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PLANT BIOLOGY AND BIODIVERSITY MANAGEMENT PROGRAM UNIT

**FLORISTIC COMPOSITION, DIVERSITY AND STRUCTURE OF WOODY PLANT
SPECIES IN MENAGESHA SUBA STATE FOREST, CENTRAL ETHIOPIA**

By

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**Floristic Composition, Diversity and Structure of Woody Plant Species in Menagesha Suba
State Forest, Central Ethiopia**

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**A Thesis submitted to the School of Graduate Studies of Addis Ababa University in Partial
Fulfillment of the Requirements for the Degree of Master of Science in Biology (Plant
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ACRONYMS

BMNP ----- Bale Mountains National Park

DBH Diameter at Breast Height

NMA National Meteorological Agency

EPA Environmental Protection Authority

FAO Food and Agricultural Organization of the United Nations

IBCR Institute of Biological Conservation and Research

IVI Important Value Index

SFCDD..... State Forest Conservation and Development Department

SMNP..... Semien Mountains National Park

UNDP..... United Nations Development Programme

UNEP..... United Nations Environmental Programme

UNESCO United Nations Education, Science and Culture organization

ABSTRACT: The study presents analysis of woody plant diversity and structure of Menagesha Suba Forest, in Central Highlands of Ethiopia. Seventy five quadrats each 20 m X 20 m were laid out along three line transects in Menagesha Suba State Forest to collect vegetation data. A total of 112 woody plant species, representing 84 genera and 51 families were recorded. The Family Fabaceae with 12 species had the highest number of species followed by Asteraceae, with 8 species, and Rosaceae, Euphorbiaceae, Flacourtiaceae and Oleaceae with 5 species each. The forest had the Shannon- Wiener diversity index of 2.57 and evenness of 0.92. Six community types were recognized from the hierarchical cluster analysis of polythetic divisive TWIINSPAN output: *Dovyalis verrucosa* - *Maytenus arbutifolia*, *Dovyalis verrucosa* - *Sideroxylon oxyacanthum*, *Dovyalis abyssinica* - *Myrsine africana*, *Myrsine melanophloeos* - *Landolphia buchananii*, *Myrsine africana* - *Olea europaea* subsp. *cuspidata* and *Juniperus procera* - *Ficus sur*. A floristic comparison of Menagesha Suba State Forest with other related forests in Ethiopia revealed relatively high floristic similarity. The analysis of the diameter at breast height distribution shows normal inverted J-shaped pattern. The five most dominant tree species of Menagesha Suba State Forest occupied 41.77% of total important value index. By recognizing the significance of Menagesha Suba State Forest, recommendation is made to improve the protection and conservation status of the forest, through modern joint forest management approaches and sustainable utilization.

Key Words: *Biodiversity, Dry Evergreen Afromontane Forests, Menagesha Suba State Forest, Woody Plant Diversity, Plant Community*

1. INTRODUCTION

1.1. Background of the Study

The term biodiversity reflects the number, variety and variability of living organisms. It includes diversity within species (genetic diversity), between species (species diversity), and between ecosystems (ecosystem diversity). Biodiversity also incorporates human cultural diversity, which can be affected by the same drivers as biodiversity, and which has impacts on the diversity of genes, other species and ecosystems (Whittaker, 1975; Niles, 2009). The concept also covers how this diversity changes from one location to another and over time and space. Indicators such as the number of species in a given area can help in monitoring certain aspects of biodiversity.

Plant biodiversity is one of the major groups of biological diversity. Plant diversity can be affected by different biotic and abiotic factors. The plant communities and their component species are exposed to changes in the environmental, physical, biological, technological, economic or social factors (Frankel *et al.*, 1995). Globally, patterns of plant species diversity are influenced by latitudinal, altitudinal and soil gradients (Whittaker, 1975). Locally in mountainous ecosystems at high rate of change in altitude, slope and moisture gradients, temperature, rainfall and drainage, the diversity of plants may also change within a short distance (Lovett, 1990). The other factors that highly influence plant diversity are human beings, as destructive factor (Ababu Anage, 2009). So, the fate of plant communities in a given area can be determined by these and other different factors. In this case, diversity and distribution patterns of species must be studied to clarify the plant diversity in certain area and to determine major factors influencing the diversity.

Ethiopia has great biodiversity resources due to the diversity in physical features, climatic types, topography, habitat, vegetation types and fauna (Friis *et al.*, 2010). The Forest resources once covered most of the landmass of the country, but these days clearing of land for agricultural expansion and the cutting of trees for fuel with all other factors diminished the closed Forest cover of Ethiopia to less than 3 per cent (EPA, 1998), which is almost restricted in distribution to the inaccessible areas of southern and southwestern highlands of Ethiopia (UNESCO, 2003; Ababu Anage, 2009).

The Forest resource of the country is under serious threat from deforestation, Forest fire, land degradation, overexploitation, overgrazing, shifting cultivation, habitat loss and invasive species (Friis, 1992; EPA, 1997). As a result of these threats, the trend in the conservation status of biodiversity is declining by alarming rate.

The montane Forests are specifically highly disturbed by wind throws, natural and human-made fires, landslides, grazing, tree felling and clearing for cultivation (Demel Teketay, 2005). Menagesha Suba State Forest, which is one of the few remaining Forests in central Ethiopia, has received long years of attention and protection, which goes back to the 1600s (Sebsebe Demissew, 1980; 1988; Demel Teketay, 2004; Abate Zewdie, 2007). Some report indicated that Menagesha Suba State Forest is highly subjected to exploitation by local community around the Forest (Sebsebe Demissew, 1988; Abate Zewdie, 2007; Abebe Haile *et al.*, 2009; Mulugeta Lemenih, 2009), this includes non-timber Forest products (NTFPs) for home consumption and for markets (Abebe Haile *et al.*, 2009; Mulugeta Lemenih, 2009). The present trend of management needs improvement depending on scientific data or information for the remaining Forest resources and to minimize uncontrolled exploitation and restrict the conversion of Forest

into agricultural land and substitution by the exotic species. Otherwise, the small ruminants of natural Forest left will be gone in the very near future.

1.2. Statement of the problem

Menagesha Suba State Forest is one of the few accessible remaining patches of Dry Evergreen Afromontane Forest in the central highlands of Ethiopia. Emperor Zera Yacob (1434-1468), designated the Wochacha Forest as one of the 'Crown Forestlands' of the country. He arranged for the area to be planted with seedlings of the giant *Juniperus* trees and some other species (von Breitenbach, 1962).

Sebsebe Demissew (1980; 1988) and comparative floristic study by Abate Zewdie (2007) made a study of Menagesha Suba State Forest. Since in both cases only the general floristic composition were studied, detailed study of specifically woody species diversity is very essential. The base line data of woody species should be useful for the management and sustainable utilization of the Forest resources of the area. Therefore, species documentation, classification and description of the Forest have to be a continuous exercise.

2. OBJECTIVES OF THE STUDY

2.1. General objective

- To assess the floristic composition, species diversity and structure of the woody plant species of the vegetation of Menagesha Suba State Forest.

2.2. Specific objectives

- To analyze the woody plant species composition of the Forest including the woody climbers.
- To classify the Forest vegetation in to plant community types.
- To make floristic comparison of the Forest with other similar Forests in the country
- To analyze the structure of the Forest

3. LITERATURE REVIEW

3.1. Floristic diversity of Ethiopia

Ethiopia has a large natural and cultural diversity with a wide range of climate, which results from its topography and latitudinal position. Ethiopia has diverse vegetation types in which diverse flora and fauna exist.

The great plains of Ethiopia occur on top of massive highland plateaus like slopes of the Semien Mountains National Park (SMNP), Bale Mountains National Park (BMNP) and other mountain ranges, where as the lowlands are dividing the highlands and the whole country into two unequal halves by the Great Rift Valley. Many of these mountain ranges reach over 4000 m a.s.l. and are home to numerous endemic species of flora and fauna (Friis, 1992; EPA, 1998; Demel Teketay, 2004; Friis *et al.*, 2010).

The differences in altitude and latitude have resulted in a wide variation in climate i.e., rainfall, humidity, temperature and exposure to wind, etc. These differences along with edaphic variations form the basis for the wide biodiversity of the country. This geographical and ecological diversity of Ethiopia, with extraordinary range of terrestrial and aquatic ecosystems, contributed to the high rate of endemism and diversity (Demel Teketay *et al.*, 2004; IBCR, 2009).

The vegetation of the country is very heterogeneous. It varies from semi-desert to Afro-alpine vegetation type (Friis *et al.*, 2010). There are more than 6000 higher plant species in Ethiopia of which about 10 percent are endemic (Vivero *et al.*, 2005). The Forest and woody vegetation resources of Ethiopia were estimated to cover greater than 11.7 percent of the land, of this the woodlands cover about 4.5 percent of the total land of Ethiopia (EPA, 1998).

The woody plant species in the Flora of Ethiopia and Eritrea was estimated to be 1100; out of these about 300 are tree species (Demel Teketay *et al.*, 2000). The vegetation of Ethiopia has a rich endemic element (Tewolde Berhan Gebre Egziabher, 1991). For instance, of the total woody plant species 428 are estimated to be endemic and near endemics. From this, 107 are trees and 321 are shrubs (Vivero *et al.*, 2005).

Most of Ethiopia's population are living in rural areas and depend on natural resources like land, water, Forests and trees for economic development, food security and other basic necessities (Alemneh Dejene, 2003). This implies that the majority of the economic activities and life of most of Ethiopians are either directly or indirectly related to the Forest resources (Demel Teketay, 2001; Kitessa Hundera, 2007). This implies that the services of Forests are unlimited.

3.2. Vegetation types of Ethiopia

Ethiopia endowed with wide range of vegetations. Different Authors studied and described the vegetation types of the country at different time. The recent study indicated that there are twelve major vegetation types in Ethiopia. These major vegetation types include; *Desert and Semi-desert* scrubland Forest; *Acacia - Commiphora* woodland and bushland; *Wooded grassland* of the Western Gambela region; *Combretum - Terminalia* woodland and wooded grassland; Dry Evergreen Afromontane Forest and grassland complex; Moist Evergreen Afromontane Forest and bushland; Transitional rain Forest; Ericaceous belt; Afro-alpine belt; Riverine vegetation; Fresh - water lakes; and Salt Lakes vegetation (Friis *et al.*, 2010).

3.3. Dry Evergreen Afromontane Forests and Grassland Complex Vegetation type

The Ethiopian highlands contribute large coverage of land area with Afromontane vegetation, of which Dry Evergreen Afromontane Forests (DAF) form the largest part. Dry Evergreen Afromontane Forest and Grassland complex vegetation type is complex system of succession with grassland rich in legume shrub and small to large trees to closed Forest with a canopy of several strata. It occurs in an altitudinal range of 1800-3000 m, with average annual temperature and rainfall of 14-25°C and 700-1100 (rarely up to 1700 mm), respectively (Friis, 1992; Friis *et al.*, 2010).

About 460 species, subspecies and varieties of woody plants occur in this vegetation type, from these 128 (27.83%) are reported only from this vegetation type. This indicates that this vegetation type is rich with species composition (Friis *et al.*, 2010).

According to Friis *et al.*, (2010), there are four subtypes recognized. Undifferentiated Afromontane Forest; Dry Single-Dominant Afro-montane Forest of the Ethiopian highlands; Afromontane woodland, wooded grassland and grassland and Transition between Afromontane vegetation and *Acacia- Commiphora* Bushland on the Eastern Escarpments.

Some of the common Dry Evergreen Afromontane Forests studied from highlands and mountain chains of Ethiopia include: Anabe and Denkoro Forest in Wello (Mesfin Tadesse, 1993), Chilimo Forest (38° 10' E and 9° 05' N), 2,400 ha and Wof-Washa Forest (39° 45' E and 9° 35' N), 3,600 ha (Tamrat Bekele, 1993); Menagesha Suba State Forest (38° 35' E and 9° 00' N), 2,720 ha (Sebsebe Demissew, 1988).

3.4. Threats on plant biodiversity in Ethiopia

The rich biodiversity of the country is under serious threat from deforestation, land degradation, overexploitation, overgrazing, habitat loss and invasive species (De Vletter, 1991; EPA, 1998; Demel Teketay, 2001).

In most cases, the major destructive factor of plant diversity is deforestation caused by agricultural expansion and fuel wood scavenging (Ababu Anage, 2009). In current situations, Ethiopia is in the track of high investment rate, agro-industry expansion and population migration to a fragile ecosystem like Forests and related resources. However, almost all of these huge activities were done without prior environmental impact assessment. As a result, many virgin and irreplaceable Forests are cleared for different activities like livestock ranches, coffee plantation and tea plantation (Kumilachew Yeshitela, 2001; Yonas Yemishaw, 2001; Getachew Tesfaye and Demel Teketay, 2005).

