent material and land use of Ethiopia have the result that soils are extremely variable and that, in different parts of the country, different soil forming factors take precedence (FAO, 1984). In Illubabor and northern Kefa, soils are predominantly developed on Trap series volcanics and felsic and metamorphic Precambrian basement materials. As this area includes the descent of the high plateau to the lowlands of the Sudan, soils over large areas are also developed on alluvial and colluvial materials (FAO, 1984).

The range of parent materials on the highland plateau of western Ethiopia is not, however, strongly reflected in soil development. High rainfall of up to more than 2200 mm annually has resulted in very similar soils irrespective of the parent materials (FAO, 1984). According to soil classification system by FAO/UNESCO (1974), the soil association of the southwestern highlands is Dystric Nitosols. They are fertile soils with a shiny appearance (E.M.A., 1988). The moist colour of the soils of the study area is reddish brown to dark reddish brown, and the texture is clay to clay loam (FAO, 1984). The chemical and physical properties of some soils of the study area can be found in Murphy (1968).

3.3 Climate

The temporal and spatial variation of climate in Ethiopia has been determined by Daniel Gamachu (1977). The distribution of rainfall in Ethiopia is seasonal due to variations in pressure systems and air circulation. Daniel Gamachu (1977) recognized the following seasonal distribution of rainfall in Ethiopia: all-year rainfall in the southwest with minor maxima in summer; spring primary and autumn secondary maxima in the southeast; and pronounced summer maxima in the rest of the country. He also recognized fourteen rainfall regimes which are grouped into two main types, based on whether the rainy months are contiguously distributed (TYPE I) or whether there are two rainy seasons (TYPE II). Type I is represented in the study area with eight rainy months from March to October. Climate diagrams (following Walter, 1979) for 7 towns in the study area are given in Fig. 3

The climate diagram for the town of Bedele (2030 m a.s.l.; (935000 m N-208000 m E), (Fig.3A), about 25 km west of Jiren forest, shows that there are 8 rainy months from March to October, most falling between May and October. November to February are relatively dry months. The mean annual rainfall is 1767 mm. The mean monthly temperatures range from 17.4 to 20.6 $^{\circ}$c, while the mean daily temperature minima range from 11.4 -13.9 $^{\circ}$c and the corresponding maxima from 21.8 to 27.7 $^{\circ}$c.

Yayu town (1810 m a.s.l.; 923000 m N-810000 m E), 10-24 km far from Yayu forest, receives a mean monthly rainfall of 1688 mm. The rainy months are from March to October, but a maximum between May and October. From November to February are relatively dry months. The mean monthly temperatures range from 19.2 to 22.4 $^{\circ}$c, the mean daily temperature minima range from 11.7 to 14.3 $^{\circ}$c and the corresponding maxima from 24.5 to 30.4 $^{\circ}$c (see Fig 3B).

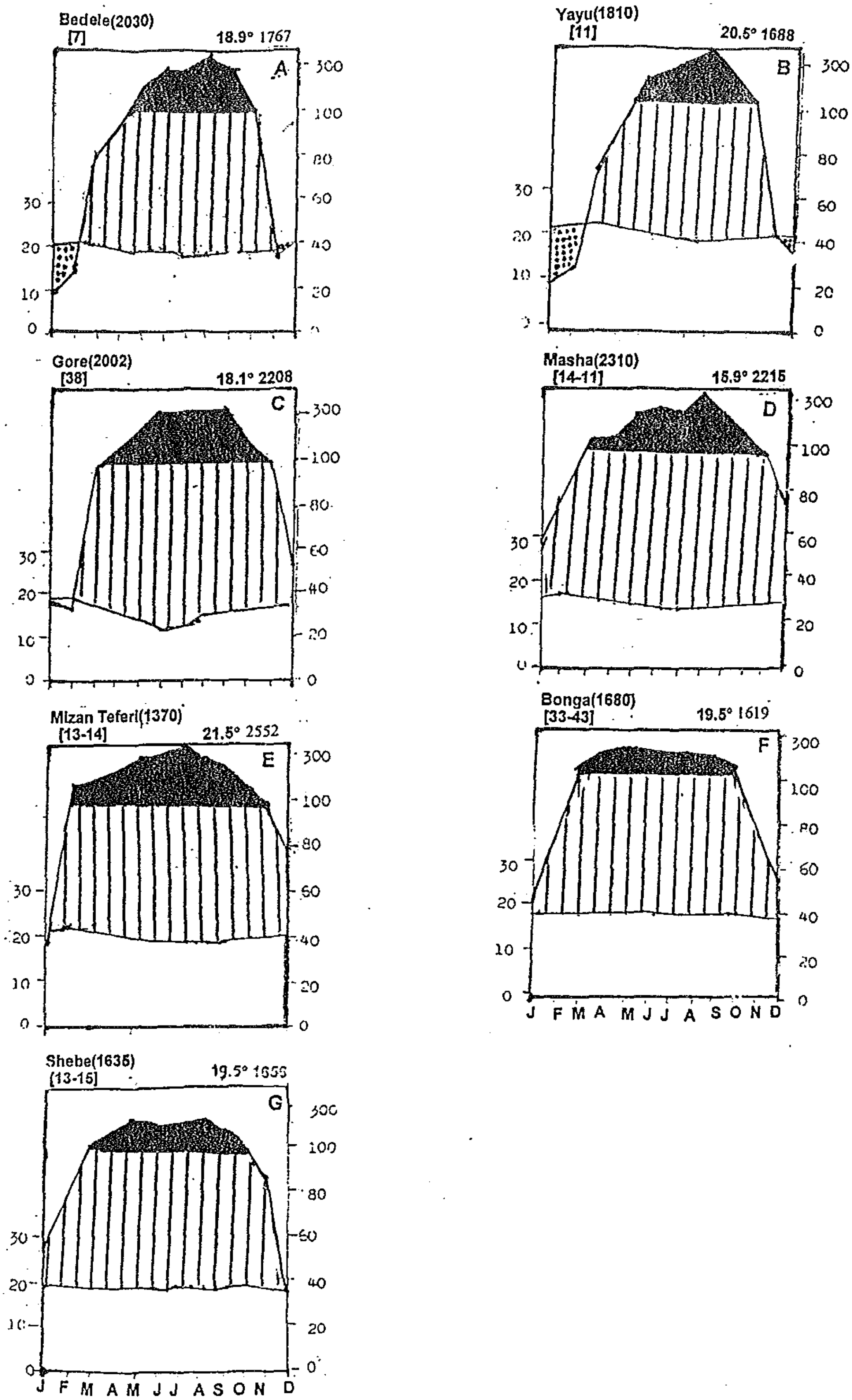

Fig. 3 Climate diagrams for 7 towns in the study area. A=Bedele, B=Yayu, C=Gore, D=Masha. E=Mizan Teferi, F=Bonga, G=Shebe

The mean annual rainfall at Gore (2002 m a.s.l.; 902000 m N-779000 m E), a town ca. 15 km north of Gebre Dima forest, is 2208 mm. There are 9 rainy months from March to Novomber, most falling between April-November. January and February are relatively dry months. The mean monthly temperatures ranges from 17.0 to 20.2 °c, the mean daily temperature minima range from 12.4 to 14.3 °c and the corresponding maxima from 20.3 to 26.0 °c (see Fig.3C).

Masha (2310 m a.s.l.; 857000 m N-773000 m E), a town about 10 km south of Sele-Anderacha forest, receives a year round rainfall. Most of the rain falls between March and November. The mean annual rainfall is 2215 mm. The mean monthly temperatures range between 15-14.3°c, while the mean daily temperature minima range between 9.8-11.1 °c, and the corresponding maxima between 20-23.2°c (see Fig.3D).

At Mizan Teferi (1370 m a.s.l.;774000 m N-786000 m E), 20 km far north of Sheko forest, the mean annual rainfall is 2552 mm. February to December are rainy months, most falling between February and November. January is relatively dry (Fig.3E). The mean monthly temperatures range from 20.0-22.7 °c, the mean daily temperature minima range from 15.0-16.3 °c, and the corresponding maxima from 25.0-29.2 °c.

At Bonga (1650 m a.s.l; 804000 m N-196000 m E), south of Bonga forest, the rain falls throughout the year. The mean annual rainfall is 1619 mm, most falling between March and October. The mean monthly temperatures range from 18.6-20.5 °c, while the mean daily temperture minima range from 9.7-12.5 °c and the corresponding maxima from 25.0-29.3 °c (see Fig.3F).

The mean annual rainfall at Shebe (1635m a.s.l.; 226000 m N-831000 m E), a town 7 km east of Belete-Gera forest, is 1656 mm. The rainy month are February to November, with maximum between March and October. December and January are relatively dry months. The mean monthly temperatures range from 18.1-20.8 °c, the mean daily temperature minima range from 13.0-14.0 °c and the corresponding maxima from 22.7-27.7 °c (see Fig.3G).

3.4 Vegetation

Botanical collections from the forests of southwestern Ethiopia commenced by foreign botanists and foresters at the turn of the century. Various authors have studied and documented on the flora and vegetation of southwestern Ethiopia. Among these are Logan (1946), Chaffy (1979), Friis *et al.* (1982), Friis (1992) and Bonnefille *et al.* (1993). These studies show the general descriptions of vegetation types and the floristic composition of the vegetation.

Friis *et al.* (1982) recognized the following vegetation types in southwestern Ethiopia: Forests; Upland evergreen bushland; *Acacia abyssinica* woodland; Deciduous woodland and Upland grassland.

The forest vegetation of southwestern Ethiopia falls into the Moist evergreen montane forest zone (Tewolde Berhan Gebre Egziabher, 1986). According to Friis (1992), the floristic types of natural forests in southwestern Ethiopia comprise Transitional rainforest, Broad-leaved Afromontane rain forest and Riverine forest. The Transitional rain forest and Afromontane rain forest of the study area are described in section 2.1.2.

The Riverine forest of the study area occurs along water courses in the Transitional and Afromontane rain forest types of southwestern Ethiopia. The floristic composition of riverine forest at Gabba river (Illubabor) at altitudes from 1200 - 1500 m include the canopy trees *Albizia grandibracteata, Ficus thonningii, Miusops kummel*, and *Syzygium guineense* ssp. *guineense*. The majority of the canopy species are evergreen. The smaller trees or shrubs are *Argomuellera macrophylla, Eugenia bukobensis* Engl., *Sesbania dummerii* Phil. & Hutch. and *Phoenix reclinata*. Lianas include *Hippocrtea pallens* planchon ex Oliver and *Salacia congolensis* De Wild & Th. Dur. The floristic composition of riverine forest at Gojeb river (Kefa) at altitude about 1250 m include the canopy trees *Albizia grandibracteata, Baphia abyssinca, Ficus sur, F. thonningii, Mimusops kummel* and *Syzygium guineense* ssp *guinneense*. The small trees or shrubs are *Agromuellera macrophylla, Diospyros abyssinica, Oncoba spinosa* Forssk., *and Phoenix reccinata*. Lianas include *Artabotrys monteiroae* Oliv., *Hippocratea africana* (Willd.) Loes. and *Salacia congolensis*.

The description of the other vegetation types of the study area is based on Friis *et al.* (1982). Upland evergreen bushland is the type of vegetation in southwestern part of

Ethiopia around Jimma. It is associated with dry evergreen forest, but the species composition is influenced by the altitude (Friis *et al.* 1982). This bushland forms a mosaic with fields and wooded grassland or woodland, all evidently seral stages in the regrowth following shifting cultivation. The upland evergreen bushland doesn't seem to be the natural vegetation at Jimma. It invaded abandoned farmland and pasture land (secondary upland grassland). A number of species were in common with the lower strata in moist montane evergreen forest, e.g. *Pittosporum manni* ssp. r*ipicala* (J. Leon.) Cuf., others were forest pioneer species, e.g. *Maesa lanceolata* Forrsk. and *Clausena anisata*, some were associated with forest margins, e.g. *Cordia abyssinica* R. Br. and *Calpurnia aurea*, and some typical evergreen bushland species e.g. *Carissa edulis* and *Rhamnus staddo.*

Another vegetation type in southwestern Ethiopia is the *Acacia abyssinca* woodland (Friis *et al.*, 1982). It is found in many places in Kefa and Illubabor. It followed abandoned cultivation or invaded pasture land, and was also observed to form a fringe around patches of moist evergreen forest. A stratum of shrubs is mostly developed under the *Acacia* trees, the crowns of which form an almost continuous canopy. This stratum of shrubs is floristically closely related to the upland evergreen bushland described above from Jimma. Epiphytes are rare, the most common being the parasite *Loranthus woodfordioides*.

The deciduous woodlands cover large areas on the western escarpment between 500 and 1400 m on crystalline rock (Friis *et al.*, 1982). Friis *et al.* (1982) studied this vegetation type in the deep river valleys, particularly Gojeb valley, and on some rocky slopes with unimpeded drainage on the southwest plateau. The floristic composition includes *Albizia malacophylla* (A. Rich.) Walp., species of *Combretum, Dombeya quiqueseta, Pilostigma thonningii* (Schumach.)Milne-Redlh., *Stereospermum kunthiaanum* Cham., *Grewia mollis, Maytenus senegalensis* (Lam.) Exell, *Opilia celtidifoli* (Guill. & Perr.) Endl. ex Walp. (climber), and *Polystachya steudneri* Reichb.f. (epiphyte). The ground herbs include *Urginea altissima* and *Sansevieria nilotica*.

Upland grassland was studied by Friis *et al.* (1982) at Jimma, and a special type of grassland with water oozing through the sward was studied at Kochi near Jimma. The grassland at Kochi is termed as "seepage grassland" (Friis *et al.*, 1982). This type of grassland was observed by the present author near Dimbera around Bonga. The floristic composition includes the fern *Thelypteris confluens* (Thaunb) Morton and the seed plants *Acroceras macrum, Cyperus spp., Anagallis tenuicaulis* Bak., and *Pennisetum glabrum* Steud.

3.5 Population and Land Use

The size, distribution and cultural practices of the population has had a tremendous impact on the vegetation cover of the country. According to the 1994 Population and Housing Census of Ethiopia (CSA, 1996), the population of Illubabor zone is 847,048 of which 80,290 live in urban and 766,758 in rural areas. The populatoon of Jimma zone is 1,961,262 out of which 190,395 live in urban and 1,770,867 live in rural

4 MATERIALS AND METHODS

4.1 Field Data Collection

A reconnaissance survey was made between March 1, 1995 and March 7, 1995 across the forests of Southwestern Ethiopia in order to obtain an impression in site conditions and physiognomy of the vegetation and to identify sampling sites. The sites selected for sampling were along the Jimma-Bedelle-Metu-Tepi-Mizan Teferi-Bonga-Jimma road, stretching over a length of more than 700 km. In order to reduce the effect of human interference, the sites selected were as much as possible far away from human settlement and the main road. The field work was performed between April, 1995 and April, 1996.

4.1.1 Vegetation Analysis

During sampling, a visually checked uniform representative stand was selected and sample plots of 900 m^2 (30 m x 30 m) were delimited by relascope and tape. Floristic analysis inside the plot was carried out following the procedure of Braun-Blanquet (see Poore, 1955, 1956; Becking, 1957; Braun-Blanquet, 1965; Mueller-Dombois and Ellenberg, 1974; Westhoff & van der Mareel, 1978). A complete list was made for all trees, shrubs and herbaceous plants, and species were rated according to their abundance and aerial cover using the modified cover-abundance scale of Braun-Blanquet (van der Maarel, 1979). Floristic analysis of herbaceous species was made on a 2 m x 2 m subplot laid within the larger plot where the vegetation was thought to be representative . Analysis of bamboos was made on a 2 m x 2 m plot.

The height and diameter at breast height (DBH), *i.e.* 1.3 m, of all trees and shrubs were measured. Individuals with a DBH of less than 2 cm were not considered in both cases. Height measurement was done with a marked pole up to 5 m for shorter trees, and a Sunnto Height-meter for longer trees and DBH with a DBH measuring tape. For trees with buttresses extending up above breast height, diameter was measured just above the buttress. Where trees had multiple stems, each stem was measured separately for DBH. The leaf size of tree species with heights 6 m and above were measured from specimens collected for identification. The measurements were done on a single average mature leaf for simple leaves and a single average mature leaflet for compound leaves. The area of each leaf or leaflet was calculated using the formula: Leaf area = 2/3 lamina length X width, following Thompson *et al.* (1992). The presence of epiphytic mosses, lichens, ferns and other vascular epiphytes on each woody individuals was noted. Lianas were recorded as present.

The state of human interference at each quadrat was estimated as follows: using a 0-5 scale by taking into consideration the presence or absence of bee hives, stumps, logs and signs of grazing activities:

Scale 0 - Insignificant or no disturbance

Scale 1 - Only bee hives present

Scale 2 - Bee hives present, grazing activity or its signs observed

Scale 3 - Stumps and logs present

Scale 4 - Stumps and logs present, grazing activity or its sign observed

Scale 5 - Serious disturbance where there are bee hives, stumps and logs and grazing activity is observed.

Plant specimens were collected from the quadrat, numbered 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 Floras of Ethiopia (Hedberg & Edwards, 1989; 1995 ; and Edwards *et al.,* 1995). For species belonging to the following families, nomenclature follows Hedberg & Edwards (1989;1995) and Edwards *et al* (1995): Aquifoliaceae; Alagniaceae; Araliaceae; Celasteraceae; Euphorbiaceae; Fabaceae; Guttiferae; Icacinaceae; Meliaceae; Melianthaceae; Moraceae; Myrtaceae; Pittosporaceae; Poaceae; Rosaceae; Rhamnaceae; Rhizophoraceae; Rutaceae; Steruculiaceae; Ulmaceae; and Urticaceae. Nomenclature of Pteridophytes follows Agnew (1974). For the remaining species nomenclature follows Cufodontis (1953 - 1972). Voucher specimens are kept in the National Herbarium (ETH).

4.1.2 Site Description and Soil Sampling

At each sampling site the following environmental parameters were measured. Altitude was measured using " Thommen " altimeter, aspect was measured using " Type 15 T SILVA " compass, and slope was measured using a clinometer. Soil samples up to 20 cm depth (topsoil) and 40-60 cm depth (subsoil) were collected from five points in each quadrat, four at the corners and one at the middle. A composite soil sample weighing ca. 1.5 kg was taken and carried in polythene bags and brought to Addis Ababa University where they were air dried and passed through a 2 mm sieve for physical and chemical analysis.

4.2 Soil Analysis

Soil analysis was performed in the soil laboratories of Addis Ababa University and Ministry of Agriculture based on the procedures outlined by Jou (1978), Chopra & Kanwar (1982) and Dewis & Freitas (1984).

1. Soil particle size distribution was determined using the Bouyoucos hydrometer method outlined in Jou (1978).
2. The wet colour of the soil was determined by comparing with the Munsell colour charts of 1975 edition.
3. Soil pH was measured by taking a 1:1 soil/water suspension using a glass electrode pH-meter following Jou (1978).
4. Electrical conductivity of the soil sample was measured by preparing a 1:2 soil/water suspension using a conductivity-meter following Chopra & Kanwar (1982).
5. Available Phosphorus was determined following Bray No. 1 method (Jou, 1978).
6. Organic matter was determined according to the Walkely-Black method outlined in Jou (1978).
7. Total Nitrogen was determined following the Kjeldahl method outlined in Dewis & Frietas (1984).
8. Exchangeable Potassium and Sodium were extracted using ammonium acetate, pH 7 and the extract was measured by a flame photometer (Dewis & Frietas, 1984).
9. Exchangeable Calcium and Magnesium were extracted using ammonium acetate, pH 7 and the extract was measured using Varian AA-1275 series Atomic absorption Spectrometer following Dewis & Frietas (1984

10. Cation exchange capacity (CEC) was determined using Kjeldahl distillation unit after saturation with ammonium acetate, pH 7 and washing the excess ammonium acetate with ethanol and repalcing it with 10% sodium chloride following Dewis & Frietas (1984).

4.3 Data analyses

4.3.1 Floristic data

The cover-abundance values were used as class entities to classify the floristic data using Average-linkage clustering procedure with the program SYNTAX: PROGRAMME NCLAS- Hierarchical clustering by distance optimization (Podani, 1988). In the SYNTAX program, similarity ratio was selected for resemblance coefficient and dissimilarities among the various relevès were measured using average linke. The different clusters were then arranged hierarchically.

4.3.2 Environmental data

To get a mean value for the various environmental parameters for each distinct plant community type, the values for all relevès that make up the particular community type were added and averaged for the topsoil and subsoil. In order to use aspect for data analysis, it was codified following Zerihun *et al.* (1989): N=0; NE=1; E=2; SE=3; S=4; SW=3.3; W=2.5; NW=1.3; Ridge top=4. Analysis of variance (ANOVA) was performed to see if there is any variation among the various community types with respect to any one environmental parameter. Duncan's multiple range test was performed to detect significant differences among the different means of the environmental parameters of each community type. The correlation of the various environmental parameters among each other was evaluated by calculating Pearson's product-moment correlation coefficient. All statistical analysis were performed with the program STATISTICA.

4.3.3. Structural data

The structure of the various plant community types derived from the classification output were described in terms of tree density, diameter, height, leaf size, and epiphytes.

Tree density was computed by converting the count from the sample plot to a hectare basis. The diameter at breast height (DBH) was classified into 6 DBH-classes and the percentage distribution of trees in each class was computed for each community type. For the analysis of tree height, leaf size and epiphytes, trees with heights 6 m and above were considered. Tree height was classified into 8 height-classes and the percentage distribution of trees in each class was calculated. The leaves were assigned into one of Raunkiaer's leaf size class as modified by Webb (1959) and the percentage distribution of the tree species in each class was calculated. The percentage of trees supporting epiphytic mosses, lichens, pteridophytes, and spermatophytes was calculated for each community type.

5 RESULTS AND DISCUSSION

5.1 Floristics

A total of 139 species of vascular plants representing 56 families were recorded from the tree, shrub, and field layers (see Appendix 1). Of these 41.7% were trees, 10.1% trees/shrubs, 12.9% shrubs, and 35.2% herbs. Seventy-one per cent of the families were dicots, 14.6% monocots, and 14.3% pteridophytes. Seventy-seven per cent of the species were dicots, while 15.1% monocots, and 7.9% pteridophytes. The families with the highest number of species were Euphorbiaceae and Moraceae (10 species each) from dicots, Poaceae(7 species) from monocots, and Aspleniaceae (3 species) from Pteridophytes.

Fifteen species of vascular epiphytes belonging to 9 families were recorded. Four species belonged to Orchidaceae, while 3 species belonged to Polypodiaceae, and 2 species belonged to Piperaceae. The families Adianthaceae, Amaryllidaceae, Aspleniaceae, Camponviaceae, Lycopodiaceae, and Oleandraceae were represented with one species each. The species list of vascular epiphytes recorded in this study is shown in Appendix 2.

Twelve species of woody climbers (lianas) belonging to 11 families were recorded from the quadrats. Two of the species belonged to the family Celasteraceae/Hippocrateaceae, where as rest belonged to Apocynaceae, Araceae, Combretaceae, Menispermaceae, Myrsinaceae, Oleaceae, Phytolaccaceae, Ranunculaceae, Rhamnaceae and Urticaceae. The complete list of lianas recorded in this study is given in Appendix 3.