The other threats to the plant biodiversity of the country are unsustainable utilization of natural resources, Forest fires, land degradation, habitat loss and fragmentation, extensive replacement of farmer's/local varieties/breeds by improved ones, invasive species, wetland destruction and climate change. But all these are related to the root causes of poverty, which are lack of alternative viable livelihoods, increasing population pressure and inadequate awareness of the threats (De Vletter, 1991; EPA, 1998). These different threats are in rapid progress to decline the trend in the conservation status of Ethiopia's plant diversity.

The challenges to conserve and sustainable use of Ethiopia's biodiversity are very complicated and interlinked (Ababu Anage, 2009). Some reports indicated that there are still high rate of

deforestation in Ethiopia beyond any expectations (De Vletter, 1991; EPA, 1997; EPA, 1998; Demel Teketay, 2001; Yonas Yemishaw, 2001; FAO, 2007). So, the plant biodiversity of Ethiopia need better attention to conserve and protect from these losses.

3.5. Diversity Indices

Biological diversity can be quantified in different ways. A diversity index is a mathematical measure of species diversity in a community. The two main factors taken into account when measuring diversity are richness and evenness. A diversity index, must be sensitive to both factors, thus must also be sensitive to the different number of species in two or more communities (Mueller-Dombois and Ellenberg, 1974; Frosini, 2006).

Species richness is a measure of the number of different species in a given site and can be expressed in a mathematical index to compare diversity between sites. A richness index may simply coincide with the number of species present in a community, but may also be a function of the number of all the individuals in the community. The species richness of each community is simply the number of species present with at least one individual in a given area (Mueller-Dombois and Ellenberg, 1974; Frosini, 2006). The index is essential in assessing taxonomic and ecological values of a habitat (Mueller-Dombois and Ellenberg, 1974).

The second factor, evenness, measures a relative abundance of different species making up the richness of the area (Mueller-Dombois and Ellenberg, 1974). According to Frosini (2006), an evenness index is a function of the frequencies or proportions pertaining to the species; such an index increases when the proportions tend to be equal or perfect homogeneity and decreases when one species tend to dominate all the others. The interpretation of evenness is strictly dependent on the richness.

Species diversity is the product of species richness and evenness. Species diversity index provides information about species endemism, rarity and commonness (Frosini, 2006). Diversity indices also provide more information about community composition than simply species richness and relative abundances of different species (Kent and Coker, 1992; Frosini, 2006). The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure. And also measuring diversity has been of historical significance due to the obvious declines in habitat diversity (Frosini, 2006).

Among many species, diversity indices the most widely used were Shannon-Wiener index and Sorenson's index of Similarity (Mueller-Dombois and Ellenberg, 1974).

3.5.1. Shannon- Wiener index of Diversity

It is the most applicable index of diversity (Grieg-Smith, 1983). The Shannon-Wiener diversity index is one that measure what we will use to draw information from samples in the field. It combines two quantifiable measures; the species richness and species equitability. The Shannon Diversity Index (H') is calculated using the following formula.

$$H' = - \sum_{i=1}^S P_i(\ln P_i)$$

Where S = total number of species; P_i = is the proportion of each species (individuals) or the abundance of the i^{th} species expressed as proportion of total cover; and \ln = log base n

High values of Shannon- Wiener diversity index is a representative of more diverse communities (Grieg-Smith, 1983; Kent and Coker, 1992; Frosini, 2006).

Shannon's Equitability (EH) or Evenness is given by

$$EH = H'/H_{\max} = H/\ln S \quad (\text{Kent and Coker, 1992})$$

The value of EH is between 0 and 1 with 1 being complete evenness. If the species are evenly distributed then the H' value would be high. So the H' value allows us to know not only the number of species but how the abundance of the species is distributed among all the species in the community (Frosini, 2006).

3.5.2. Measurement of Similarity and Dissimilarity

Similarity indices measure the degree to which the species composition of quadrats or samples is alike; whereas dissimilarity coefficient assesses which two quadrats or samples differ in composition. Sorenson is the most common binary similarity coefficients because it relies on presence or absence data. The coefficient of Sorenson differs from the other measurements since it gives more weight to species that are present in both quadrats/samples and therefore less weight to species that are present in only one quadrat.

Sorenson's Coefficient is expressed as

$$S_s = 2a / (2a+b+c) \quad (\text{Kent and Coker, 1992})$$

Where a=number of species with common to both quadrats; b= number of species unique to quadrat 1; and c = number of species unique to quadrat 2

Mostly the coefficient is multiplied by 100 to give percentage similarity index.

Dissimilarity is then computed as $Ds = \frac{b+c}{2a+b+c}$ or $1-Ss$ (Kent and Coker, 1992).

3.6. Plant Community type

According to Mueller-Dombois and Ellenberg (1974) and Kent and Coker (1992), vegetation cover of a given area has a definite structure and composition. Therefore, in order to have good mental picture of the vegetation of an area and to understand distribution of species of plant, floristic composition and vegetation structure study are essential. Vegetation characteristics are either derived from plant morphological characters, usually structure or from plant species recognized in area, as floristic composition. Both vegetation structure and floristic composition are usually measured or estimated on the basis of plant community (Mueller-Dombois and Ellenberg, 1974). The description of plant communities involves the analysis of species diversity, evenness and similarity (Kent and Coker, 1992).

The Two-Way Indicator Species Analysis (TWINSpan) is recently widely applied technique for polythetic divisive method in vegetation classification to communities (Goodwall, 1980; Digby and Kempton, 1985; Kent and Coker, 1992). This method divides quadrats on the basis of all the species information. It's used to carry out joint classification of quadrat and species simultaneously.

The TWINSpan method differs fundamentally from the agglomerative techniques in its divisive strategy, and is usually more informative. Generally, advantages of polythetic divisive (TWINSpan) method were, it uses the original vegetation data, rather than secondary matrix; it clusters species and quadrats; it produces and orders data matrix, and it is economical in the use of computer time and store (Goodwall, 1980; Digby and Kempton, 1985; Kent and Coker, 1992).

4. RESEARCH QUESTIONS

- I. What are the components of woody species of the Forest?
- II. What are the major woody communities occurring in the Forest?
- III. What is the pattern of distribution of woody species along environmental gradients?
- IV. What is the conservation status of the woody plant species of Menagesha Suba State Forest?

5. MATERIALS AND METHODS

5.1. Materials

5.1.1. Description of the study area

Menagesha Suba State Forest is one of 58 National Forest Priority Areas (NFPAs) in Ethiopia to ensure essential protection of the natural Forest and the plantation of both exotic and indigenous plants (SFCDD, 1990). It is located in the central part of the country 30 km West of Addis Ababa. It is found between $38^{\circ}31'$ and $38^{\circ}35'$ E and $9^{\circ} 89'$ and $9^{\circ} 00'$ N in Oromia National Regional State (Figure 1). As a part of central plateau covering an altitudinal range of 2200-3385 m a.s.l. (Afework Bekele, 1994). The Forest borders Mount Wochacha to the south, Kolbo Kebele to the north, Wellmera and Sademo town to the west and Gefersa town to the east.

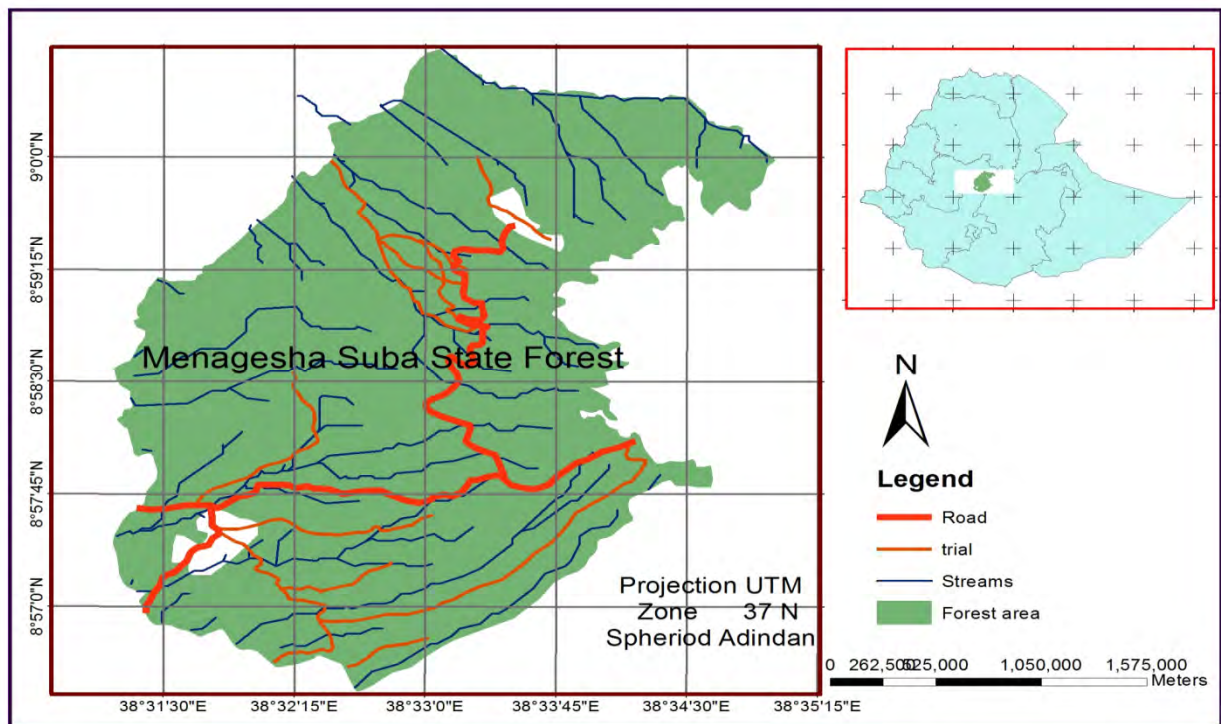


Figure 1. Location of Menagesha Suba State Forest.

5.1.2. Geology

The geological aspect of Menagesha Suba State Forest could be defined based on volcanic dome of Mountain Wochacha. The topography of Menagesha Suba State Forest was the result of siliceous volcanic cone. There are various rock types, including trachytes and basalt trap series. The basalts are the main rock types from which the soil parent material of this area was derived (Mohr, 1971). According to Tamrat Bekele (1993), the soil of the Forest at lower altitudes was reddish brown, deep and less gravelly, whereas at higher altitudes light brown and shallow; the substrate is locally rocky.

5.1.3. Climate

The rainfall and the temperature condition of the area was described based on the data collected from 2004-2010 by the National Meteorological Agency (NMA) from Addis Ababa station. According to the data from NMA, the result of the analysis showed that the mean annual temperature of the study area is about 17.1^oC. The range of mean monthly minimum and maximum temperature of the study area is 8.2 and 25.6 ^oC which belongs to December and March respectively. Then the hottest month is March with a maximum temperature of 25.6^oC, followed by May (25.1^oC) and the coldest month is December with a minimum temperature of 8.2^oC. Mean annual rainfall were estimated to be 1314 mm with the rains mainly falling from June to September, with peak in July-August, show unimodal type of rainy season (Figure 2).

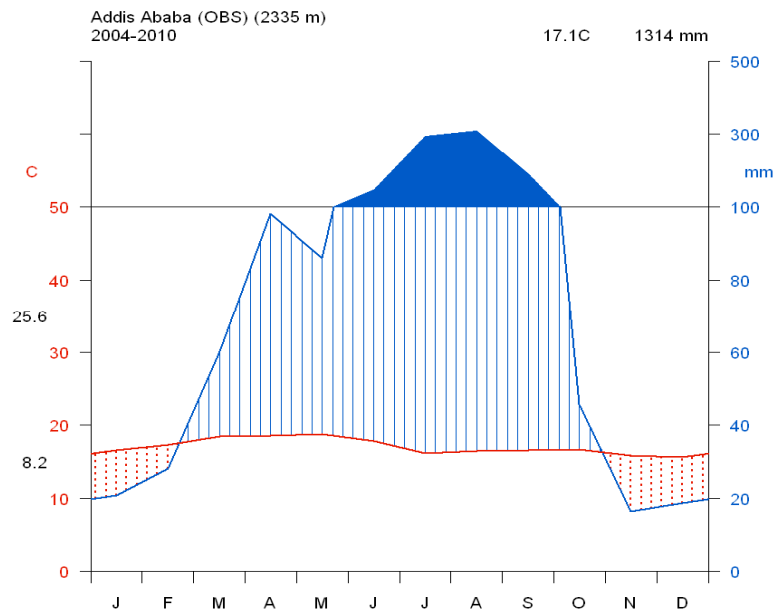


Figure 2. Clima diagram of Addis Ababa (based on seven years data, 2004-2010), dry periods are dotted and wet periods are blackened. Data Source: National Meteorological Agency (NMA).