5.2 Vegetation classification

Nine clusters can be recognized from the SYNTAX output at dissimilarity level above 0.7 (Fig. 4). These clusters were designated as local plant community types and given names after one or two dominating and/or characteristic species, usually a tree and a shrub. A dominant species in this case is a species having a synoptic cover-abundance value (mean frequency X mean cover-abundance, van der Maarel 1987) of at least 7, and a characteristic species being a species with higher synoptic values (4, 5 or 6) in the type but absent in most of the other community types. Synoptic cover-abundance values for the most important species are shown in Table 2.

The description of the plant community types based on the dominant and characteristic species with their altitudinal distribution is as follows. The cluster numbers in the dendrogram (Fig. 4) correspond to numbers of the community types in the subsequent discussion.

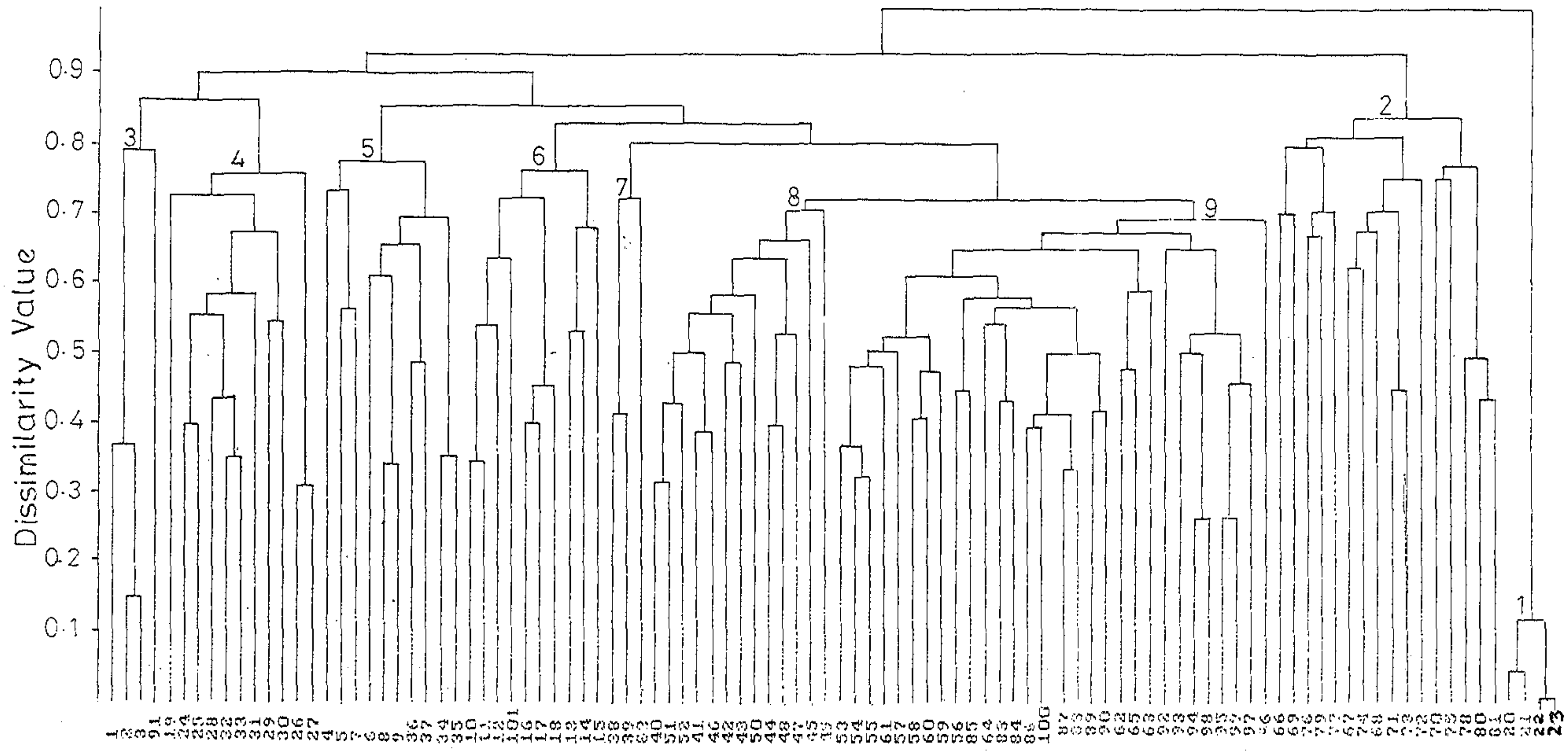

Fig. 4 Dendrogram of the relevè group of southwestern Ethiopian Forest

Table 2 Synoptic cover-abundance values for species reaching a value of >1.0 in at least one community type; values in bold refer to occurrences as characteristic species

SPECIES	Cluster number								
	1	2	3	8	5	7	9	6	4
Arundinaria alpina	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dicliptera laxata	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pilea bambuseti	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Laportea alatipes	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteris dentata	3.5	0.0	1.3	0.0	0.0	0.0	0.0	4.9	4.4
Coffea arabica	0.0	7.3	0.0	0.0	3.8	0.0	3.7	0.5	0.0
Manilikara butugi	0.0	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Argomuellera macrophylla	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alchornea laxiflora	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aningeria altissima	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Celtis zenkeri	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dracaena fragrans	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brillantaisia madagascariensis	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mimusops kummel	0.0	1.4	0.0	0.8	1.3	0.0	0.0	0.0	0.0
Dorstenia soerensenii	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leptaspsis zeylanica	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bersama abyssinica	0.0	0.8	3.5	2.2	1.1	2.7	0.4	1.3	0.3
Canthium oligocarpum	0.0	0.0	1.8	0.2	0.4	0.0	0.0	0.0	0.8
Maytenus gracilipes	0.0	0.0	6.3	0.8	1.7	0.0	0.0	2.1	0.0
Solanecio mannii	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Vangueria apiculata	0.0	0.0	3.2	0.0	0.4	0.0	0.0	0.0	0.0
Phaulopsis imbricata	0.0	0.0	2.3	0.9	0.0	0.0	0.0	0.0	0.0
Impatiens hochstetteri	0.0	0.0	7.3	0.0	0.0	0.0	0.0	0.0	3.1
Syzygium guineense	0.0	0.0	7.5	7.1	1.8	2.0	3.1	1.8	2.5
Apodytes dimidiata	0.0	0.0	5.8	4.8	0.0	0.0	0.0	0.5	0.0
Oplismenus compositus	0.0	1.1	0.0	7.5	4.1	0.0	5.9	0.0	0.0
Acanthus eminens	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.4
Maytenus obscura	0.0	0.0	0.0	1.7	0.0	0.0	0.9	0.0	0.0
Dracaena steudneri	0.0	0.0	0.0	1.5	0.0	0.0	0.6	1.0	0.6
Piper capense	0.0	0.1	0.0	1.9	0.0	0.0	0.0	1.5	0.5
Setaria megaphylla	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Thelypteris longicuspis	0.0	2.1	0.0	3.4	0.0	0.0	0.0	0.0	0.0
Dracaena afromontana	0.0	0.8	0.5	5.9	7.1	3.7	1.8	4.2	4.5
Teclea nobilis	0.0	0.0	0.0	2.2	4.8	1.0	2.8	4.1	0.3
Albizia grandibracteata	0.0	0.0	0.2	0.9	2.8	0.0	0.0	0.0	1.6
Cassipourea malosana	0.0	0.0	0.0	0.0	1.1	0.0	1.2	0.0	0.5
Celtis africana	0.0	1.3	0.0	0.0	5.1	0.0	0.0	0.0	0.0
Cordia africana	0.0	1.3	0.0	0.0	2.3	0.0	0.0	0.0	0.0
Fagaropsis angolensis	0.0	0.0	0.0	0.0	1.4	0.0	0.7	0.0	0.0
Rothmannia urcelliformis	0.0	2.3	0.0	0.7	3.6	1.7	0.0	2.2	0.0
Trilepisium madagascariense	0.0	0.6	0.0	0.0	1.4	0.0	0.0	0.0	0.0
Pseudechinolaena polystachya	0.0	0.0	1.3	1.8	5.1	8.0	2.2	0.0	0.0
Chionanthes mildbraedii	0.0	0.0	0.0	3.5	3.5	6.0	4.1	3.6	0.1
Rytigynia neglecta	0.0	0.0	1.5	1.4	0.9	2.3	1.6	1.1	1.1
Aningeria adolfi-friederici	0.0	0.0	0.0	1.6	0.9	7.0	0.0	4.2	0.0
Poecilostachys oplismenoides	0.0	2.1	1.1	1.5	0.0	8.0	1.7	3.4	0.0
Croton macrostachyus	0.0	0.4	1.5	2.3	1.2	6.0	0.0	1.8	0.6
Diospyros abyssinica	0.0	1.0	0.0	0.0	2.8	4.0	0.0	1.7	0.5
Psychotria orophila	0.0	0.0	0.0	3.0	0.8	4.0	0.9	0.0	2.8
Desmodium repandum	0.0	0.6	0.0	5.5	0.0	6.0	0.0	0.0	0.0
Olea welwitschii	0.0	0.0	0.0	2.0	2.5	0.0	5.4	1.5	0.0
Sapium elipticum	0.0	1.2	0.0	0.0	1.2	0.0	2.2	2.7	0.0
Aframomum korarima	0.0	0.0	0.0	0.0	0.0	0.0	4.1	2.2	0.0
Vepris daniellii	0.0	0.6	0.0	0.0	0.0	0.0	2.8	0.0	0.3
Cassipourea malosana	0.0	0.0	0.0	0.0	1.1	0.0	1.2	0.0	0.5
Sanicula elata	0.0	1.4	0.0	2.4	0.0	0.0	4.0	0.0	0.0
Polyscias fulva	0.0	0.4	0.0	0.4	0.0	0.0	3.0	0.0	0.0
Achyranthus aspera	0.0	1.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0
Ehretia cymosa	0.0	0.0	0.0	0.0	0.1	0.0	0.0	1.1	0.0
Ekebergia capensis	0.0	0.0	0.0	0.0	0.1	0.0	0.0	1.1	0.0
Ficus sur	0.0	0.1	0.0	1.1	0.2	1.3	0.8	2.7	0.0
Justicia schimperiana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
Albizia gummifera	0.0	0.4	0.0	0.8	0.1	0.0	0.0	2.9	0.1
Millettia ferruginea	0.0	1.1	0.3	0.0	2.3	0.0	2.7	2.8	0.5
Schefflera abyssinica	0.0	0.0	0.0	2.1	0.0	0.0	2.5	2.7	0.4
Deinbollia kilimandscharica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.2
Allophylus abyssinicus	0.0	0.0	1.3	0.0	0.0	0.0	0.9	5.2	2.6
Schefflera abyssinica	0.0	0.0	0.0	2.1	0.0	0.0	2.5	2.7	0.4
Cyathea manniana	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	4.1
Galiniera saxifraga	0.0	0.0	0.0	0.7	0.5	0.0	0.5	2.0	5.3
Ilex mitis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	5.1
Macaranga capensis	0.0	0.9	1.3	0.0	0.0	0.0	0.0	0.0	3.5
Maesa lanceolata	0.0	0.0	0.0	0.9	0.2	0.0	0.0	0.0	1.4
Maytenus arbutifolia	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	2.5
Aneilema beninese	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	2.9
Elatostemma monticolum	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	2.5
Asplenium bogoiense	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3

1 *Arundinaria alpina* type

The *Arundinaria alpina* type is found growing at altitudes from 2450 to 2550 m. The dominant species of this type is the highland bamboo *Arundinaria alpina*. There is no shrub layer in this type. *Dicliptera laxata* and *Pilea bambuseti* are dominant species in the field layer. The characteristic species of the field layer is *Laportea alatipes*. Lianas are not present in this community type. Isolated trees of *Syzygium guineense* and *Schefflera volkensii* are present scattered through the bamboo stand.