5.1.4. Ecology

Menagesha Suba State Forest is one of the representatives of Dry Evergreen Afromontane Forests. The major part of the Forest and woodlands are located on a drained soil of the mountains and sides of the valleys while the grassland occupies the heavy clay soils of the valley bottoms. This Forest is highly affected by human interference; as a result some part of the Forest is changed to degraded lands. The marginal land of the Forest (including the demarcated part of the Forest) consists of settlements, farmland and grazing areas. The Forest holds different wildlife's including endemic Minilik bushbuck (Abate Zewdie, 2007). It also contains Abyssinian cat bird, banded barbet, golden backed wood pecker, black headed Forest Oriole and wattled ibis and indigenous animals like Columbus monkey. The main ecological problem in the Forest were encroachment by farmers for timber, non-timber products (NTFPs), fire-wood

collection, grazing and farming in the demarcated area of the Forest are commonly observed in the Forest.

5.1.5. Natural vegetation

The vegetation shows the general patterns of Afromontane zonation (Friis, 1992; Tamrat Bekele, 1993). The dominant tree species in at lower elevation and river valleys include *Podocarpus* and at middle altitude (around 2700 m a.s.l.) *Juniperus* trees. At the upper limit the vegetation changes to heather zone and *Helichrysum* species dominating with the top part exposed rocks, and secondary growth due to cultivation and grazing may be observed. At the top exposed rocks, ruminant vegetation and secondary growth due to cultivation and grazing may be observed. Friis, *et al.* (2010) classified the Forest as one of Undifferentiated Afromontane Forests, of *Juniperus–Podocarpus* Forest dominating type with an element of broad-leaved species. The Natural Forest of Menagesha Suba State Forest is dominated by *Juniperus procera*, *Olea europea* subsp *cuspidata*, *Podocarpus falcatus* *Allophylus abyssinicus*, *Croton macrstachyus*, *Maytenus* sp., *Osyris quadripartita*, *Euphorbia ampliphylla*, etc.

The Forest has a long-term history of disturbance and conservation practices that date back to at least five centuries (Afewerk Bekele, 1994), which may include the establishment of sawmill in the Forest. The original Forest cover when protection was initiated was estimated to be about 7,360 ha, but now it is only about 2,720 ha so that 62.5 % of the original Forest has been destroyed. In 1984 an area of 9,557 ha was designated as part of the State Forest and steps are being taken to re afforest the already deforested area with both indigenous and introduced trees (Sebsebe Demissew, 1988). In 2006 the area covered by the original Forest were diminished to around 2,500 ha (Abate Zewdie, 2007), indicating the high rate of deforestation.

5.2. Methods

5.2.1. Vegetation Data Collection

During November 9–25, 2010, reconnaissance survey was conducted to familiarize myself with the study area, to get an insight of the vegetation pattern, topography and other environmental conditions in order to locate sampling quadrats in the Forest. This is followed by actual sampling and three parallel line transect, each about 400 m apart from each other were laid out. In each transect, quadrats each with 20 m x 20 m were laid out with 80 m apart from each other. To cover most of the representative of the Forest seventy-five quadrats were used.

In each quadrat a complete list of trees and shrubs including woody climbers (lianas) and their number (count) and percentage cover was estimated. Specimens of all woody plant species were collected, pressed and identified at the National Herbarium (ETH) using Flora of Ethiopia and Eritrea (FEE). All woody plants outside of the quadrats were collected for floristic composition. Trees, shrubs, seedling and sapling were collected. In this study, tree refers to single stemmed woody plant or woody plant with single bole; shrubs as multiple stemmed woody plant; and seedling as young woody species with height less than 2 m and DBH less than 2.5 cm, while sapling refers to woody plant is with height greater than 2 m.

The cover values of the study Forest for all species was first estimated visually, recorded and later converted to the Braun-Banquet 1-9 modified scale (Kent and Coker, 1992) as follows: 1 = one or few individuals, 2 = occasional and less than 5% cover, 3 = abundant and with very low cover or less abundant but with higher cover, in any case less than 5% cover, 4 = very abundant and less than 5% cover, 5 = cover values between 5-12.5% irrespective of number of individuals,

6 = cover values between 12.5-25%, 7 = cover values between 25-50%, 8 = cover values between 50-75%, 9 = cover values between 75-100%, of the total quadrat area.

5.2.2. Floristic data analyses

All trees, shrubs and liana inside and outside the quadrats in the Forest were counted to analyze the floristic composition of the Forest. In addition, the number of species collected in the previous studies were added and compared with present study for this study area.

In addition to floristic composition the following were analyzed for the Forest:

- i. Vegetation classification:** - this was made using cover abundance values as class labels. The vegetation classification of the study area was done by Two-Way Indicator Species Analysis (TWINSpan), (Hill, 1979). It is a divisive polythetic method of vegetation classification. It classifies both samples and species.

The following option were chosen in TWINSpan program:

- Number of cut levels, 0, 2, 5, 10, 20;
- Minimum group size for division, 2;
- Maximum group size for division, 5;
- Maximum division levels, 6.

- ii. Plant community:** - Following classification above, the plant community types were determined and named as 'type' by dominant characteristic species; mainly trees and shrubs with high cover abundance values were used. The community types distinguished were further refined in a synoptic Table with a species having at least 2.5 cover-abundance value in one of the communities.

- iii. **Plant diversity**- the analysis was done by one of the most widely used approaches in measuring the diversity of species, Shannon and Wiener index of species diversity.
- iv. **Floristic comparison**: - the floristic comparison of Menagesha Suba State Forest with other related Dry Evergreen Afromontane Forests in Ethiopia was made using the Sorensen's similarity index.

5.2.3. Analyses of vegetation structure

For analyses of vegetation structure of the study area, all individuals of trees and shrubs with a diameter at breast height (DBH) greater than 2.5 cm, and height greater than 2 m were measured for DBH using Meter tape. Individuals with DBH less than 2 cm and height less than 2 m were counted.

The following analyses were done to describe the structure of the Menagesha Suba State Forest:

- i. **Density**: - Tree density was computed by converting the count from the total quadrats into hectare basis.
- ii. **Frequency**:-frequency is the number of times a particular species is recorded in the sample area.
- iii. **DBH (Diameter at Breast Height)**:-It is obtained by dividing the circumference of each tree recorded in the field by π or by equivalent value (3.14).
- iv. **Basal Area**: - Basal area calculations were made on the diameter measurements the stem with DBH's of two centimeter and above. It is expressed in square meter/ hectare. Basal area = $(DBH/2)^2 \times 3.14$.

v. For all individuals of tree having > 2.5 cm DBH, Relative density, Relative frequency, Relative Dominance and Importance Value Indices (IVI) were calculated for each tree species using the following formula.

a. **Relative density** = number of individuals of species **A**/total number of individuals of all species * 100

b. **Relative frequency** = number of quadrats occurrence/ total number of quadrats * 100.

c. **Relative Basal area** = total basal area of all individuals of a species/total basal area of all species * 100.

d. **Importance Value Index (IVI)** = Relative density + Relative frequency + Relative Basal area.

6. RESULTS AND DISCUSSIONS

6.1. Floristic Composition

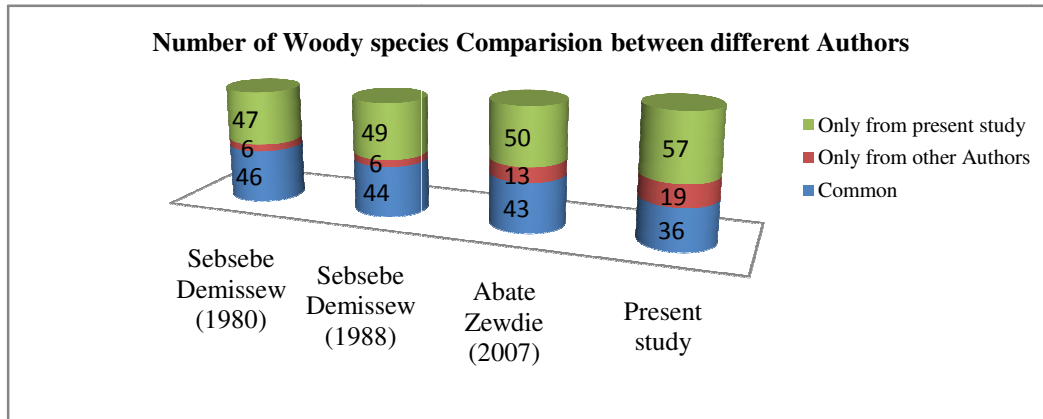
A total of 112 species of woody plants representing 84 genera and 51 families were recorded from the trees, shrubs, and lianas (Appendix 1). Of these only 93 species were encountered during this study, including 21 species that are recorded out of the quadrat for floristic composition. From the total number of plants recorded, 107 species were angiosperms (102 of the species are dicots and five monocots) and five gymnosperms. The Forest has higher number of as compared to other similar forest like Denkoro Forest with 64 species located in Wello (Abate Ayalew, 2003), Menagesha Amba Mariam Forest with 70 species in Central Shewa (Abiyuo Tilahun, 2009) and less number of species than Gedo Forest with 130 species in West Shewa (Birhanu Kebede, 2010) and Anabe Forest with 120 species located in Southern Wello (Mesfin Tadesse, 1993). The Families with the highest number of species (from highest to lowest) were Fabaceae with 12 (10.62%) species; Asteraceae with eight (7.08%) species, Rosaceae with five (4.42%) species; Euphorbiaceae, Flacourtiaceae and Oleaceae each with five (4.42%) species; Anacardiaceae, Celasteraceae, Rubiaceae and Myrsinaceae each with four (3.56%) species; Apocynaceae, Cupressaceae and Malvaceae each with three species; Acanthaceae, Asclepiadaceae, Ericaceae, Hypericaceae, Rhamnaceae, Rutaceae and Verbenaceae each with two species; and all the rest 30 (59.7%) Families with only one genus and one species (Appendix 2). There were about 52 (46.4%) shrubs, 49 (43.8%) and 12 (10.7%) liana in the Forest. Number, percentage and lifeforms of the species are indicated in Table one below.

Table 1. Number of species, percentage and lifeforms of Menagesha Suba State Forest.

Ser.No	Life forms	Number	Percentage (%)
1	Trees	49	43.8
2	Shrubs	52	46.4
3	Lianas	12	10.7

The comparison between different collectors at different time shows a difference in number of woody plant species. Six species were reported only from Sebsebe Demissew (1980; 1988); 13 species from Abate Zewdie (2007); and 57 species are collected only during the present study, that is these species are not recognized before this study (Appendix 1). The comparison between different collectors at different time show that there is an increase in number of species collected over the years as shown in Figure 3.

Figure 3. Comparison of number of woody species recorded by different collectors.



Endemic species of Menagesha Suba State Forest includes nine endemic woody species. This includes trees and shrub both four (44%), and one (11%) liana (Table 2). According to Friis *et al.* (2001), the general trends of endemism shows a decrease above altitude of 2000 m in Ethiopia, this may be true for Menagesha Suba State Forest.

Table 2. List of endemic species in Menagesha Suba Forest.

No.	Botanical name	Family	Habit
1	<i>Erythrina brucei</i>	Fabaceae	T
2	<i>Jasminum stans</i>	Oleaceae	L
3	<i>Lippia odoennis</i> var. <i>odoennis</i>	Lamiaceae	S
4	<i>Maytenus addat</i>	Celasteraceae	T
5	<i>Millettia ferruginea</i>	Fabaceae	T
6	<i>Rhus glutinosa</i> subsp. <i>glutinosa</i>	Anacardiaceae	T
7	<i>Satureja punctata</i>	Lamiaceae	S
8	<i>Rytigynia neglecta</i> var. <i>vatkeana</i>	Rubiaceae	S
9	<i>Vernonia leopoldi</i>	Asteraceae	S

6.1.1 Species Diversity

The Forest had the mean species richness of 17 species per 400 m². The Shannon –Wiener diversity index shows (Appendix 3) that quadrats number 48 and 69 are the richest with regard to the number of species (25) per quadrat, while the lowest number of species (7) was recorded for quadrat 42. The Forest had the Shannon diversity index of 2.57 and evenness of 0.92. Relatively high levels of species evenness was recorded for quadrat 11 (0.99) while the lowest value were recorded for quadrats 42 (0.85) and five (0.864). The highest diversity index was recorded for quadrat 59 (H'=3.005) followed by quadrat number 47 (H'=2.963) and 27(H'= 2.927) on the other hand, the lowest diversity index (H'=1.654) was recorded for quadrat 42. The lowest number of species were recorded in this was associated with high disturbances, open canopy and many small roads crossing the quadrat. Whereas the highest species richness and diversity indices observed for the quadrats which are almost homogenous and less disturbances in the area. This agrees with work of Abate Zewdie, (2007).

6.1.2. Plant Community Analysis

Six clusters could be recognized from the TWIINSPAN output. The community types were further refined in a twin result text, which shows the community types in detail. Twin result text values for each woody species and the six major clusters identified in the TWIINSPAN output are shown in Table 3. Each community should be named with two or more dominant species within group (Whittaker, 1975). Based on this each cluster distinguished in this study was described as community types and named after two dominant species. The dominant species were those with highest cover- abundance value for a given community (Table 4).