2 *Manilikara butugi-Coffea arabica* type

This community type is distributed between 1050 and 1500 m. *Manilikara butugi* is the characteristic species in the tree layer and *Coffea arabica* is the dominant species in the shrub layer. *Aningeria altissima, Alchornea laxiflora, Argomuellera macrophylla, Celtis zenkeri,* and *Dracaena fragrans* are associated with this type. *Brillantaisia madagascariensis, Leptaspsis zeylanica*, and *Dorstenia sorensenii* are the species recorded from the field layer of this type only. *Strychnos mitis, Garcinia buchananii, Hallea robrostipulata, Morus mesozygia*, and *Rungia grandis* are species recorded from this type only but with lower frequency. *Landolphia buchananii, Combretum paniculatum,* and *Hippocratea africana* are the lianas abundant in this type.

3 *Syzygium guineense-Maytenus gracilipes* type

This community type is distributed between 2280 and 2420 m a.s.l. *Syzygium guineense* is the dominant species in the tree layer. *Apodytes dimidiata* is the characteristic species in the tree layer. *Maytenus gracilipes* and *Vangueria apiculata* are the characteristic species in the shrub layer. *Impatiens hochstetteri* is the dominant species in the field layer. The lianas *Landolphia buchananii* and *Urera hypeselodendron* are well represented in this type.

4 *Ilex mitis-Galiniera saxifraga* type

The main characterstic species of this type are *Ilex mitis* and *Galiniera saxifraga.* Other characteristic species of this type is the tree fern, *Cyathea manniana* *Asplenium bugoiense and Pteris dentata* are the characteristic species in the field layer. The altitudinal distribution of this community type is from 1950 to 2340 m. The herbs *Drymaria cordata* and *Triestemma mauritanum* were recorded from this type only. *Hippocratea africana* and *Landolphia buchananii are the lianas represented in this type.*

5 *Celtis africana-Dracaena afromontana* type

This type has altitudinal distribution between 1460-1960 m. *Celtis africana is* the characteristic species of the tree layer. *Dracaena afromontana* is the dominant species in the shrub layer. The grass *Pseudechinolaena polystachya* is the characteristic species in the field layer. *Ritchia albersii* was recorded from this community type only. The lianas most abundant in this type are *Landolphia buchananii, Combretum paniculatum, Hippocratea goetzei,* and *H. africana* .

6 *Allophylus abyssinicus-Justicia schimperiana* type

This community type is distributed between 1760 and 2030 m. *Allophylus abyssinicus* and *Aningeria adolfi-freiderici* are the characteristic species of this type in the tree layer. *Justicia schimperiana* is the characteristic shrub. The characteristic species of the field layer is *Pteris dentata*. Lianas and woody climbers represented in this type are *Hippocratea goetzei, H. africana, Tiliacora troupinii, Combratum paniculatum,* and *Jasminum abyssinicum*.

7 *Aningeria adolfi-friederici-Chionanthes mildbraedii* type

Aningeria adolfi-friederici is the dominant species of the tree layer. *Croton macrostachyus* and *Diospyros abyssinica are* the characteristic species in the tree layer. *Chionanthes mildbraedii* is the characteristic species in the shrub layer. *Pseudechinolaena polystachya* and *Poecilostachyus oplismenoides* are dominant in the field layer and *Desmodium repandum* is the charactersyic species in the same layer. *Landolphia buchananii* and *Hippocratea goetzei* are the lianas most abundant here. This type is distributed between 1880 and 1940 m.

8 *Syzygium guineense*

This type is distributed at altitudes from 1845 to 2240 m. The dominant species in the tree layer is *Syzygium guineense*. *Apodytes dimidiata* is the characteristic species in the tree layer. *Oplismenus compositus* is the dominant grass in the field layer and *Desmodium repandum* is the characteristic herb. This type is different from the next type in having *Apodytes dimidiata* and *Desmodium repandum* as characterstic specie. The lianas abundant in this type are *Landolphia buchananii* and *Combretum paniculatum* .

9 *Olea welwitschii-Chionanthes mildbraedii* type

This community type has distribution range between 1675 and 2010 m. This community type is characterized by *Olea welwitchii* in the tree layer. *Schefflera abyssinica, Polyscias fulva* and *Vepris daniellii* are the associated trees. *Chionanthes mildbraedii* is the characteristic shrub. *Oplismenus compositus, Sanicula elata*, and *Aframomum korarima* are characteristic herbs. *Landolphia buchananii, Hippocratea africana, H. goetzei*, and *Combretum paniculatum* are the lianas represented in this type.

The altitudinal limit of *Arundinaria alpina* community type encountered in this study is close to the lower altitudinal limit of the bamboo zone in East Africa as delimited by Morrison & Hamilton (1974). The upper limit of this type in the study area has not been investigated. *Arundinaria alpina* type distributed above 2700 m in Jibat forest, Shewa (Tamrat Bekele, 1993).

5.3 Community-environment relationship

The community types identified from the classification output showed differences with respect to all the environmental parameters except for slope, exposure, exchangeable sodium, and potassium, cation exchange capacity and available phosphorus in the subsoil. All the soil parameters determined, except clay content are higher in the topsoil than in the subsoil. The values of the various environmental parameters averaged for each plant community type are presented in Table 3.

The major discrimination among the community types is due to altitude. The community types could be grouped into four groups based on altitude: Group 1 with altitude > 2300 m (types 1 and 3); Group 2 altitude between 1900 and 2300 m (types 4, 7, and 8); Group 3 altitude between 1700 and 1900 m (types 5, 6, and 9); and Group 4 with altitude < 1500 m (type 2). Bonnefille *et al.* (1993) reported the presence of altitudinal zonation delimiting vegetation types in southwestern Ethiopia from palynological studies of forests and woodlands. Altitude is an important environmental factor that affects atmospheric pressure, moisture, and temperature which have a strong influence on the growth and development of plants and the distribution of vegetation (Hedberg, 1964).

There is little variation in the soil colour of the community types. The hue (the dominant spectral colour or quality) is 2.5YR or 5YR, the value (the measure of the lightness or darkness of the colour) is either 2.5 or 3, and the chroma (the degree of colour purity) ranges from 1 to 4. Most of the soils are dark reddish brown in colour.

There are five textural classes for topsoil of the community types and three for subsoil. The topsoil of community types 1 and 4 are loamy sand in texture, of type 2 clay loam, of types 3 sandy loam, of type 5 sandy clay loam and of types 6, 7, 8, and 9 loam in texture. The subsoil of community types 1 and 4 are sandy loam in texture, of type 3 loam, and of types 2, 5, 6, 7, 8, and 9 clay loam in texture. Soil texture is an important soil parameter that affects site quality. It influences the nutrient supplying ability of soil solids, soil moisture and air relations, and root development (Spurr and Barnes, 1980).

Comparison of the community types based on the sand content of the soil shows that type 1 is significantly different from types 2, 5, 6, 8, and 9, and type 4 differs from types 2, 5, 6, 7, 8, and 9 in both layers of soil, and type 6 differs from types 3, 5, and 9 for topsoil. Community type 4 differs from types 8 and 9 in its silt content in the topsoil and from types 7 and 9 in the subsoil. Community types 8 and 9 differ in their silt content in the subsoil. Community type 2 differs from types 1 and 9 and community type 4 from type 2 and 6 in the clay content of topsoil and community types 4 and 8 differ in the clay content of subsoil.

The plant communities of southwestern Ethiopia forests developed on acidic soil. The soils of community types 1, 4, and 6 have pH values between 4 and 5 and of community types 2, 3, 5, 7, 8, 9, have pH values between 5 and 6. The acidity of the soil could be caused by a more intense breakdown of organic matter and leaching of the soils as the study area has more than 1600 mm annual rainfall. Community types 1, 4, and 6 differ from the rest and type 6 is different from types 1 and 4. In the subsoil types 1 and 6 are different from types 2, 5, 7, 8 and 9. Soil pH affects the growth of plants and the distribution of vegetation types by its effect on the availability of mineral nutrients and decomposition of organic matter (Buckman & Brady, 1969).

Community type 1 is different from the remaining types in soluble salts in both topsoil and subsoil and type 2 differs from type 9 in topsoil. The electrical conductivity of the soil solution is mainly determined by soluble salts of carbonates, bicarbonates, sulphates, chlorides and nitrates (Chopra and Kanwar, 1982). The concentration of salts in the soil solution influences an exchange of nutrients between the soil solution and plants.

Table 3. Duncan's multiple range test between c
within each column indicate significant differe

Comm Type	Altitude (m)	Slope (°)	Exposure	TS
1	2505^{a} ±28.86	8.3^{ns} ±2.17	2.0^{ns} ±0.09	71.8 ±3.
2	1338^{f} ±61.15	15.5^{ns} ±1.88	2.5^{ns} ±0.12	43.6 ±3.6
3	2378^{a} ±32.75	13.0^{ns} ±4.69	3.0^{ns} ±0.05	62^{ab} ±2.3
4	2152^{b} ±44.95	9.6^{ns} ±1.87	2.5^{ns} ±0.08	70.4 ±3.5
5	1729^{c} ±63.0	12.4^{ns} ±1.88	2.8^{ns} ±0.09	51.2 ±3.3
6	1880^{cde} ±33.97	11.0^{ns} ±3.71	1.6^{ns} ±0.15	35.8 ±4.6
7	1910^{bcde} ±17.32	6.7^{ns} ±1.73	4.0^{ns} ±0.11	52.0 ±4.9
8	2021^{d} 36.28	12.5^{ns} ±1.15	2.4^{ns} ±0.11	46.4 ±2.4
9	1860^{e} ±18.29	10.1^{ns} ±1.15	2.1^{ns} ±0.08	48.3 ±1.1

Table 3 contd.

Comm. Type	Total Nitrogen (%)		Available P (pp
	TS	SS	TS
1	0.9^{a} ±0.08	0.69^{a} ±0.08	26.3^{ab} ±9.1
2	0.51^{bc} ±0.03	0.23^{b} ±0.04	59.2^{b} ±15.8
3	0.58^{bc} ±0.05	0.34^{bc} ±0.04	13.3^{ab} ±1.7
4	0.62^{c} ±0.07	0.39^{c} ±0.03	24.2^{ab} ±7.2
5	0.48^{bc} ±0.04	0.26^{bc} ±0.02	54.6^{ab} ±25.6
6	0.44^{bc} ±0.04	0.31^{bc} ±0.04	15.4^{ab} ±3.8
7	0.44^{bc} ±0.02	0.21^{bc} ±0.02	26.6^{ab} ±17.3
8	0.44^{bc} ±0.03	0.29^{bc} ±0.01	6.0^{a} ±1.6
9	0.38^{b} ±0.02	0.2^{b} ±0.01	4.2^{a} ±1.5

The organic matter content of the soils of the plant communities of southwestern Ethiopian forests is generally high (8.6-20.1%). This high content of organic matter is important in the fertility status and productivity of these soils. The mineralization of organic matter is a contributing factor in supplying available mineral nutrients for plant use, and through decomposition process the available nitrogen (Murphy, 1969). Higher amount of organic matter content has also been reported from the humid forest of Jibat (Tamrat, 1993). Westphal (1975) indicated that dark red-brown soils that are slightly to strongly acid have a higher organic matter content. There is significant variation in the organic matter content of the soils of the plant community types. Community type 1 is different from the other types and type 4 differs from types 2, 5, 6, 8, and 9. Community type 3 differs from types 2, 8 and 9. Community types 1 and 4 are from region which receives higher amounts of annual rainfall with lower temperature (see the climate diagrams of Masha, Fig. 3). The higher amount of organic matter is due to the inhibition of mineralization of organic matter by low temperature and acidic pH.

The total nitrogen content of the soil follows closely the amount of organic matter. It is higher in those community types with higher organic matter content and lower in those having lower organic matter content. This is due, similarly, to the effect of rainfall and temperature. Much of the soil nitrogen is in the organic form and its distribution in the soil is approximately as that of organic matter (Thompson and Troeh, 1979).

Community types 2, 4, and 5 have higher amount of available phosphorus, types 3, 6 and 9 have medium amount and type 8 has lower amount of available phosphorus both in topsoil and subsoil while community types 1 and 7 have higher amount in topsoil and medium amount in subsoil. There is no much difference between the community types in available phosphorus except the differences between community type 2 and types 8 and 9.

The soils of the community types are rich in exchangeable bases particularly in exchangeable calcium which accounts for 70.5-79.9% and 54.5-76% of the exchangeable bases in the topsoil and subsoil respectively. There is no variation among the community types in exchangeable sodium except for type 7 which differs from the other types for topsoil only. Community type 4 differs from types 5 and 8 in its exchangeable potassium and from types 2, 5, and 8 in exchangeable calcium of the topsoil. In the subsoil, type 5 differs from types 1, 2, 4, 6, 8, and 9 in exchangeable calcium. The variation could be accounted to the differences in soil pH and the amount of rainfall. The amount of exchangeable calcium and potassium present in the soil decline as a soil becomes more acidic and increases as the acidity declines (Thompson and Throen, 1969). Community type 5 has more amount of exchangeable magnesium than types 1, 6, and 9 in the topsoil and than types 1, 2, 4, 6, 8, and 9 in the subsoil and type 4 has lower amount of exchangeable magnesium than types 2, 3, 5, 7, 8, and 9 in the topsoil. The exchangeable bases have their highest concentration in community types 3, 5, and 7 and these communities occurred in areas which received the least amount of rainfall (see Fig.3A,3B,3G)resulting in little loss of the cations by leaching.

The cation exchange capacity (CEC) of the soils of the plant community types is generally less. The CEC of the soils of community types 3, 4, and 5 is higher than the soils of types 2 and 9. The factors that influence CEC are texture, organic matter, and pH of the soil, but these contrasting groups of community types showed different degree of variability in terms of these factors, therefore, no single factor is responsible for the variation. The base saturation of the soils increases from 19.8% to 83.3% as pH rises from 4.1 to 5.8. Those community types whose soils' pH are relatively higher have most of their cation exchange portion occupied by basic cations (K^+, Na^+, Ca^{++}, and Mg^{++}) and those whose pH is lower have most of their cation exchange portion occupied by acidic cations (H^+ and Al^{+++}).

The results of Pearson's product-moment correlation of the environmental parameters (Table 4a and 4b) shows that some of the environmental parameters are correlated.

Altitude is positively correlated with sand and organic matter in topsoil and with electrical conductivity, organic matter and total nitrogen in subsoil, but negatively with clay in both topsoil and subsoil and available phosphorus in subsoil. Organic matter, total nitrogen and electrical conductivity are positively correlated in both topsoil and subsoil. The correlation of organic matter with electrical conductivity could be explained by its capacity to supply replaceable cations to the soil solution which increases the conductivity. The sand content of the soil is positively correlated with organic matter and total nitrogen but negatively with silt and clay content of the soil in both topsoil and subsoil. The correlation of organic matter and nitrogen with sand contradicts the fact that sandy soils usually carry less organic matter and nitrogen

(Buckmann and Brady, 1969). pH is positively correlated with silt, exchangeable calcium, magnesium, and potassium (topsoil) and negatively with sand (subsoil), organic matter and total nitrogen. When the soil pH is lower the rate of organic matter decomposition decreases, this is due to the effect of soil pH on the activity of soil microorganisms that are involved in the decomposition of organic matter. The positive correlation between pH and calcium, magnesium, and potassium is to be expected as soils that are highly leached have lower pH because the basic cations have lower proportions than the acidic cations (Buckman and Brady, 1969). Among the exchangeable bases, potassium, calcium, and magnesium are positively correlated.

Table 4a. Pearson's product-moment

	Alt	Slope	Expo
Alt	-		
Slope	-0.49	-	
Expo	-0.06	-0.24	-
Sand	0.73*	-0.42	0.09
Silt	-0.47	0.05	0.32
Clay	-0.84*	0.64	-0.28
pH	-0.66	0.39	0.46
Cond	0.45	-0.44	-0.2
Org	0.69*	-0.18	-0.17
N	0.65	-0.24	-0.19
P	-0.57	0.37	0.22
Na	-0.12	-0.46	0.85
K	-0.17	0.30	0.63
Ca	-0.35	0.31	0.70
Mg	-0.29	0.32	0.64
CEC	0.66	0.07	0.25

Table 4b. Pearson's product-moment correla

	Alt	Slope	Expo	Sand
Alt	-			
Slope	-0.49	-		
Expo	-0.06	-0.24	-	
Sand	0.63	-0.14	-0.25	-
Silt	-0.22	-0.29	0.46	-0.77*
Clay	-0.73*	0.47	-0.04	-0.81*
pH	-0.63	0.18	0.62	-0.81*
Cond	0.70*	-0.34	-0.45	0.57
Org	0.78*	-0.24	-0.31	0.82*
N	0.74*	-0.31	-0.36	0.78*
P	-0.77*	0.61	0.06	-0.08
Na	0.20	-0.14	0.01	0.64
K	-0.06	0.18	0.72*	-0.36
Ca	-0.54	0.41	0.40	-0.47
Mg	-0.48	0.43	0.43	-0.53
CEC	0.54	0.12	0.12	0.66

5.4 Vegetation structure

The plant community types of southwestern Ethiopian forests generally have similar structure despite floristic differences. The major structural difference is seen between the *Arundinaria alpina* community type and the remaining types as a group.

5.4.1 Tree density

Table 5. Tree density (number of trees ha^{-1}) of community types 2-9 for trees with DBH > 10 cm and > 20 cm; figures are mean±SE

Community type	DBH >10 cm(a)	DBH >20 cm(b)	a/b
2 *Manilikara butugi-Coffea arabica*	286±26.54	178±12.92	1.6
3 *Syzygium guineense-Maytenus gracilipes*	392±20.01	203±7.09	1.9
4 *Ilex mitis-Galiniera saxifraga*	583±140.07	163±24.1	3.6
5 *Celtis africana-Dracaena afromontana*	387±38.15	148±17.59	2.6
6 *Allophylus abyssinicus-Justicia schimperiana*	261±31.13	138±13.59	1.9
7 *Aningeria adolfi-friederici-Chionanthes mildbraedii*	489±98.65	156±22.33	3.1
8 *Syzygium guineense*	464±55.8	177±17.34	2.6
9 *Olea welwitschii-Chionanthes mildbraedii*	419±29.67	189±13.05	2.2

The mean density of trees expressed, as numbers of trees over 10 cm DBH and as numbers of trees over 20 cm DBH per hectare and the ratio of the former to the latter is presented in Table 5.

Ilex mitis-Galiniera saxifraga community type has more density of trees with DBH> 10 cm and *Syzygium guineense-Maytenus gracilipes* community type has more density of trees with DBH >20 cm.

There is significant difference between the density of trees > 10 cm and density > 20 cm DBH in each community type ($p<0.01$). The ratio of density > 10 cm to density > 20 cm DBH could be taken as a measure of the distribution of size classes (Grubb *et al.*, 1963; Tamrat Bekele, 1993). The very high a/b ratio in *Ilex mitis-Galiniera saxifraga* and *Aningeria adolfi-friederici-Chionanthes mildbraedii* community types shows the predominance of small sized individuals in these types.

The very high a/b ratio in *Ilex mitis-Galiniera saxifraga* type is due to the abundance of the tree fern, *Cyathea manniana*, whose diameter never exceeds 15 cm. The predominance of small sized trees in *Aningeria adolfi-friederici-Chionanthes mildbraedii* type is due to the selective removal of large sized trees. *Aningeria adolfi-friederici* is particularly selected for removal. In the gaps formed from the removal of trees, many saplings and seedlings of *Bersama abyssinica, Diospyros abyssinica, Chionanthes mildbraedii*, and species of *Maytenus* were established.

The lowest a/b ratio in *Manilikara butugi-Coffea arabica* type is due to the selective removal of lower storey trees which could have contributed for density of > 10 cm DBH. Upper canopy trees were intentionally untouched to provide shading for coffee plants.

The density of bamboo culms in *Arundinaria alpina* type is 47,500 ha^{-1}. Bamboos are locally used for house construction and the making of household utensils. Stumps of bamboo were observed in the sampling site. Tamrat Bekele (1993) recorded 9333 bamboo culms/ha in the *Arundinaria alpina* type in Jibat forest, Shewa.

5.4.2 Tree diameter

The DBH-class distribution of trees shows (Table 6) that most of the individual trees in the eight (2-9) community types have diameter below 20 cm. More than 70 % of the trees in *Syzygium guineense-Maytenus gracilipes, Ilex mitis-Galiniera saxifraga, Celtis africana-Dracaena afromontana, Allophylus abyssinicus-Justicia schimperiana* and *Aningeria adolfi-friederici-Chionanthes mildbraedii* community types belong to the lowest diameter class (5-20 cm). Over 64 % of the trees in *Syzygium guineense* and *Olea welwitschii-Chionanthes mildbraedii* community types, and 47 % of the trees in *Manilikara butugi-Coffea arabica* type belong to the lowest diameter class . More than 90 % of the trees in the eight community types have diameter below 80 cm. *Ilex mitis-Galiniera saxifraga* and *Allophylus abyssinicus-Justicia schimperiana* community types, compared to the others, have more individuals in the highest diameter class(>100 cm). This is due to the abundance of the tree *Schefflera abyssinica* which usually has a wider bole. Very few individuals of this species having diameter over

200 cm have been recorded in *Ilex mitis-Galiniera saxifraga*, *Allophylus abyssinicus-Justicia schimperiana* and *Syzygium guinense* community types.

Table 6. Percentage tree distribution in DBH-classes for community types 2-9.