Each community was different in numbers of quadrats it contains, 31, 12, 11, 10, 7, and 4; the number of species, i.e., 56, 52, 51, 35, 33, and 41; evenness value (E), i.e., 0.92, 0.91, 0.93, 0.93, 0.93, and 0.91; and the diversity indices (H') values they have, i.e., $H' = 2.42, 2.60, 2.71, 2.56, 2.79$ and 2.71 (Table 5) from community 1-6 respectively.

A description of the six community types is given as follows:

1. *Maytenus arbutifolia* - *Dovyalis verrucosa* community type

There are 31 (41.3%) quadrats and 56 (60.2%) species included in this community. This community type is found at the lowest altitudinal gradient i.e., between 2396-2631 m (Table 5). The community is rich with all woody habits.

In addition to the characteristics species, the other dominant large tree species includes *Podocarpus falcatus*, *Olea europaea* subsp. *cuspidata*, *Juniperus procera* and *Allophylus abyssinicus*. Shrubs were *Carissa spinarum*, *Dovyalis abyssinica*, *Calpurnia aurea* and *Clausena anisata*. The community is also rich in lianas; these are *Jasminum abyssinicum*, *Jasminum stans*, and *Landolphia buchananii*. The community also contains some exotic species plantations like *Acacia mearnsi* and *Cupressus lusitanica*.

2. *Sideroxylon oxyacanthum* - *Dovyalis verrucosa* community type

Twelve (16%) quadrats and 52(56%) species were included under this community. It was found at altitudinal range of 2404- 2666 m (Table 5).

In addition to the characteristics species, the dominant tree species in this community are *Olea europaea* subsp. *cuspidata*, *Pittosporum viridiflorum* and *Juniperus procera*. Common shrubs found in this community are *Crotalaria lachnophora*, *Dovyalis abyssinica* and *Carissa spinarum*. Lianas are *Jasminum abyssinicum*, *Jasminum grandiflorum* subsp. *floribundum* , *Jasminum stans* and *Urera hypselodendron*.

3. *Dovyalis abyssinica* - *Myrsine africana* community type

There are 11 (15%) quadrats and 51 (55%) species included in this community. The community type three was found at altitude between 2572-2763 m (Table 5).

Dominant tree species include *Bersama abyssinica*, *Brucea antidysenterica*, *Allophylus abyssinicus* and *Pittosporum viridiflorum*. Most common shrub species are *Halleria lucida*, *Helichrysum argyranthum*, etc. Few liana species including *Rubus steudneri* and *Periploca linearifolia*.

4. *Myrsine melanophloeos*- *Landolphia buchananii* community type

There are ten (13%) quadrats and the community contains less number of species as compared to above communities i.e. only 35 (38%) species included in this community. It is located at altitude of 2628-2810 m (Table 5).

In addition to type characteristic species, common large tree of the upper canopy were mostly covered by *Juniperus procera*, *Bersama abyssinica* and *Ekebergia capensis*. The middle canopy was commonly dominated by shrubs like *Myrsine africana*, *Dovyalis abyssinica* and *D. verrucosa*. It also comprises the common lianas like *Urera hypselodendron*, *Jasminum abyssinicum* and *Rosa abyssinica*.

5. *Myrsine africana*- *Olea europaea subsp. cuspidata* community type

There are only seven (9%) quadrats and 33 (35.5%) species classified under this community type. The altitudinal range of the community was 2860-2896 m (Table 5).

In addition to the dominant species, the other commonly occurring species of larger tree include *Ilex mitis*, *Juniperus procera*, *Pittosporum viridiflorum*, *Maytenus adda* and *M. undata*.

The shrubs were *Osyris quadripartita*, *Rhamnus prinoides* and *R. staddo*. The lianas includes *Rosa abyssinica* and *Landolphia buchananii*. There are also few exotic species like *Cupressus lusitanica* and *Pinus radiata*.

6. *Juniperus procera* - *Ficus sur* community type.

This community contains the lowest number of quadrats four (5%) and considerable rich in the number of species, since it consists of 41 (44.1%) species. It occurs at the highest elevation when compared to other communities in the Forest that is between 2842-2951 m (Table 5). These quadrats are located on the valley and almost at the less accessible areas in the forest. So, relatively less disturbance and human interference, this make against the general finding of the trend of decrease in species richness above 2000 m a.s.l. in Ethiopian mountains.

In addition to characteristics species, other common tree species were *Myrsine melanophloeos*, *Olea europaea* subsp. *cuspidata* and *Olinia rochetiana*. Common shrubs include *Lippia odennisis*, *Maesa lanceolata* and *Dovyalis abyssinica*. Whereas the lianas include *Rosa abyssinica*, *Rubus steudneri* and *Landolphia buchananii*.

Table 4. Synoptic cover-abundance value for community types (value in bold refers to characteristic species C1-community 1, C2-community 2, C3-community 3, C4- community 4, C5-community 5, and C6-community 6).

Species	Communities					
	C1	C2	C3	C4	C5	C6
<i>Maytenus arbutifolia</i>	5.29	2.58	2.55	2.20	1.57	0.75
<i>Podocarpus falcatus</i>	2.32	0.58	0.45	0.00	0.00	0.25
<i>Carissa spinarum</i>	2.74	2.25	0.91	0.00	0.00	0.00
<i>Dovyalis verrucosa</i>	5.19	4.33	3.45	2.40	1.29	0.50
<i>Sideroxylon oxyacanthum</i>	0.52	4.42	1.09	0.00	0.00	0.25
<i>Jasminum abyssinicum</i>	3.10	4.00	2.45	3.80	2.00	2.00
<i>Dovyalis abyssinica</i>	3.39	3.58	4.09	4.90	1.43	2.75
<i>Myrsine africana</i>	1.94	1.00	3.91	1.20	7.00	0.00
<i>Brucea antidysenterica</i>	0.48	0.42	2.55	0.20	0.00	0.00
<i>Bersama abyssinica</i>	1.19	2.08	2.55	3.80	0.14	0.25
<i>Allophylus abyssinicus</i>	1.10	0.67	2.91	3.40	0.00	0.00
<i>Pittosporum viridiflorum</i>	1.55	2.50	2.64	3.60	3.43	1.25
<i>Landolphia buchananii</i>	0.03	0.50	2.00	5.20	3.43	2.25
<i>Myrsine melanophloeos</i>	0.23	0.00	1.27	6.80	1.29	4.25
<i>Ekebergia capensis</i>	0.29	0.08	0.82	2.50	0.00	0.00
<i>Urera hypselodendron</i>	0.10	0.92	0.27	2.10	0.00	0.25
<i>Erica arborea</i>	0.00	0.25	0.09	0.00	4.57	0.00
<i>Ilex mitis</i>	0.45	0.00	0.09	0.20	3.57	2.00
<i>Osyris quadripartita</i>	0.10	0.00	0.09	0.00	2.43	0.50
<i>Maytenus addat</i>	0.61	0.42	1.09	0.30	2.29	1.75
<i>Maytenus undata</i>	0.81	1.33	0.27	0.50	2.00	1.00
<i>Rosa abyssinica</i>	0.06	0.33	0.09	0.00	2.86	3.00
<i>Juniperus procera</i>	5.19	2.42	1.55	4.60	5.00	5.75
<i>Olea europaea</i> subsp. <i>cuspidata</i>	5.19	3.50	2.36	3.30	5.43	3.75
<i>Ficus sur</i>	0.26	0.92	0.82	0.00	0.00	5.50
<i>Rubus steudneri</i>	0.00	0.00	0.27	1.80	0.00	3.00

6.1.3. Species Richness, Diversity and Similarity indices of the communities.

The overall Shannon–Wiener diversity and evenness of the Forest were found to be $H' = 2.57$ and $E = 0.92$ respectively (Appendix 3). However, the H' values of the six communities were different (Table 5). The Diversity (H') and Evenness (E) values of the entire Forest were less than H' and E values of some communities like community 3 and 5 (Table 5) which implies that each communities may show variation with total mean species richness, cover abundance values and diversity indices.

Table 5. Altitudinal ranges, number of quadrats, mean species richness, evenness and Shannon-Wiener diversity of communities.

Community types	Altitudinal ranges (m)	Quadrats included in each communities	No. of species	Mean Species Richness (S)	Evenness (E)	Diversity (H')
Type 1	2396-2631	40, 7, 46, 52, 56, 38, 41, 44, 1, 2, 3, 13, 39, 43, 45, 8, 9, 10, 15, 42, 55, 65, 66, 4, 5, 6, 11, 12, 14, 17, 67 (31 quadrats)	56	14.26	0.92	2.42
Type 2	2404- 2666	63, 69, 49, 64, 68, 50, 51, 53, 54, 47, 48, 16 (12 quadrats)	52	17.83	0.91	2.60
Type 3	2572-2763	57, 58, 70, 59, 60, 62, 71, 72, 73, 74, 75 (11 quadrats)	51	19.27	0.93	2.71
Type 4	2628-2810	18, 19, 22, 20, 21, 61, 23, 24, 25, 26 (10 quadrats)	35	15.80	0.93	2.56
Type 5	2860-2896	29, 30, 32, 33, 31, 34, 35 (7 quadrats)	33	20.14	0.93	2.79
Type 6	2842-2951	36, 37, 27, 28 (4 quadrats)	41	19.75	0.91	2.71

As shown in table 5 above, the H' values of community type 5 were higher followed by community type 6 and 3. Whereas the left have lower H' values communities, with the least

observed at community type 1 ($H'=2.42$). This may be due to proximity to the residence and exposure to disturbance, like grazing, browsing and others (personal observation). Community five also consists the highest mean species richness followed by community six and three, the least at community one. The mean evenness of the communities was more or less similar pattern. The highest species richness, evenness and diversity indices in community five may be due less to disturbances, because it's relatively less number of roads crossing, far from top and bottom (found almost above center of the total study area). Overall, the possible reason for variability of each values between each community type could be difference in number of species, cover abundance values, degree of disturbance, the slope of the quadrats in the community and other related factors. Similar findings were reported by Abiyou Tilahun, (2009).

6.1.4. Sorenson's similarity for the communities

The distribution of plant species among the communities indicates different similarity patterns (Table 6). The overall similarity coefficient ranges from 56.5-85% among all the communities. The highest similarity was observed between community three and two (85%), this may be due to existence of most quadrats adjacent to each other that shows similar adaptation mechanisms and requirements for species occurring in those communities. The lowest similarity were observed between community two and five (56.5%), and community five and three (59.5%), this may as result of different factors like anthropogenic (exploitation or disturbances), physical factors like soil, slope, etc. and related to the altitudinal variation on which most of the classifications were based.

Table 6. Sorenson's Similarity coefficient (%) among the six communities.

Communities	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Type 1	1					
Type 2	80	1				
Type 3	75	85	1			
Type 4	64	64	72	1		
Type 5	61	56.5	59.5	65	1	
Type 6	68	62	72	71	70	1

6.2. Floristic comparison of Menagesha Suba State Forest with other similar Forests in Ethiopia

Menagesha Suba State Forest was compared with other similar dry Afromontane Forests found in different localities in Ethiopia. These include Gedo Forest in Shewa, which is located between latitudes $9^{\circ} 02'$ and $9^{\circ} 01'$ North and longitudes $37^{\circ} 25'$ and $37^{\circ} 16'$ East, with an altitudinal range of 1300-3060 m a.s.l. (Birhanu Kebede, 2010). The Menagesha Amba Mariam Forest in Shewa is located $9^{\circ} 01' - 09^{\circ} 03' N$ and $38^{\circ} 35' - 38^{\circ} 36' E$, with altitudinal range of between 2574-2948 m a.s.l. (Abiyou Tilahun, 2009). The Sanka Meda Forest in Arsi is located between $8^{\circ} 22' 09'' - 8^{\circ} 24' 54'' N$ latitude and $39^{\circ} 57' 02'' - 39^{\circ} 58' 52'' E$ longitude. Its altitude ranges are approximately 1200 to 3574 m a.s.l. (Shambel Bantiwalu, 2010). Adaba Dodola Forest in Bale and part of the Bale Mountains at altitudes between 2500-3500 m a.s.l. The Forest lies between latitudes $6^{\circ} 50' N$ and $7^{\circ} 10' N$, and longitudes $39^{\circ} 05' E$ and $39^{\circ} 16' E$ (Kittessa Hundera *et al.*, 2007). The Bale Mountains National Park and surrounding Forest is located between latitudes $06^{\circ} 54.6' - 07^{\circ} 43.5' N$ and longitudes $039^{\circ} 33' 19.5'' - 039^{\circ} 59.235' E$. The altitudinal range of this area lies between 2441-3600 m a.s.l. (Haile Yineger, 2005).