Community type	DBH class (cm)					
	5-20	20-40	40-60	60-80	80-100	>100
2 *Manilikara butugi-Coffea arabica*	47.0	24.4	15.5	8.6	2.4	2.1
3 *Syzygium guineense-Maytenus gracilipes*	70.8	13.4	8.0	6.0	1.0	1.4
4 *Ilex mitis-Galiniera saxifraga*	80.2	10.8	3.2	2.1	<1	3.4
5 *Celtis africana-Dracaena afromontana*	78.8	13.2	4.3	1.9	1.1	<1
6 *Allophylus abyssinicus-Justicia schimperiana*	72.0	16.4	3.6	2.5	2.1	3.4
7 *Aningeria adolfi-friederici-Chionanthes mildbraedii*	82.4	7.7	4.9	2.3	1.8	<1
8 *Syzygium guineense*	64.4	10.6	4.6	10.7	8.4	1.3
9 *Olea welwitschii-Chionanthes mildbraedii*	69.2	16.4	6.2	5.0	2.4	<1

5.4.3 Tree height

The frequency distribution of tree number in the various height classes shows (Fig.5) that all community types have individuals distributed in each height-class. Bamboos attain heights between 7 and 11 m. Over 70 % of the trees in *Ilex mitis-Galiniera saxifraga*, *Celtis africana-Dracaena afromontana*, *Allophylus abyssinicus-Justicia*

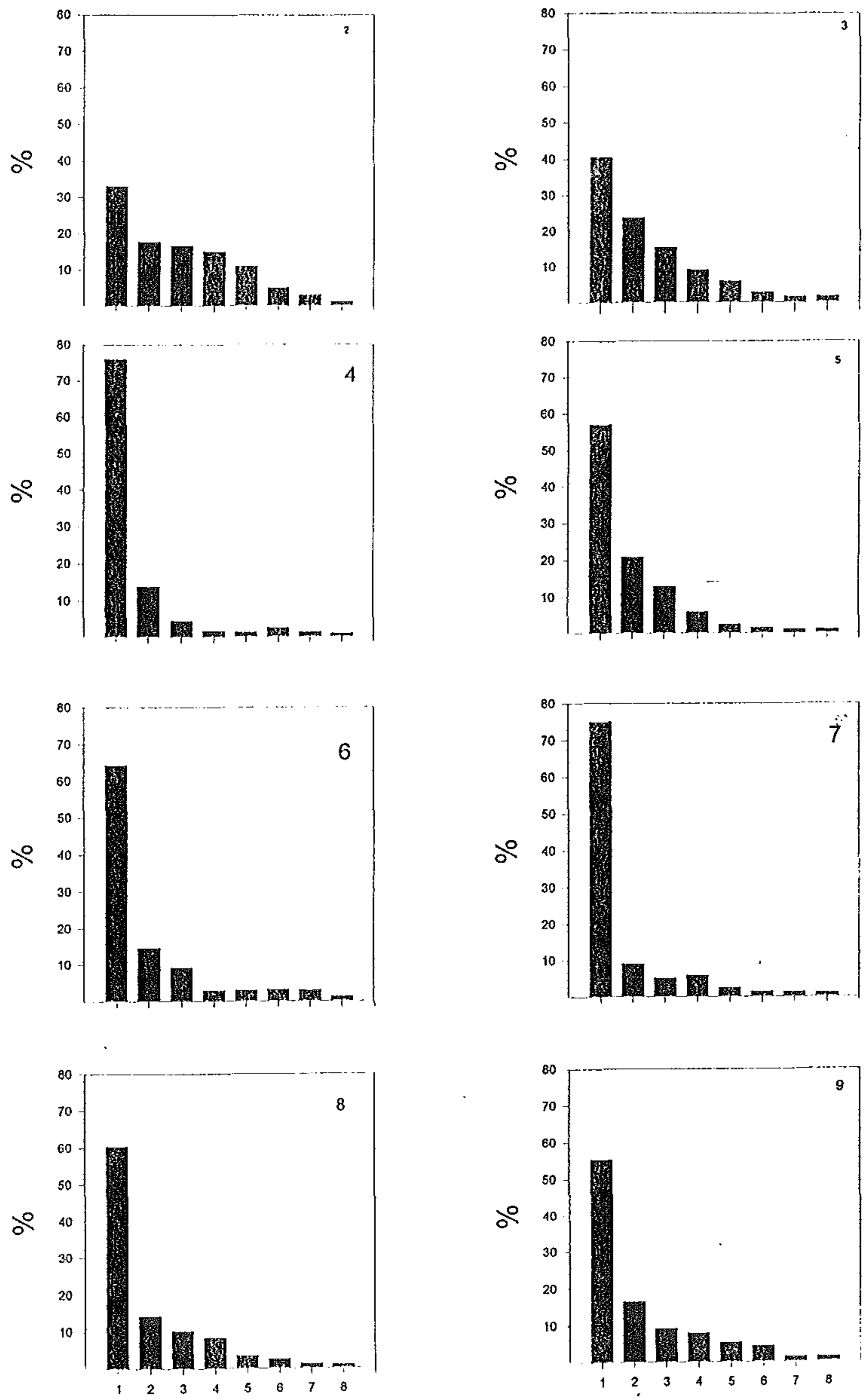

Fig. 6 Frequency distribution of tree numbers in the various height-classes for community types 2-9; class 1= 6-9 m, 2= 9-12m, 3= 12-15m, 4= 15-18 m,5= 18-21 m,6=21-24m,7= 24-27 m, 8= >27 m.

schimperiana, Aningeria adolfi-friederici-Chionanthes mildbraedii, Syzygium guineense, and *Olea welwitschii-Chionanthes mildbraedii* community types fall into the lowest height-classes (6-9, 9-12 m). The percentage of trees having heights between 9 and 12 m in *Manilikara butugi-Coffea arabica* and *Syzygium guineense-Maytenus gracilipes* community types is 50.3 and 64 respectively. In all community types more than 95 % of the trees attain heights below 24 m. The proportion of trees that reach height of 27 m and more are slightly higher than 1 % in *Syzygium guineense-Maytenus gracilipes, Allophylus abyssinicus-Justicia schimperiana* and *Olea welwitschii-Chionanthes mildbraedii* community types while this value is <1 % in *Manilikara butugi-Coffea arabica, Ilex mitis-Galiniera saxifraga, Celtis africana-Dracaena afromontana, Aningeria adolfi-friederici-Chionanthes mildbraedii* and *Syzygium guineense* community types.

The distribution of forest trees in the diameter- and height-classes shows more or less similar trends in all community types. However, in *Ilex mitis-Galiniera saxifraga* and *Syzygium guineense* community types there are more individuals in the highest diameter-class than there are in the highest height-class. This is due to the nature of some of the trees which are abundant in these community types. *Schefflera abyssinica*, for example, has diameter reaching upto 250 cm but its height never reached 25 m.

In *Manilikara butugi-Coffea arabica* community type the number of trees falling in the lowest dimeter- and height-classes are very few compared to the other types. This type is from a coffee producing area in southwestern Ethiopia (*i.e.* Sheko district). The forest in this region is usually called "coffee forest" because *Coffea arabica* is the natural component of the forest. The peasants have removed most of the lower storey trees and shrubs in favour of the growth of coffee bushes. The field layer has also been partly removed. This selective removal has resulted in relatively fewer number of trees in the lowest diameter-and height-classes.

Celtis africana-Dracaena afromontana is from a coffee producing area of Illubabor. In most parts of the forest where this type is represented, clearance of undergrowth plant for the purpose of new coffee plantation as well as to encourage the growth and fruiting of already established coffee plants is common. This forest is in a stage of secondary development but the effect of human interference might affect the succession of the community and there by retarding the forest from reaching to an advanced stage.

The relatively low number of trees in the >80 cm diameter-classes in *Syzygium guineense-Maytenus gracilipes* community type is the result of selective cutting of trees, especially *Syzygium guineense* and *Prunus africana* for timber production. This community type is perhaps in a stage of secondary development as most of the saplings and seedlings are species of the canopy and subcanopy trees.

The higher proportion of trees in *Ilex mitis-Galiniera saxifraga* type in the lowest height-class is due to the abundance of *Cyathea manniana*. The effect of human interference in this type is less severe. An all-weather road was constructed only very recently passing through the area and there is no sawmill in the region. As a result, the structure of the community type is not modified by human activity. This type is probably from the forest which is in advanced stage of development.

Selective cutting of trees from *Aningeria adolfi-friederici-Chionanthes mildbraedii* community type is very common. *Aningeria adolfi-friederici* is a valuable timber tree and its removal from this type and from other types where this species is represented is not accidental. Logs of this tree species which were prepared for loading were encountered in many places in the forest area.

Syzygium guineense and *Olea welwitschii-Chionanthes mildbraedii* community types have basically the same structure. Different degree of exploitation has taken place in the *Syzygium* and *Olea* forests of southwestern Ethiopia. *Syzygium guineense* is particularly a valuable timber tree. The distribution of small, medium, and large sized individuals indicates that *Syzygium* and *Olea* forests are in a late stage of development.

5.4.4 Epiphytes

Epiphytes are mechanically dependent plants which have solved their light requirement problems by growing on the branches or trunks of trees. They are characteristic elements in the structure of a forest.

The epiphytic plants recorded in this study could be grouped into two: non vascular epiphytes (mosses and lichens) and vascular epiphytes (ferns and spermatophytes). No attempt has been made to identify the non vascular epiphytes to any level of taxonomic position. The vascular epiphytes have been identified to the species level except for one species which has been identified to the genus level (see Appendix 2). The percentage of trees with epiphytes is presented in Table 7.

Table 7. Percentage of trees with epiphytes in the nine community types

Community type	Mosses	Lichens	Ferns	Spermatophytes
1 *Arundinaria alpina*	98.0	96.2	-	-
2 *Manilikara butugi-Coffea arabica*	92.5	98.1	19.4	15.9
3 *Syzygium guineense-Maytenus gracilipes*	98.9	48.2	22.0	-
4 *Ilex mitis-Galiniera saxifraga*	94.8	44.2	71.5	3.2
5 *Celtis africana-Dracaena afromontana*	92.3	58.9	5.8	<1
6 *Allophylus abyssinicus-Justicia schimperiana*	92.2	30.5	59.1	14.0
7 *Aningeria adolfi-friederici-Chionanthes mildbraedii*	98.2	69.6	24.7	9.3
8 *Syzygium guineense*	99.6	75.6	20.6	20.4
9 *Olea welwitschii-Chionanthes mildbraedii*	99.3	87.7	41.9	11.0

In *Arundinaria alpina* community type the epiphytes are mosses and lichens. More than 95% of the bamboo trees harbour these epiphytes. Vascular epiphytes are absent in this type. The bamboo culms have smooth hard surfaces and their colonization by vascular epiphytes is hardly possible.

In *Manilikara butugi-Coffea arabica* community type both vascular and non vascular epiphytes are present. Over 90% of the trees bore epiphytic mosses and lichens, while less than 20% of the trees bore epiphytic ferns and spermatophytes.

In *Syzygium guineense-Maytenus gracilipes* community type the most abundant epiphytes are mosses which grew on more than 98% of the trees. Epiphytic lichens and ferns grew on 48.2% and 22% of the trees respectively. There are no epiphytic spermatophytes in this community type.

In *Ilex mitis-Galiniera saxifraga* community type over 94% of the trees bore epiphytic mosses, 71.5% bore epiphytic ferns, 44.2% bore epiphytic lichens and only 3.2% bore epiphytic spermatophytes.

In *Celtis africana-Dracaena afromontana* community type 92% of the trees support epiphytic mosses. 58.9% of the trees bore epiphytic lichens, 5.8% epiphytic ferns and <1% of the trees bore epiphytic spermatophytes.

In *Allophylus abyssinicus-Justicia schimperiana* community type 92.2% of the trees bore epiphytic mosses, 30.5% epiphytic lichens, 59.1% epiphytic ferns, and 14% epiphytic spermatophytes.

The most abundant epiphytes in *Aningeria adolfi-friederici-Chionanthes mildbraedii* type are mosses, which are supported by more than 98% of the trees. 69.6%, 24.7%. 9.3% of the trees bore epiphytic lichens, ferns, and spermatophytes respectively. The fractions of trees with epiphytic mosses, lichens, ferns, and spermatophytes in *Syzygium guineense* type are 99.6%, 75.6%, 20.6%, and 20.4% respectively.

In *Olea welwitschii-Chionanthes mildbraedii* type the proportion of trees with epiphytic mosses is close to 100%. The next abundant epiphytes are lichens (>87%), followed by ferns (>41%), and spermatophytes are the list abundant (11%).

From the above description it can be concluded that mosses are the most abundant epiphytes in all community types followed by lichens, then ferns and spermatophytes are the least abundant epiphytes. The presence of both vascular and non vascular epiphytes in the forests of the study area is due to its moist climate. Local abundance in the richness and abundance of the epiphytic flora are related to climatic factors (Richards, 1964). The highest proportion of trees with epiphytic lichens in *Manilikara butugi-Coffea arabica* type compared to the other types is due to the openness of the canopy which allowed light to reach the interior of the forest as lichens are sun-loving epiphytes (Richards, 1964).

In addition to live trees, fallen logs also support epiphytic growth. Epiphytic mosses are particularly abundant on fallen logs. The fern *Drynaria volkensii* and many orchids usually prefer to grow at crown base of large old trees. The large amount of humus accumulated at crown base from the decomposition of organic matter coming from above is probably responsible for the abundance of such epiphytes.

5.4.5 Leaf size

The leaf size spectra of the plant community types of southwestern Ethiopian forests are generally the same. Nanophylls (25-225 mm^2), microphylls (225-2025 mm^2), notophylls (2025-4500 mm^2), mesophylls (4500-18,225 mm^2), macrophylls (18,225-

164,025 mm^2), and megaphylls ($>$164,025 mm^2) are the leaf size classes represented in most of the community types (Fig.6).

The predominant leaf size class in all community types is mesophyll; over 50% of the tree species in each community type fall into this category. The remaining size classes are shared by not more than 20% of the species. Less than 6% of the species in each community type have nanophyllous and megaphyllous leaves.

In Manilikara butugi-Coffea arabica, Ilex mitis-Galiniera saxifraga and *Syzygium guineense* community types, there are more macrophylls than microphylls and notophylls. In *Syzygium guinense-Maytenus gracilipes* and *Olea welwitschii-Chionanthes mildbraedii* types the number of species that have macrophyllous and notophyllous leaves are equal and there are more of such leaf sizes than microphylls. There are equal number of species with microphyllous, notophyllous, and macrophyllous leaves in *Celtis africana-Dracaena afromontana* type. Megaphylls and nanophylls are absent in *Aningeria adolfi-freiderci-Chionanthes mildbraedii* type and there are equal number of microphylls, and marophylls. There are more notophylls than microphylls and macrophylls in *Allophylus abyssinicus-Justicia schimperiana* type. Only mesophylls are present in *Arundinaria alpina* community type.

In tropical forests, leaf characteristics are known tom vary with latitude, altitude, soil fertility, amount of rainfall and the distribution of rainfall over the year (Webb, 1968). On a local scale leaf characteristics vary with the spectral and temporal distribution of the constituent species, the height in the forest, light availability, and leaf age (Bongers and Poma, 1988). In general, leaf size in tropical forests is negatively related to latitude and altitude, and positively to annual rainfall (Webb, 1968).

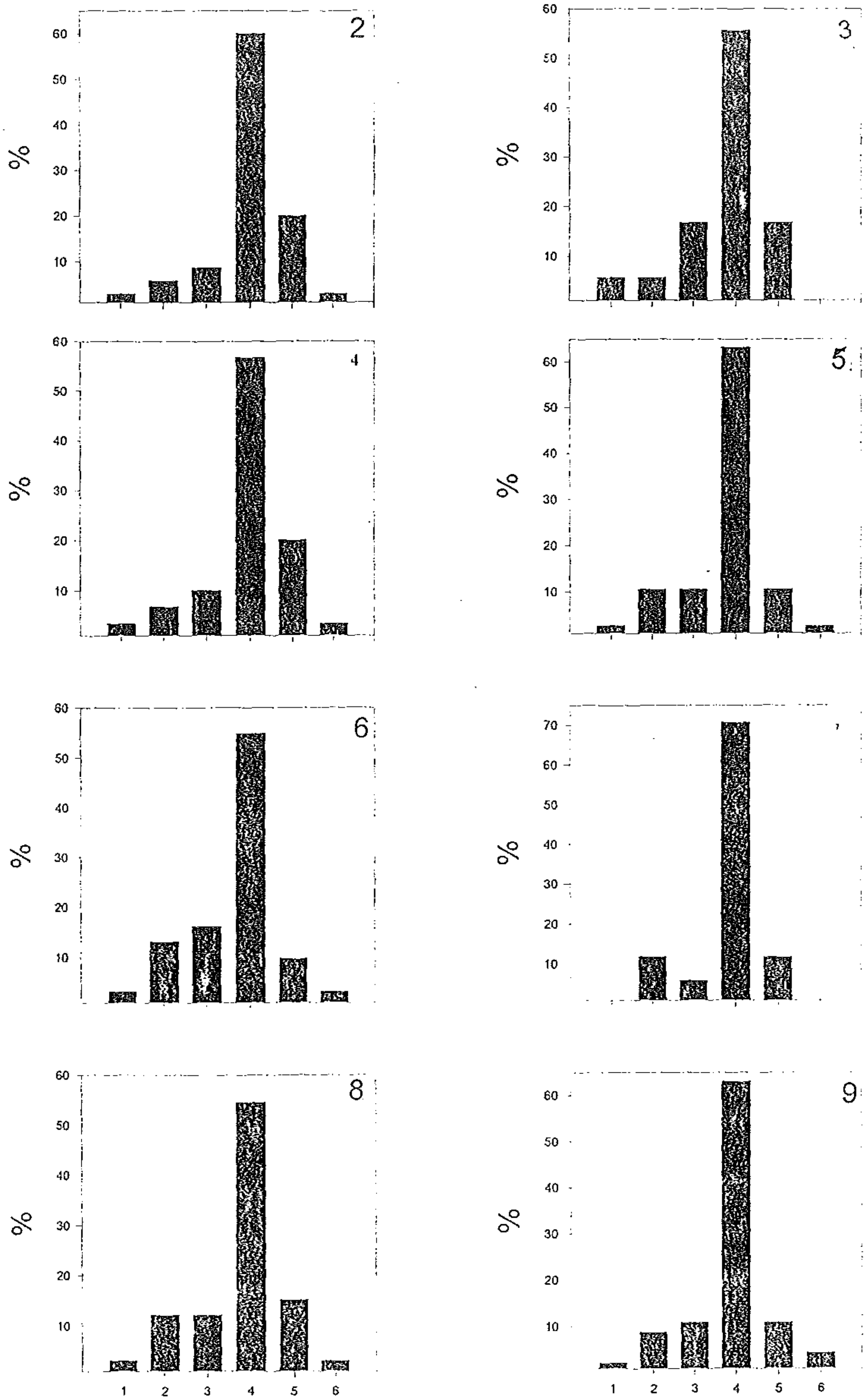

Fig. 6: Leaf size spectra of tree species for community types 2-9; 1= nanophyll, 2= microphylll, 3= notophyll 4= mesophyll, 5= macrophyl, 6= megaphyll

6 CONCLUSIONS AND RECOMMENDATIONS

Hedberg (1951) recognized three vegetation belts in East African mountains: Montane belt; Ericaceous belt; and Afroalpine belt. The montane belt is divided into three zones: montane forest zone; bamboo zone; and *Hagenia-Hypericum* zone. The Ericaceous and Afroalpine belts are not represented in southwestern Ethiopia, only the montane belt is represented. The montane forest and bamboo zones have been described in this study; the former from Jiren, yayu, Gebre Dima, Sele-Anderacha, Bonga, and Belete-Gera forests and the latter from Sele-Anderacha forest. The *Hagenia-Hypericum* zone has not been encountered, this is because the altitudinal range covered in this study is below the lower limit of *Hagenia-Hypericum* zone.

Arundinaria alpina and *Ilex mits-Galiniera saxifraga* community types are from Sele-Anderacha forest. This forest is probably the list exploited forest in southwestern Ethiopia. The forest developed under higher annual precipitation, lower annual temperature and where human interference is less severe. Sele-Anderacha forest occupies the highest altitude,*i.e.* up to > 2500 m. The forest soil is loamy sand in texture, strongly acidic, with higher amount of organic matter and total nitrogen and lower exchangeable bases. Soil erosion is not a problem since the soils are under forest cover with gentle slope. Logging was not much evident but the newly constructed Gore-Tepi all-weather road has opened access to the forest by motor vehicle and timber cutting is becoming common.

Manilikara butugi-Coffea arabica community type is from Sheko forest. The forest developed on an escarpment and on clay loam soil with slightly acidic pH and slightly higher organic matter, total nitrogen, exchangeable bases and lower cation exchange capacity. Human interference is severe in this forest. The whole forest has been manipulated by the farmers and many trees and shrubs have been removed. Logging activity has taken place for many years and most of the logs are transported to Jimma and Addis Ababa.

Jiren forest, where *Syzygium guineense-Maytenus gracilipes* community type is represented, is probably a remnant of a previously large area of forest. The texture of the soil is sandy loam, the pH being slightly acidic, and with higher organic matter, total nitrogen, exchangeable bases and cation exchange capacity. Logging, although now prohibited, was intense before. Many parts of the forest are now devoid of larger trees and forest pioneer species have been established in these parts. If the forest remains untouched, it may rehabilitate itself. Large areas of this forest have been planted with exotic coniferous species and a considerable area of the forest was being prepared for further plantations when this study was conducted.

Celtis africana-Dracaena afromontana community type is from Yayu forest. This forest has been heavily manipulated by man. Large scale deforestation due to shifting cultivation, for new coffee plantation, and for human settlement has taken place. Many people have settled here from the northern parts of Ethiopia after the 1985 draught and a large area of forested land was cleared for settlement. It is common to see a previously forested land now converted to an agricultural land in many places in

Yayu forest. *Acacia abyssinica* woodland, perhaps a seral stage in the regrowth of forest, has developed on some areas where cultivation was abandoned for some time. The texture of the forest soil is sandy clay loam, its pH being slightly acidic, with moderate amount of organic matter and total nitrogen and higher exchangeable bases.

Gebre Dima forest, where *Allophylus abyssinicus-Justicia schimperiana* community type is represented, has suffered from logging activities. Intensive cutting of *Aningeria adolfi-friederici* trees has taken place both in this forest and in Belete-Gera forest for long time. Unless some practical steps are taken to ban logging of such tree, complete removal of this species is likely to occur. When this investigation was carried out in Gebre Dima forest, part of the forest along the main road was being deforested in order to plant exotic species (*Eucalyptus* and conifers). While plantation of such species on degraded land is to be encouraged, replacement of hardwoods with softwoods is not beneficial from an ecological point of view.

Olea welwitschii-Chionanthes mildbraedii community type is represented both in Belete-Gera and Bonga forests. *Syzygium guineense* and *Aningeria adolfi-friederici-Chionanthes mildbraedii* community types were represented from Belete-Gera forest. Logging activity was previously extensive in Belete-Gera forest, the species most widely used for timber was *Aningeria adolfi-friederici*. At present such activity is much reduced and since the local people that were settling in the forest area were transferred to outside the forest, tree cutting for local purpose is also reduced. Plantation of *Eucalyptus* and conifers occupied large area in Belete-Gera forest. Tree cutting is mostly restricted to this plantation.

In Bonga forest widespread deforestation for cultivation of annual crops and for plantation of perennial crops such as tea has resulted the forested land to reduce in size. Remnant trees of *Olea welwitschii* and *Sapium ellipticum* can be seen in farmlands in many places around the forested area. Large area has also been deforested for *Eucalyptus* plantation by the Wush Wush tea plantation. The *Olea* forest in Bonga is the natural home for *Coffea arabica,* and the spice *Aframomum korarima*, therefore, its management is very essential for the conservation of the gene pool of such economically important plants. The *Olea* forest in Belete-Gera is better managed than the *Olea* forest in Bonga.

Forests regulate microclimate, protect water resources, provide forest products and are homes to plant and animal species. From the foregoing discussion, it can be seen that the forest vegetation of southwestern Ethiopia requires better management so that the forest resources could be effectively utilized on a sustainable basis. Therefore, the following recommendations are made to meet this requirement:

-Creating awareness by the public about the various uses of forest coverage so that they will be refrained from unwisely exploiting the forest resources.