Denkoro Forest in Wello, at altitudinal ranges of 1500 to 3500 m.a.s.l.. The Forest is located between 10⁰ 35' – 11⁰ 15'N and 38⁰ 30' – 39⁰ 07'E, (Abate Ayalew, 2003). The Anabe Forest in Wello is located at altitudinal range of 2100-2200 m a.s.l.. The Forest lies between 10.5-11.5⁰N latitude and 39.5-41⁰E longitude (Mesfin Tadesse, 1993).

Table 7. The floristic Comparison of Menagesha Suba State Forest with other similar Forest in Ethiopia (where a, b, and c, are species unique to the Forest under comparison (a), Menagesha (b), and common to both (c), Sc is similarity coefficient).

No.	Forest	a	b	c	Sc %	Sources
1	Southern Wello (Anabe)	76	69	44	38	Mesfin Tadesse, 1993
2	Menagesha Amba Mariam (Egdu)	16	59	54	59	Abiyou Tilahun, 2009
3	Gedo	56	39	74	61	Birhanu Kebede, 2010
4	Bale Mountains National Park and surrounding areas (Central and Northern Areas of the Park)	43	74	39	40	Haile Yineger, 2005
5	Denkoro Forest	20	69	44	50	Abate Ayalew, 2003
6	Sanka Meda Forest	26	47	46	58	Shambal Bantiwalu, 2010
8	Dodola Forest	21	55	38	50	Kittessa Hundera <i>et.al.</i> 2007

Direct comparison of species diversity with some other Forests is not feasible due to differences in size of the Forests, survey methods and objectives of the study, so that only certain phytogeographic comparison will be practically possible. As indicated above in Table 7 Menagesha Suba State Forest have higher similarity ($\geq 50\%$ similarity coefficient) with four Forests (Gedo 61%, Menagesha Amba Mariam (Egdu), 59%, and Sanka Meda Forest, 58%, Denkoro Forest and Dodola Forest each with 50%), less similarity with Bale Mountains National Park and surrounding areas, 40% and Southern Wello, 38%.

High similarity with Gedo Forest, Menagesha Amba Mariam (Egdu) and Sanka Meda Forests was probably due to similarity in altitudinal and latitudinal, similarity in management of the Forests and also other environmental factors. Especially, for Gedo and Menagesha Amba Mariam Forests similarity with the present study may be due to proximity to the Forest and its conservation status, in addition to other factors. On the other hand dissimilarity with Bale Mountains National Park and Southern Wello were due to the difference in topographic variation, and distance between the Forests will be barrier for transfer of species between the Forests. And also the significant dissimilarity may be due to the differences in the purpose of study rather than only the specific species composition.

6.3. Population Structure of Menagesha Forest

To analyze the population structure of the Forest few dominant species were selected. The analysis result indicates that there are different patterns of population dynamics.

6.3.1. Frequency

The tree and shrubs were classified into five frequency classes on the basis of their frequency values. The three species that frequently occur are *Juniperus procera*, *Olea europaea* subsp. *cuspidata* and *Dovyalis abyssinica* (that occur in 73, 69 and 68 quadrats out of 75 quadrats respectively) (Table 8). The species with more than 50% distribution were *Jasminum abyssinicum*, *Bersama abyssinica* and *Myrsine africana*. The species with the least occurrence include *Clusia abyssinica*, *Discopodium penninervum* and *Rhamnus prinoides*.

Table 8. The seven most frequently occurring woody species in the Forest.

Species	Frequency	Percentage Frequency	Relative Frequency	Priority
<i>Juniperus procera</i>	73	97	5.71	1
<i>Olea europaea subsp. cuspidata</i>	69	92	5.41	1
<i>Dovyalis abyssinica</i>	68	91	5.35	1
<i>Maytenus arbutifolia</i>	63	84	4.94	2
<i>Jasminum abyssinicum</i>	60	80	4.71	2
<i>Pittosporum viridiflorum</i>	54	76	4.47	3
<i>Dovyalis verrucosa</i>	46	61	3.59	4

6.3.2. Height distribution

About 25 woody species having 2,875 individuals were selected to describe the structure of Menagesha Suba State Forest plant communities. Eight height classes, class 1) 2.0-5.0 m, 2) 5.01-10.0 m, 3) 10.01-15.0 m, 4) 15.01-20.0 m, 5) 20.01-25.0 m, 6) 25.01-30.0 m, 7) 30.01-35.0 m, 8) >35 m were conventionally established (Table 9).

Table 9. The count of individuals selected in height classes (m) in Menagesha Suba State Forest.

Height classes	Class intervals	Density	%
1	2.0-5.0 m	902	31.37
2	5.01-10.0 m	1069	37.18
3	10.01-15.0 m	389	13.53
4	15.01-20.0 m	255	8.87
5	20.01-25.0 m	137	4.76
6	25.01-30.0 m	62	2.16
7	30.01-35.0 m	30	1.04
8	>35 m	31	1.10

As shown in table 9, the number of individuals in each successive height class were decreasing beginning from the first lower height class to the highest height class. The majority of

individuals contributing to the first height class came from *Dovyalis verrucosa*, *Juniperus procera* and *Maytenus arbutifolia*. The second and the third height class was contributed mostly by *Pittosporum viridiflorum* and *Scolopia theifolia* and *Sideroxylon oxyacanthum* respectively. Above the fourth classes, *Juniperus procera*, *Olea europaea* subsp. *cuspidata* and *Podocarpus falcatus* are mainly with many individuals.

Thus, the height distribution patterns of Menagesha Suba State Forest was characterized by fewer individuals at mature stage, than middle and young aged population, suggesting that the Forest was dominated by low stature individuals. This agrees with the work of Abate Ayalew, (2003), Abate Zewdie, (2007), Birhanu Kebede, (2010). Thus the general scheme of height class distribution confirms with reversed J shaped pattern (Figure 4), showing almost stable size distribution common in natural Forests. The pattern of height class distribution with respect to number of individuals shows different patterns (Fig.5a-j), indicating different population dynamics. Generally, three patterns of population structure were analyzed.

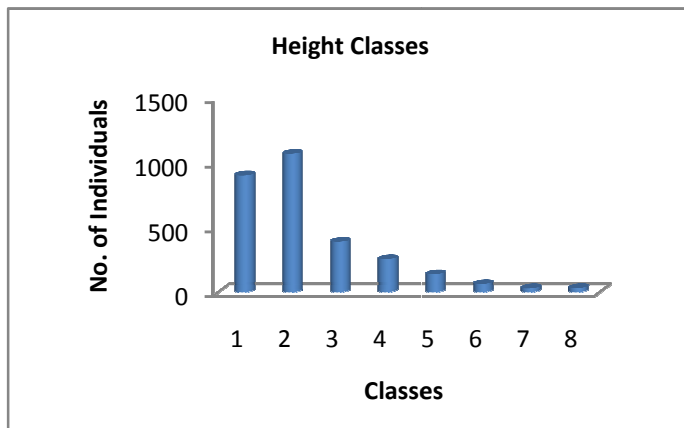


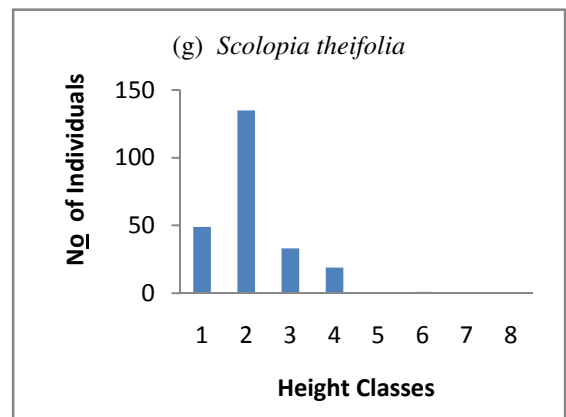
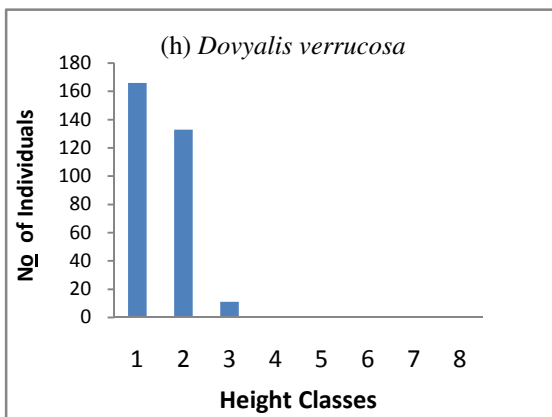
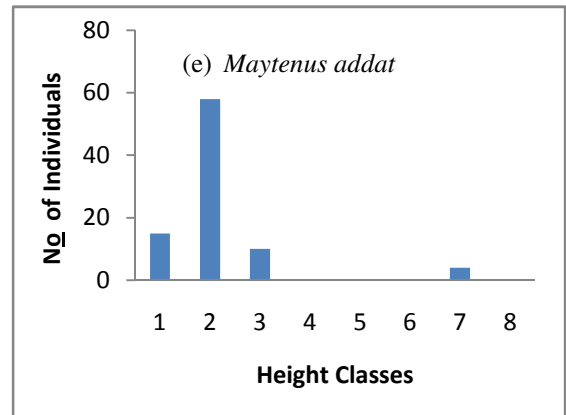
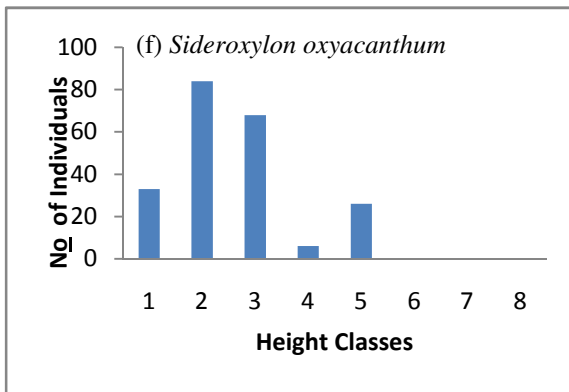
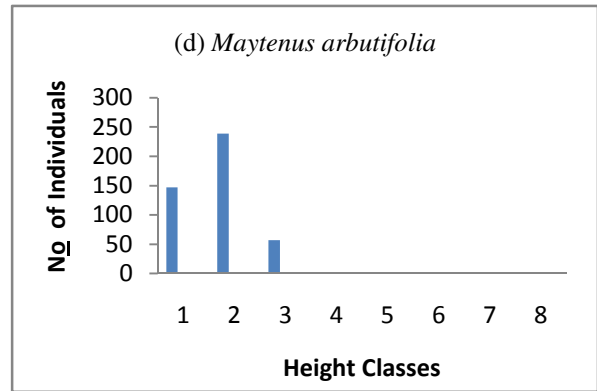
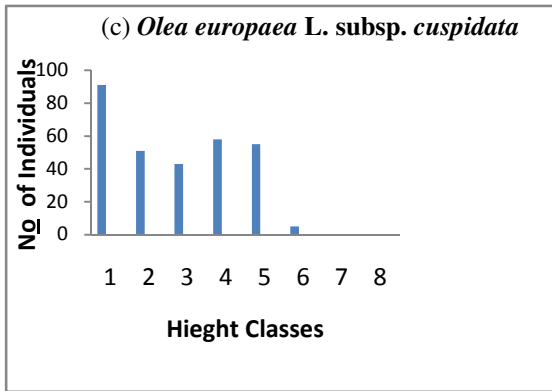
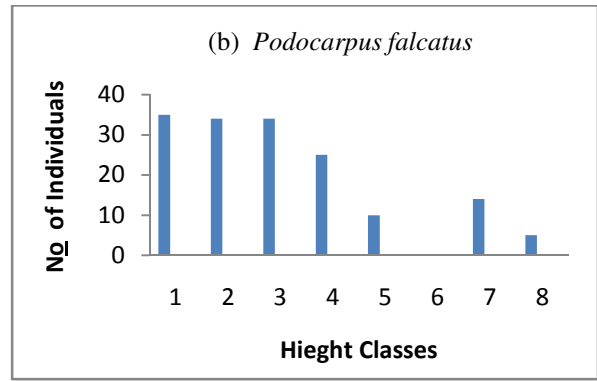
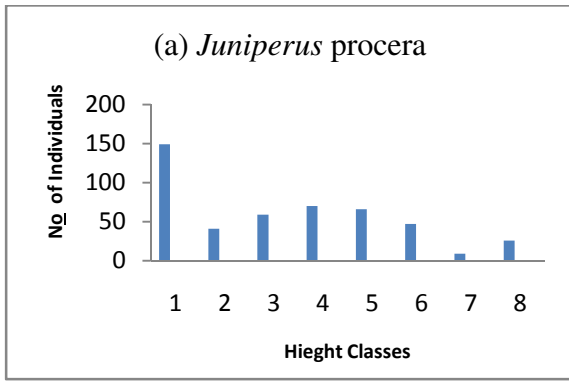
Figure 4. General height distribution patterns (structure) of Menagesha Suba State Forest

The first pattern indicates (Fig.5a, c, and h) a normal distribution of species with reversed J-shape. Maximum values occurred in the first class and then reduced gradually up to the fourth

class. This pattern represents good reproduction status and regeneration potential. It includes *Juniperus procera* and *Olea europaea* subsp. *cuspidata*, and *Dovyalis verrucosa* are taken as representative of this pattern. This agrees with the work of Birhanu Kebede, (2010).

The second with bell-shaped distribution pattern (Fig.5d, g, i, f, and j). That was formed by species with highest density in the second-class, medium value in the first, third and fourth classes, small values in classes five, six and seven and no value in the rest classes. This pattern indicates better reproduction but a bad recruitment potential in the Forest. This was observed in height class of *Scolopia theifolia*, *Pittosporum viridiflorum*, *Sideroxylon oxyacanthum* and *Allophylus abyssinicus*.

The third pattern (Fig. 5 b and e) was with few or many individuals in lower height classes but have no individuals in third, fourth, five or sixth classes, and with medium number of individuals in the last two height classes. This kind of distribution is observed when there is selective cutting in the middle classes. Thus, there is no reproduction and only few large and old individuals will be left after a certain time. This pattern is frequent in few woody species that are under uncontrolled exploitations. Species with such pattern could become endangered in the future, because individuals are being harvested before reaching reproductive ages, and this could result in the future decline of the species population because these reflect good reproduction but, bad recruitment. The height class of *Maytenus addat* shows this type of pattern.



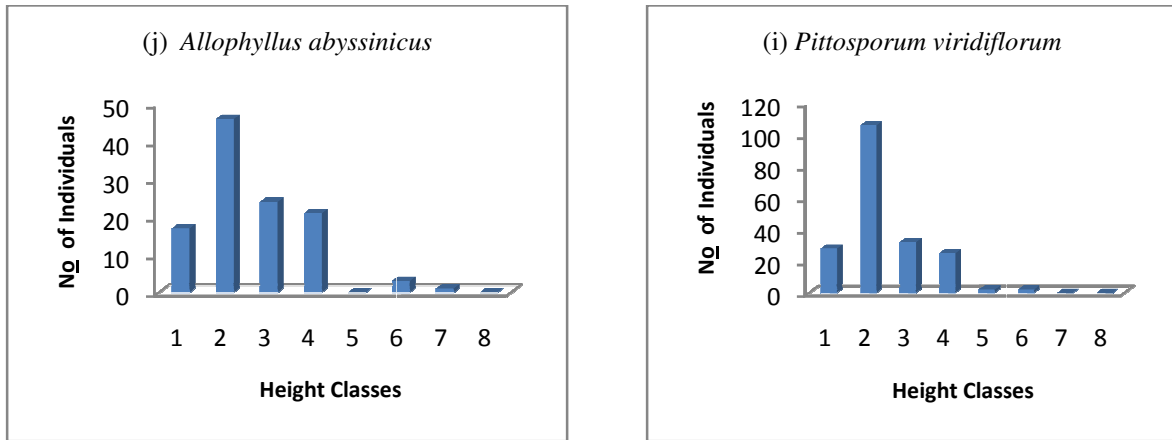


Figure 5. Distribution patterns of height of woody species of Menagesha Suba State Forest.

6.3.3. Vertical structure

Population structure refers to the distribution patterns of individuals of each species within arbitrarily defined height classes. According to height classification scheme (Lamprecht, 1989) there were three vertical hierarchies of trees in the Forest community, these were; 1) the upper storey-tree with height $>2/3$ of the top upper height, 2) middle storey-tree with height between $1/3$ and $2/3$ of top upper height; and lower story tree height $< 1/3$ of top height).

The tallest trees observed was *Juniperus procera* and *Podocarpus falcatus* about 50 m and 60 m tall, in quadrats 49 and 56 respectively. Only 61 individuals (2.12%) were recorded within the last two highest height classes, consisting $2/3$ of the total storey in the Forest, i.e., above 30.44 m. However, *Allophylus abyssinicus*, *Ekebergia capensis*, *Ficus sur*, *Maytenus undata*, *Myrsine melanophloeos*, *Olea europaea* subsp. *cuspidata*, *Pittosporum viridiflorum*, *Prunus africana*, *Rhus glutinosa* subsp. *glutinosa*, *Scolopia theifolia* and *Teclea nobilis* with about 454 (15.79%) individuals were constituted the middle storey (15.33-30.44 m tall which fall between $1/3$ - $2/3$) and lastly *Bersama abyssinica*, *Brucea antidysenterica*, *Carissa spinarum*, *Clausena anisata*, *Dovyalis abyssinica*, *Dovyalis verrucosa*, *Galiniera saxifraga*, *Ilex mitis*, *Maytenus*

addat, *Maytenus arbutifolia* and *Osyris quadripartita* 2360 (82.1%) individuals constituted the lower storey (below 15.33 m) i.e., less than 1/3 of the tallest tree. The total height of Menagesha Suba State Forest is summarized into three layers (storey) as shown in Figure 6 (pie chart) below. This agrees with the work of This agrees with the work of Abate Ayalew, (2003) and Birhanu Kebede,(2010).

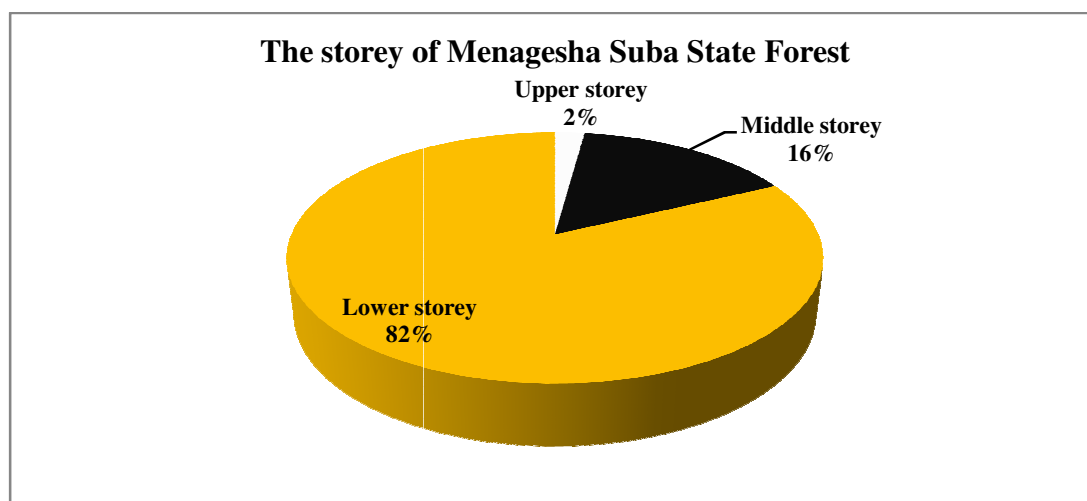


Figure 6. Pie chart representing three stories of Menagesha Suba Forest.

6.3.4. DBH distribution

Total number of trees in each DBH class decreased with and increasing tree diameter classes (Fig. 7). A total of 2,316 individuals whose height >2 m and DBH >2.5 cm were recorded in Menagesha Suba State Forest for DBH analysis. Seven DBH classes are established, class 1) 2.5-10 cm, 2) 10.01-20.0 cm, 3) 20.01-40.0 cm, 4) 40.01-60.0 cm, 5) 60.01-80.0 cm, 6) 80.01-100.0 cm, 7) DBH> 100.01cm (Table 10). Few individuals of *Juniperus procera*, *Maytenus addat*, *Podocarpus falcatus*, *Ekebergia capensis*, *Ficus sur*, *Olea europaea* subsp. *cuspidata*, and *Prunus africana* were encountered in the higher DBH classes. The middle DBH classes were also dominated by the above species and additionally few individuals of *Pittosporum*

viridiflorum, *Maytenus arbutifolia*, *Scolopia theifolia*, *Allophylus abyssinicus*, *Maytenus undata* and *Rhus glutinosa* subsp. *glutinosa*. High proportion of DBH density was contributed by *Maytenus arbutifolia*, *Scolopia theifolia*, *Juniperus procera*, *Podocarpus falcatus*, *Olea europaea* subsp. *cuspidata* and *Pittosporum viridiflorum* also at lower DBH classes. The density of individuals in each DBH class abruptly decreased after the second DBH class onwards (Table 10).

Table 10. DBH class distribution of woody species in Menagesha Suba Forest.

DBH classes	Class intervals	Density	%
1	2.5-10.0 cm	1589	68.61
2	10.01-20.0 cm	529	22.84
3	20.01-40.0 cm	110	4.75
4	40.01-60.0 cm	47	2.03
5	60.01-80.0 cm	33	1.42
6	80.01-100.0 cm	6	0.26
7	>100.01 cm	2	0.09

The majority of the populations, 1,589 (68.61%), were found in the first lower DBH class, while the rest 529 (22.84%), 110 (4.75%), 47 (2.03%), 33 (1.42%), 6 (0.3%), and 2 (0.1%), were found between DBH classes 2-7 respectively (Table 10). This was a normal DBH distribution pattern when viewed from the whole set of plant community, confirming reversed J shape (Figure 7) but there would be variation with respect to individuals species when it was analyzed separately (Figure 8a-d).

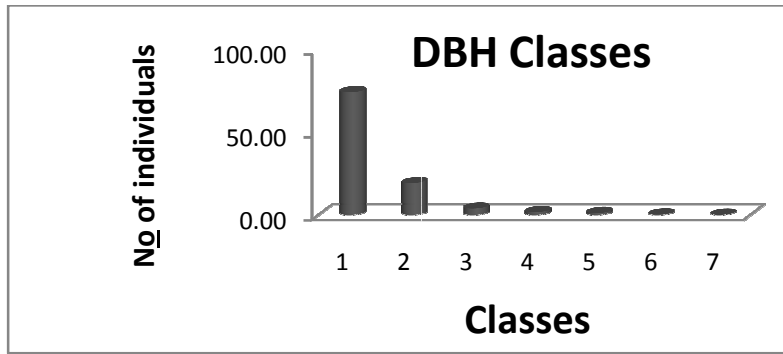


Figure 7. The general DBH distribution patterns (structure) of Menagesha Suba State Forest.

The evaluation of most dominant species revealed that there is normal DBH distribution patterns in most species, the inverted J-shaped. It indicates a pattern where species frequency distribution had the highest frequency in the lower DBH classes and gradually decreases towards the higher diameter. E.g. *Juniperus procera* and *Olea europaea* subsp. *cuspidata*. This agrees with the work of Abate Ayalew, (2003), Abate Zewdie, (2007), and Birhanu Kebede, (2010).

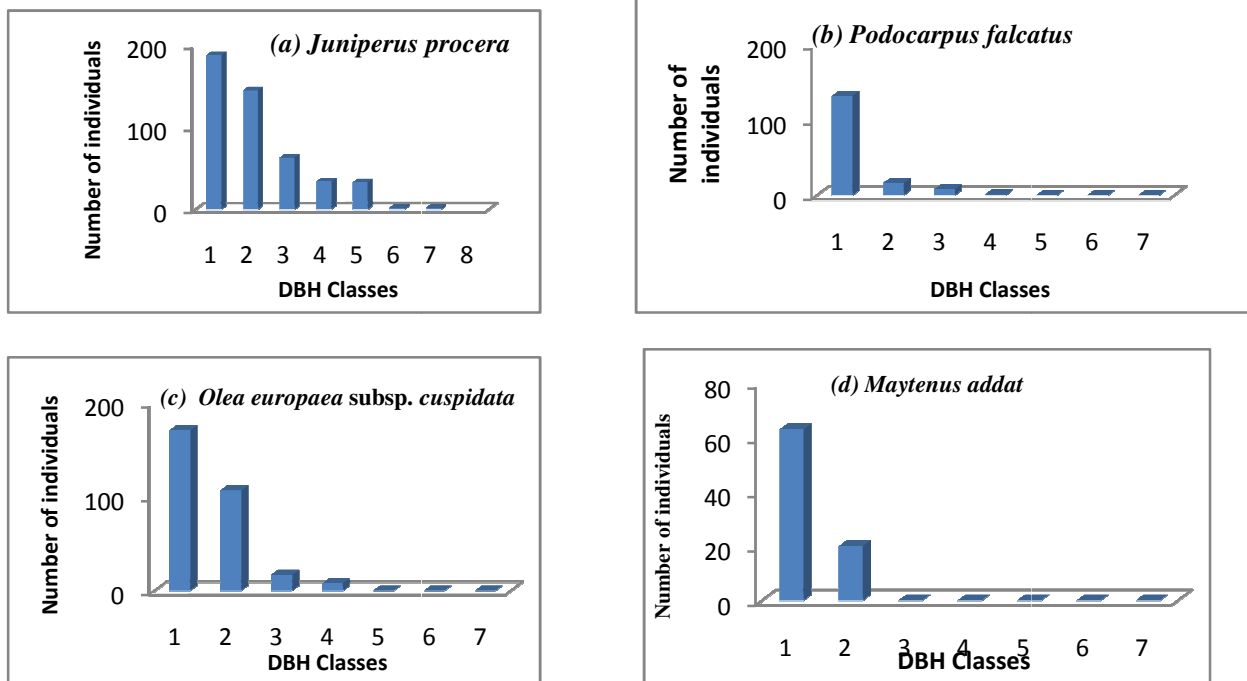


Figure 8. The DBH class distribution of selected trees of Menagesha Suba Forest.