-The expansion of cultivated land in southwestern Ethiopia is at the expense of the forest. Therefore, the farmers should depend much on coffee plantation than on cultivating cereals.

-Tree planting in the form of agroforestry should be encouraged.

-Extension services should be extended to include forest management.

-Timber cutting from the forests of Gebre Dima should be abandoned.

-The plywood and other factories which use forest trees as raw materials should look for alternative trees. The plantation of *Eucalyptus* trees in areas far from forests could be a solution.

-Forested land should not be given for investors for large scale plantation of perennial crops.

-Any forest planning and development activities should include the active participation of local communities. These communities should be benefit sharing so that they will develop sense of individual responsibility. It should be known at the outset that environmentally sound development plans and activities will not succeed without the full participation of the public.

The planning and management of forests should be based on research works and therefore basic research on various aspect of forest ecology should be encouraged. I hope that this little work contributes to the understanding of the phytosociology and ecology of the forest vegetation of southwestern Ethiopia and stimulates further research on this largest remaining forest of the country.

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Appendix 1. Species collected from the tree tree, shrub, and field layers of southwestern Ethiopian forest. T = Tree; T/S = Tree or Shrub; S = Shrub; H = Herb; T/B = Bamboo tree; H/G = Graminoid herb. Five specimens (4 herbs and 1 tree) were not identified.

ACANTHACEAE	
Acanthus eminens C.B. Clarke	S
Brillantaisia madagascariensis And. ex Lindau.	H
Dicliptera laxata C.B. Clarke	H
Hypoestes forskalei (Vahl) Soland ex Roem. & Schult.	H
Isoglossa spp.	H
Justicia schimperiana (Hochst. ex Nees) T. Anders	S
Phaulopsis imbricata (Forsk.) Sweet	H
Rungia grandis T. Anders	H
AGAVACEAE	
Dracaena afromontana Mildbr.	T/S
Dracaena fragrans (L.)Ker-Gawler	S
Dracaena steudneri Engl.	T
AMARANTHACEAE	
Achyranthes aspera L.	H
AMARYLLIDACEAE	
Scadoxus multiforus (Martyn) Raf.	H
APIACEAE	
Sanicula elata Ham. ex Don	H
AQUIFOLIACEAE	
Ilex mitis (L.) Radlk.	T

ARALIACEAE	
Polyscias fulva (Hiern) Harms	T
Schefflera abyssinica (Hochst. ex A.Rich.) Harms	T
Schefflera volkensii (Engl.) Harms	T
ARECACEAE	
Phoenix reclinata Jacq.	T
ASPIDACEAE	
Tectaria gemmifera (Feè) Alston	H
ASPLENIACEAE	
Asplenium hypomelas kuhn	H
Asplenium lunulatum Sw.	H
Asplenium sandersonii Hook.	H
ASTERACEA	
Crassocephalum montuosum (S.Moore) Milne-Redhead	H
Solanecio mannii (Hook. f.) C. Jeffrey	S
Vernonia amygdalina Del.	T
BALSAMINACEAE	
Impatiens hochstetteri warb.	H
BORAGINACEAE	
Cordia afridana Lam.	T
Ehreteia cymosa Thonn.	T
CAPARIDACEAE	
Ritchiea albersii Gilg.	T
CARYOPHILACEAE	
Drymaria cordata (L.) Roem. & Schultes	H
Stellaria mannii Hook.f.	H

CELASTERACEAE

Maytenus addat (Loes.) Sebsebe	T
Maytenus arbutifolia (A.Rich.) Wilczek	T/S
Maytenus gracilipes (Welw. ex Oliv.) Exell	S
Maytenus obscura (A. Rich.) Cufod.	S

CLAUSIACEAE

Garcinia buchananii Bak.	T

COMMELINACEAE

Aneilema beninense (P.Beauv) Kunth	H
Commelina latifolia Hochst. ex A.Rich	H

CYATHACEAE

Cyathea manniana Hook.	T

EBENACEAE

Diospyros abyssinica (Hiern) F.White	T

EUPHORBIACEAE

Acalypha psilostachya Hochst. ex A.rich	S
Alchornea laxiflora (Benth.) Pax & Hoffm.	T/S
Argomuellera macrophylla Pax	S
Croton macrostachyus Del.	T
Erythrococca trichogyne (Muell. Arg.) Prain	S
Euphorbia ampliphylla Pax	T
Macaranga capensis var. kilimandscharica (pax) Friis & Gilbert	T
Phyllanthus fischeri Pax	H
Phyllanthus limmuensis Cufod.	S
Sapium ellipticum (Hochst. ex Krauss.) Pax	T

FABACEAE

Albizia grandibracteata Taub. T

Albizia gummifera (J.F.Gmel.) C.A. Smith T

Calpurnia aurea (Ait.) Benth. S

Desmodium repandum (Vahl) Dc. H

Millettia ferruginea (Hochst.) Bak T

FLACOURTACEAE

Oncoba routledgei Sprague T

HEMIONITIDACEAE

Coniogramme africana Hieron H

ICACINACEAE

Apodytes dimidiata E.Mey.ex Arn. T

LAMIACEAE

Achyrospermum schimperi (Hochst. ex Briq.) Perkins H

LAURACEAE

Ocotea kenyensis (Chiov.) Robyns & Wolczik T

LOGANIACEAE

Strychnos mitis S.Moore T

MARRATIACEAE

Marattia fraxinea Sm. H

MELATOSTEMATACEAE

Triestemma mauritanum J.f.Gmelin H

MELIACEAE

Ekebergia capensis Sparrm. T

Lepidotrichilia volkensii (Gürke) Leroy T

Trichilia dregeana Sond. T

Turraea holstii Gürke	S
MELIANTHACEAE	
Bersama abyssinica Fresen.	T/S
MORACEAE	
Antiaris toxicara Lesch.	T
Dorstenia sorensenii Friis	H
Ficus exasperata Vahl	T
Ficus ovata Vahl	T
Ficus sur Forssk.	T
Ficus thonningii Blume	T
Ficus vallis-choudae Del.	T
Ficus vasta Forssk.	T
Morus mesozygia Stapf	T
Trilepisium madagascariense Dc.	T
MYRSINACEAE	
Maesa lanceolata Forssk.	T/S
Myrsine africana L.	S
MYRTACEAE	
Syzygium guineense (Willd.) Dc.	T
OLEACEAE	
Chionanthus mildbraedii (Gilg & Schellenb.) Stearn	T/S
Olea hochstetteri Bak.	T
Olea welwitschii (Knobl.) Gilg. & Schellenb.	T
PIPERACEAE	
Piper capense Linn.f	H

PITTOSPORACEAE	
Pittosporum virdiflorum Sims.	T
POACEAE	
Arundinaria alpina K.Schum.	T/B
Leptaspsis zeylanica Nees ex steud.	H/G
Olyra latifolia L.	H/G
Oplismenus compositus (L.) P.Beauv.	H/G
Poecilostachys oplismenoides (Hack.) W.D.Clayton	H/G
Pseudechinolaena polystachya (Kunth) Stapf	H/G
Setarium megaphylla (Steud.) Th.Dur. & Schinz	H/G
POLYPODACEAE	
Asplenium bugoiense Hieron.	H
PTERIDACEAE	
Pteris dentata Forssk.	H
Pteris pteridioides (Hook.) Ballard	H
RANUNCULACEAE	
Thalictrum rhynchocarpum Dill. & Rich.	H
RHAMNACEAE	
Rhamnus prinoides L'Hérit.	S
RHIZOPHORACEAE	
Cassipourea malosana (Baker) Alston	T
ROSACEAE	
Alchemilla fischeri Engl.	H
Prunus africana (Hook.f.) Kalkm.	T

RUBIACEAE	
Canthium oligocarpum Hiern	T
Coffea arabica L.	S
Galiniera saxifraga (Hochst.) Bridson	T/S
Hallea rubrostipulata (K.Schum.) J.F.Leroy	T
Oxyanthus speciosus Dc.	T/S
Psychotria orophila Petit	T/S
Rothmannia urcellioformis (Hiern) Robyns	T
Rytigynia neglecta (Hiern) Robyns	S
Vangueria apiculata K.Schum.	T/S
RUTACEAE	
Clausena anisata (Willd.) Benth	T/S
Fagaropsis angolensis (Engl.) Dale	T
Teclea nobilis Del.	T/S
Vepris daniellii (Pichi-Sermolli) Kokwaro	T/S
SAPINDACEAE	
Allophylus abyssinicus (Hochst.) Radlk.	T
Blighia unijugata Bak.	T
Deinbollia kilimandscharica Taub.	T/S
SAPOTACEAE	
Aningeria adolfi-friederici (Engl.) Robyns & Gilbert	T
Aningeria altissima (A.Chev.) Aubrev. & Pellegr.	T
Manilikara butugi Chiov.	T
Mimusops kummel Bruce ex Dc.	T
SIMARUBIACEAE	
Brucea antidysentrica J.F.Miller	S

STERCULIACEA	
Dombeya torrida (J.F.Gmel) P.Bamps.	T
THELYPTERIDACEAE	
Thelypteris longicuspis (Bak.) Schelpe	H
ULMACEAE	
Celtis africana Burm.f.	T
Celtis philippensis Blanco	T/S
Celtis zenkeri Engl.	T
URTICACEAE	
Droguetia iners (Forssk.) Schweinf.	H
Elatostemma monticolum Hook.f.	H
Laportea alatupes Hook.f.	H
Pilea bambuseti Engl.	H
VERBENACEAE	
Premna schimperi Engl.	S
ZINGEBERACEAE	
Aframomum korrarima (Per.) Engler	H
Aframomum polyanthus (K.Schum.) K.Schum.	H

Appendix 2. Species list of vascular epiphytes recorded from the forest vegetation of Southwestern Ethiopia

ADIANTHACEAE

Vittaria guineensis Des.

AMARYLLIDACEAE

Scadoxus nutans (Friis & Bjornst.) Friis & Nordal

ASPLENIACEAE

Asplenium sandersonii Hook.

CAMPONVIACEAE

Canaria eminii Aschers ex Schweinf

LYCOPODIACEAE

Lycopodium dacrydioides Bak.

OLEANDRACEAE

Arthropteris monocarpa (Cord.) C.Chr.

ORCHIDACEAE

Aerangis spp

Diaphanthe adoxa Rasm.

Polystachya bennettiana Rehb.f.

Polystachya cultriformis (Thouars) Spreng.

PIPERACEAE

Peperomia abyssinica Miq.

Peperomia tetraphylla (Forster) Hook. & Arn.

POLYPODIACEAE

Drynaria volkensii Hieron

Loxogramme lanceolata (Sw.) S.Presl.

Microsorium scolopendrium (Burm.f.) copel

Appendix 3. Species list of woody climbers (lianas) recorded from the forest vegetation of southwestern Ethiopia

APOCYNACEAE

Landolphia buchananii (Hall.f.) Stapf.

ARACEAE

Culcasia palcifolia Engl.

CELASTERACEAE/HIPPOCRATEACEAE

Hippocratea africana (Willd.) Loes.

Hippocratea goetzei Loes.

COMBRETACEAE

Combretum paniculatum Vent.

MENISPERMACEAE

Tiliacora troupinni Cuffod.

MYRSINACEAE

Embelia schimperi Vatke

OLEACEAE

Jasminium abyssinicum Hochst. ex Dc.

PHYTOLACCACEAE

Phytolacca dodecandra L'Hèrit

RANUNCULACEAE

Climatis longicauda Steud. ex A.Rich.

RHAMNACEAE

Gouania longispicata Engl.

URTICACACEAE

Urera hypselodendron (A.Rich) Wedd.