6.3.5. Basal area

The total basal area of Menagesha Suba Forest was about 158.68 m² ha⁻¹. *Juniperus procera* has the highest basal area (37.45 m² ha⁻¹) followed *Olea europaea* subsp. *cuspidata* (20.9 m² ha⁻¹). On the other hand the lowest (below 0.05 m² ha⁻¹) was recorded for most species like *Carissa spinarum*, *Dovyalis abyssinica*, and *D. verrucosa* (Table 11). The basal area of dominant species (species with higher IVI) was given in table 11. It is important to note here that species with the highest basal area do not necessarily have the highest density, indicating size difference between species (Tamirat Bekele, 1994; Dereje Denu, 2006). Thus, the species with the largest BA could be considered the most important species in the Forest. With regard to BA, only the most important species of the study Forest includes *Juniperus procera*, *Maytenus arbutifolia*, *Maytenus addat*, *Olea europaea* subsp. *cuspidata*, *Podocarpus falcatus*, *Scolopia theifolia* and *Sideroxylon oxyacanthum*.

Table 11. List of species with higher basal area (from highest to lowest) with respect to BA m² ha⁻¹, %BA, and Relative Basal area.

Species	BA/ha	%BA	Relative Basal area	Priority
<i>Juniperus procera</i>	37.45	18.25	23.6	1
<i>Olea europaea</i> subsp. <i>cuspidata</i>	20.9	11.84	13.17	2
<i>Podocarpus falcatus</i>	12.36	4.96	7.79	3
<i>Maytenus arbutifolia</i>	12.15	9.31	7.96	3
<i>Scolopia theifolia</i>	11.85	9.26	7.5	3
<i>Sideroxylon oxyacanthum</i>	10.20	7.97	6.43	3
<i>Pittosporum viridiflorum</i>	9.71	7.54	6.12	4
<i>Maytenus addat</i>	7.36	3.4	4.68	4
<i>Maytenus undata</i>	4.75	3.71	3.0	5

6.3.6. Important value Index (IVI)

Important Value index combines data from three parameters, which include Relative Frequency, Relative Density and Relative Basal area (Kent and Coker, 1992). IVI is ecologically important and a key structural parameter in vegetation study. It is the most realistic aspect in vegetation study and used to compare the ecological significance of species (Lamprecht, 1989). Five IVI classes were established for Menagesha Suba State Forest. Percentages of species in the IVI classes were 3.62%, 26.67%, 28.01%, 18.59%, 6.21%, and 16.9% for classes 6, 5, 4, 3, 2, and 1 respectively (Table 12 and Figure 9) with some representatives in the class (Table 13). The highest IVI value (90.2%) was in classes 1, 3, 4, and 5 while the remaining (9.83%) in classes 2 and 6.

Table 12. IVI Classes, sum of species belonging to each class and their percentage value.

IVI classes and intervals	No_ Species	Sum of IVI	Percentage (%)
6(<1)	16	11.40	3.62
5(1.1-5.0)	36	83.92	26.67
4(5.1-10.0)	12	88.13	28.01
3(10.1-15.0)	5	58.49	18.59
2(15.1-20.0)	1	19.54	6.21
1(>20)	2	53.12	16.9

The five most dominant tree species of Menagesha Suba Forest occupied 41.77% of total important value index (Table 13). The dominant species were *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Maytenus arbutifolia*, *M. addat*, *Podocarpus falcatus*, *Pittosporum viridiflorum*, *Scolopia theifolia* and *Sideroxylon oxyacanthum*. The result indicates that much of

IVI was attributed by few species. These species are those well adapted to the high pressure of disturbance, natural and environmental factors, and the effect of local communities. *Clutia abyssinica*, *C. lanceolata* and *Euphorbia abyssinica* are species among the lowest relative IVI values and were found to be the least dominant species among the study area. Priority for conservation of these species must be given based on their IVI values (i.e the first priority for species with highest IVI value and the last priority of conservation for species with the least IVI values) (Table 13). The result (Table 13) shows *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, and *Maytenus arbutifolia* are grouped in priority class one that require immediate conservation and protection while species like *Euphorbia abyssinica* and *Clutia abyssinica* in the last priority class and they need the last priority of conservation (Table 13). The rest species are in the intermediate priority classes (3, 4, 5), indicating that they need intermediate conservation programme.

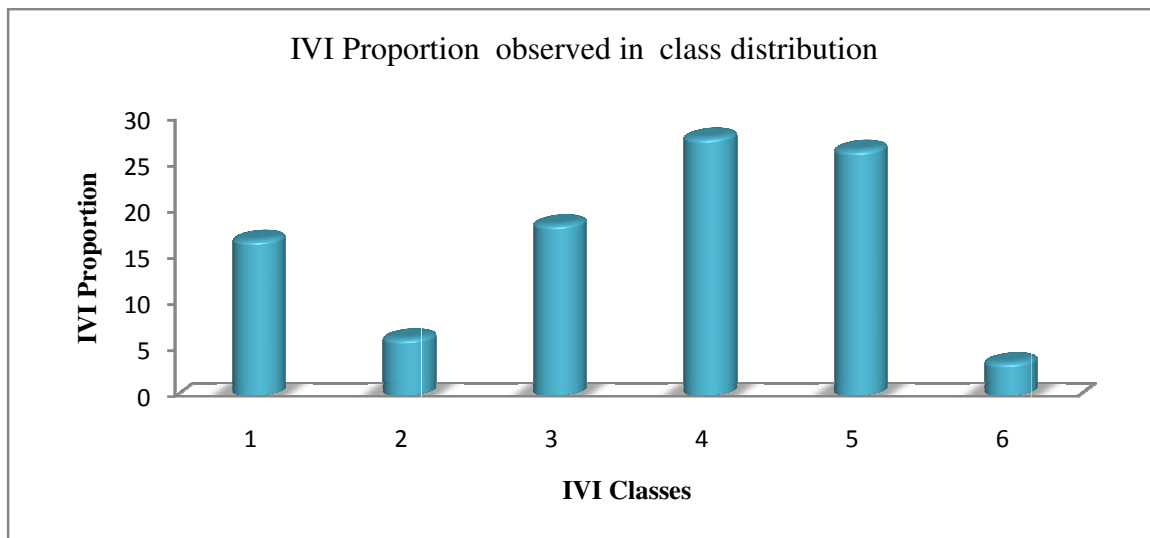


Figure 9. The IVI proportion of most frequent and dominant trees and shrubs in the study area, IVI class: 1=>20, 2=15.1-20.0, 3=10.1-15.0, 4=5.1-10.0, 5=1.1-5.0, 6=<1.

Table 13. The IVI of selected (five species from each class as representative) woody species in Menagesha Suba Forest. The Priority group of species based on the IVI values priority 1=IVI value>20, 2=15.1-20.0, 3=10.1-15.0, 4=5.1-10.0, 5=1.1-5.0, 6=<1.

Species	Relative Basal area	Relative Frequency	Relative Density	IVI	%IVI	Priority
<i>Clutia lanceolata</i>	0.00	0.06	0.32	0.38	0.12	6
<i>Euphorbia abyssinica</i>	0.02	0.18	0.32	0.52	0.17	6
<i>Clutia abyssinica</i>	0.00	0.06	0.48	0.54	0.17	6
<i>Galiniera saxifraga</i>	0.38	0.65	0.46	1.48	0.47	5
<i>Rhus glutinosa</i> subsp. <i>glutinosa</i>	0.22	1.00	0.30	1.52	0.48	5
<i>Ilex mitis</i>	0.47	1.24	0.92	2.62	0.83	5
<i>Nuxia congesta</i>	1.1	1.47	1.15	3.69	1.18	5
<i>Prunus africana</i>	1.98	1.71	0.61	4.30	1.37	5
<i>Ekebergia capensis</i>	2.05	1.59	0.73	4.37	1.39	5
<i>Landolphia buchananii</i>	0.00	2.53	2.21	4.74	1.51	5
<i>Bersama abyssinica</i>	0.50	3.53	1.68	5.71	1.81	4
<i>Maytenus undata</i>	3.0	2.41	0.76	6.17	1.96	4
<i>Olinia rochetiana</i>	4.53	0.65	1.07	6.25	1.99	4
<i>Rosa abyssinica</i>	0.03	4.94	1.39	6.36	2.03	4
<i>Ficus sur</i>	2.18	0.41	4.29	6.89	2.18	4
<i>Jasminum abyssinicum</i>	0.03	4.71	2.29	7.02	2.24	4
<i>Allophylus abyssinicus</i>	3.62	2.59	0.93	7.15	2.27	4
<i>Dovyalis abyssinica</i>	0.01	5.35	1.92	7.28	2.32	4
<i>Carissa spinarum</i>	0.01	5.71	2.71	8.43	2.68	4
<i>Myrsine melanophloeos</i>	1.17	1.88	5.82	8.88	2.83	4
<i>Myrsine africana</i>	0.05	3.53	5.38	8.96	2.85	4
<i>Dovyalis verrucosa</i>	0.01	3.59	5.45	9.05	2.88	4
<i>Podocarpus falcatus</i>	7.79	2.18	0.95	10.91	3.47	3
<i>Sideroxylon oxyacanthum</i>	6.43	1.65	3.12	11.20	3.57	3
<i>Maytenus addat</i>	4.64	5.71	0.96	11.31	3.60	3
<i>Pittosporum viridiflorum</i>	6.12	4.47	1.37	11.96	3.81	3
<i>Scolopia theifolia</i>	7.47	2.06	3.59	13.12	4.18	3
<i>Maytenus arbutifolia</i>	12.15	4.94	3.24	20.33	6.05	2
<i>Olea europaea</i> subsp. <i>cuspidata</i>	13.2	5.41	0.96	19.54	6.22	2
<i>Juniperus procera</i>	23.60	5.71	1.68	30.98	9.87	1

7. CONCLUSIONS AND RECOMMENDATIONS

The Menagesha Suba State Forest is one of the oldest protected and conserved areas in Ethiopia. In this Forest, 112 woody plant species were recorded or compiled from present and previous studies (Appendix 1). From this, only 93 species were collected during the present study. There are nine endemic species collected from the area. The Forest shows relatively high floristic similarity with other related Forests in Ethiopia.

Analysis of species population structure pointed out the variability of population dynamics in the Forest. It confirmed at least the existence of two major types of woody species, species able to regenerate in the Forest and others with difficulties to reproduce and regenerate in the Forest, due to different factors like selective cutting and disturbances.

The vegetation of the Menagesha Suba State Forest is disturbed through grazing and browsing by domestic livestock and other human uses, these further affects the quality of regeneration processes of the trees and shrubs. Recognizing these issues as possible future scenario underlies the need for management intervention to increase quality of regeneration being recruited and to accelerate the growth of the young plants already present.

The Forestry Department or the Agency should make the policy that increase the awareness of the society and plan to use community based approach or participatory approach.

The demarcation of the forest is yet not complete, so it needs to be complete for further planning and to adjust the buffer zone for the natural forest, plantation area and the interaction sites.

Overall, there is a need to use the modern joint forest management method that improves the protection, conservation status of the forest and sustainable utilization of the resources.

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9. APPENDICES

Appedinix 1. List of species in Menagesha Suba State Forest:

No	Scientific Name	Family	Habit	Remark	Col. No
1	<i>Acacia abyssinica</i> Hochst. ex Benth.	Fabaceae	T	ODB	-
2	<i>Acacia mearnsii</i> De Wild.	Fabaceae	T	DB	DB001
3	<i>Acacia melanoxyton</i> R. Br.	Fabaceae	T	ODB	-
4	<i>Agarista salicifolia</i> (Comm. ex Lam.) Don	Ericaceae	T	DB	DB002
5	<i>Albizia lophantha</i> (Willd.) Benth.	Fabaceae	T	DB	DB003
6	<i>Allophylus abyssinicus</i> (Hochst.) Radlkofer	Sapindaceae	T	DB	DB004
7	<i>Apodytes dimidiata</i> E. Mey. ex Am.	Icacinaceae	T	AB	-
8	<i>Asparagus africanus</i> Lam.	Asparagaceae	S	DB	DB005
9	<i>Barleria ventricosa</i> Hochst. ex Nees	Acanthaceae	L	SD	-
10	<i>Bersama abyssinica</i> Fresen.	Meliantaceae	T	DB	DB006
11	<i>Blyttia fruticosum</i> (Decne.) D. V. Field	Asclepiadaceae	S	DB	DB007
12	<i>Brucea antidysenterica</i> J.F. Mill.	Simaroubaceae	T/S	DB	DB008
13	<i>Calpurnia aurea</i> (Ait.) Benth.	Fabaceae	T/S	DB	DB009
14	<i>Carissa spinarum</i> L.	Apocynaceae	L	DB	DB010
15	<i>Cassipourea malosana</i> (Baker) Alston	Rhizophoraceae	T	DB	DB011
16	<i>Chionanthus mildbraedii</i> (Gilg & Schellenb.) Stearn	Oleaceae	S	AB	DB012
17	<i>Clausena anisata</i> (Willd.) Benth.	Rutaceae	S	DB	DB013
18	<i>Clutia abyssinica</i> Jaub. & Spach.	Euphorbiaceae	S	DB	DB014
19	<i>Clutia lanceolata</i> Forssk.	Euphorbiaceae	S	DB	DB015
20	<i>Cordia africana</i> Lam.	Boraginaceae	T	ODB	-
21	<i>Crotalaria emarginella</i> Vatke	Fabaceae	S	DB	DB016
22	<i>Crotalaria lachnophora</i> Hochst. ex A. Rich.	Fabaceae	S	DB	DB017
23	<i>Croton macrostachyus</i> Del.	Euphorbiaceae	T	DB	DB018
24	<i>Cupressus lusitanica</i> Mill.	Cupressaceae	T	DB	DB019
25	<i>Cupressus phiyramidalis</i> Mill.	Cupressaceae	T	ODB	-
26	<i>Delonix elata</i> (L.) Gamble	Fabaceae	T	ODB	-
27	<i>Discopodium penninervium</i> Hochst.	Solanaceae	S	DB	DB020
28	<i>Dovyalis abyssinica</i> (A. Rich.) Warb.	Flacourtiaceae	S	DB	DB021
29	<i>Dovyalis caffra</i> (Hook. f. & Harv.) Hook. f.	Flacourtiaceae	S	ODB	DB022
30	<i>Dovyalis verrucosa</i> (Hochst.) Warb.	Flacourtiaceae	S	DB	DB023
31	<i>Dracaena steudneri</i> Engler	Dracaenaceae	T	ODB	-
32	<i>Ekebergia capensis</i> Sparrm.	Meliaceae	T	DB	DB024
33	<i>Embelia schimperii</i> Vatke	Myrsinaceae	L	DB	DB025
34	<i>Erica arborea</i> L.	Ericaceae	T	DB	DB026
35	<i>Erythrina brucei</i> Schweinf.	Fabaceae	T(E)	ODB	-
36	<i>Eucalyptus globulus</i> Labill.	Myrtaceae	T	ODB	-
37	<i>Euphorbia abyssinica</i> Gmel.	Euphorbiaceae	T	DB	DB027
38	<i>Euphorbia ampliphylla</i> Pax	Euphorbiaceae	T	AB	-

39	<i>Ficus sur</i> Forssk.	Moraceae	T	DB	DB028
40	<i>Flacourtia indica</i> (Burm.f) Merr.	Flacourtiaceae	T	AB	-
41	<i>Galiniera saxifraga</i> (Hochst.) Bridson	Rubiaceae	T	DB	DB029
42	<i>Gnidia glauca</i> (Fresen.) Gilg	Thymelaceae	T/S	SD	-
43	<i>Hagenia abyssinica</i> (Bruce) J.F. Gmel.	Rosaceae	T	ODB	DB030
44	<i>Halleria lucida</i> L.	Scrophulariaceae	S	DB	DB031
45	<i>Helichrysum argyranthum</i> O. Hoffm.	Asteraceae	S	DB	DB032
46	<i>Helichrysum foetidum</i> (L.) Moench.	Asteraceae	S	AB	-
47	<i>Helichrysum forsskahlii</i> (J.F. Gmel.) Hilliard & Burt	Asteraceae	S	AB	-
48	<i>Helichrysum meyeri-johannis</i> Engl.	Asteraceae	S	AB	-
49	<i>Heteromorpha arborescens</i> (Spreng.) Cham. & Schltldl. var. <i>abyssinica</i> (A. Rich.) H. Wolff	Apiaceae	S	DB	DB033
50	<i>Hibiscus ludwigii</i> Eckl. & Zeyh.	Malvaceae	S	AB	-
51	<i>Hypericum quartinianum</i> A. Rich.	Hypericaceae	S	ODB	-
52	<i>Hypericum revolutum</i> Vahl	Hypericaceae	S	DB	DB034
53	<i>Ilex mitis</i> (L.) Radlk.	Aquifoliaceae	T	DB	DB035
54	<i>Jasminum abyssinicum</i> Hochst. ex DC.	Oleaceae	L	DB	DB036
55	<i>Jasminum grandiflorum</i> L. subsp. <i>floribundum</i> (R.Br. ex Fresen.) P.S.Green	Oleaceae	L	DB	DB037
56	<i>Jasminum stans</i> Pax	Oleaceae	S (E)	DB	DB038
57	<i>Juniperus procera</i> Hochst. ex Endl.	Cupressaceae	T	DB	DB039
58	<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	Acanthaceae	S	ODB	DB040
59	<i>Landolphia buchananii</i> (Hall.f.) Stapf	Apocynaceae	L	DB	DB041
60	<i>Lantana trifolia</i> L.	Verbenaceae	S	AB	-
61	<i>Lippia odoennis</i> Hochst. ex Walp. Var. <i>odoensis</i>	Verbenaceae	S (E)	DB	DB042
62	<i>Maesa lanceolata</i> Forssk.	Myrsinaceae	T/S	DB	DB043
63	<i>Maytenus addat</i> (Loes.) Sebsebe	Celasteraceae	T(E)	DB	DB044
64	<i>Maytenus arbutifolia</i> (A. Rich.) Wilczek	Celasteraceae	T	DB	DB045
65	<i>Maytenus obscura</i> (A.Rich.) Cuf.	Celasteraceae	T	AB	-
66	<i>Maytenus undata</i> (Thunb.) Blakelock	Celasteraceae	T	DB	DB046
67	<i>Millettia ferruginea</i> (Hochst.) Bak.	Fabaceae	T(E)	ODB	-
68	<i>Myrica salicifolia</i> A. Rich.	Myricaceae	T	ODB	DB047
69	<i>Myrsine africana</i> L.	Myrsinaceae	S	DB	DB048
70	<i>Myrsine melanophloeos</i> (L.) R. Br.	Myrsinaceae	T	DB	DB049
71	<i>Nerium oleander</i> L.	Apocynaceae	S	ODB	DB050
72	<i>Nuxia congesta</i> R. Br. ex Fresen.	Loganiaceae	T	DB	DB051
73	<i>Olea europaea</i> L. subsp. <i>cuspidata</i> (Wall. ex G. Don.) Cif.	Oleaceae	T	DB	DB052
74	<i>Olinia rochetiana</i> A. Juss.	Oliniaceae	T	DB	DB053
75	<i>Osyris quadripartita</i> Decn.	Santalaceae	S	DB	DB054
76	<i>Otostegia tomentosa</i> A.Rich subsp. <i>ambigens</i> (Chiov.) sebal	Lamiaceae	S	SD	DB055
77	<i>Pentas lanceolata</i> (Forssk.) Defl.	Rubiaceae	S	DB	DB056
78	<i>Pentas schimperiana</i> (A. Rich.) Vatke subsp.	Rubiaceae	S	DB	DB057

	<i>Schimperiana</i>				
79	<i>Periploca linearifolia</i> Quart. Dill & A. Rich.	Asclepiadaceae	L	DB	DB058
80	<i>Phoenix reclinata</i> Jacq.	Palmae	T	ODB	DB059
81	<i>Phytolacca dodecandra</i> L'Herit	Phytolaccaceae	L	DB	DB060
82	<i>Pinus radiata</i> D. Don.	Pinaceae	T	DB	DB061
83	<i>Pittosporum viridiflorum</i> Sims	Pittosporaceae	T	DB	DB062
84	<i>Podocarpus falcatus</i> (Thunb) Mirb.	Podocarpaceae	T	DB	DB063
85	<i>Prunus africana</i> (Hook. f.) Kalkm.	Rosaceae	T	DB	DB064
86	<i>Pterocephalus frutescens</i> Hochst. ex A. Rich subsp. <i>frutescens</i>	Dispacaceae	S	SD	-
87	<i>Pterolobium stellatum</i> (Forssk.) Brenan	Fabaceae	S	DB	-
88	<i>Rhamnus prinoides</i> L' Herit	Rhamnaceae	S	DB	DB065
89	<i>Rhamnus staddo</i> A. Rich.	Rhamnaceae	S	DB	DB066
90	<i>Rhus glutinosa</i> A.Rich.subsp. <i>glutinosa</i>	Anacardiaceae	T(E)	DB	DB067
91	<i>Rhus ruspolii</i> Engl.	Anacardiaceae	T	AB	-
92	<i>Rhus vulgaris</i> Meikle	Anacardiaceae	S	AB	-
93	<i>Rosa abyssinica</i> Lindley	Rosaceae	L	DB	DB068
94	<i>Rubus apetalus</i> Poir.	Rosaceae	L	ODB	DB069
95	<i>Rubus steudneri</i> Schweinf.	Rosaceae	L	DB	DB070
96	<i>Rumex nervosus</i> Vahl	Polyganaceae	S	DB	DB071
97	<i>Rytigynia neglecta</i> (Hiern) Robyns var. <i>vatkeana</i> (Hiern) Verdc	Rubiaceae	S(E)	DB	DB072
98	<i>Satureja imbricata</i> (Forssk.) Briq.	Lamiaceae	S	SD	-
99	<i>Satureja punctata</i> (Benth.) Briq.	Lamiaceae	S	DB	DB073
100	<i>Schefflera abyssinica</i> (Hochst.) ex A.Rich.) Harms	Araliaceae	T	SD	-
101	<i>Schinus molle</i> L.	Anacardiaceae	T	ODB	-
102	<i>Scolopia theifolia</i> Gilg	Flacourtiaceae	T	DB	DB074
103	<i>Senna didymobotrya</i> (Fresen.) Irwin & Barneby	Fabaceae	S	ODB	DB075
104	<i>Sida schimperiana</i> Hochst. ex A. Rich.	Malvaceae	S	DB	DB076
105	<i>Sida tenuicarpa</i> Vollesen	Malvaceae	S	AB	-
106	<i>Sideroxylon oxyacanthum</i> Baill.	Sapotaceae	S	DB	DB077
107	<i>Teclea nobilis</i> Del.	Rutaceae	T/S	DB	DB078
108	<i>Urera hypselodendron</i> (A. Rich.) Wedd.	Urticaceae	L	DB	DB079
109	<i>Vernonia amygdalina</i> Del.	Asteraceae	S	ODB	DB080
110	<i>Vernonia bipontini</i> Vatke	Asteraceae	S	ODB	DB081
111	<i>Vernonia hochstetteri</i> Sch. Bip. ex Walp.	Asteraceae	S	DB	DB082
112	<i>Vernonia leopoldi</i> (Sch. Bip. ex Walp.) Vatke	Asteraceae	S(E)	DB	DB083

T= trees; **S** = shrubs; **T/S** = tree or shrub; **L**= Liana; **E** = Endemic species, where as **ODB** = out of quadrat within this study; **DB** = collected and identified in the quadrat in this study; **AB** = collected by Abate Zewdie (2006), **SD**= collected by Sebsebe Demissew, (1980) or/and Sebsebe Demissew, (1988).

Appendix 2. Family, Genera and Species distribution of woody plants in Menagesha Suba State Forest.

N_o	Family Name	Number of Genera	Number of species	% total
1	Fabaceae	9	12	10.62
2	Asteraceae	2	8	7.08
3	Euphorbiaceae	3	5	4.42
4	Flacourtiaceae	3	5	4.42
5	Oleaceae	3	5	4.42
6	Rosaceae	4	5	4.42
7	Anacardiaceae	2	4	3.54
8	Celasteraceae	1	4	3.54
9	Myrsinaceae	3	4	3.54
10	Rubiaceae	3	4	3.54
11	Apocynaceae	3	3	2.65
12	Cuppressaceae	2	3	2.65
13	Malvaceae	2	3	2.65
14	Lamiaceae	2	3	2.65
15	Acanthaceae	2	2	1.77
16	Asclepiadaceae	2	2	1.77
17	Ericaceae	2	2	1.77
18	Hypericaceae	1	2	1.77
19	Rhamnaceae	1	2	1.77
20	Rutaceae	2	2	1.77
21	Verbenaceae	2	2	1.77
23	30 families each with	1	1	0.88
Total	51 Families	84	112	100

Appendix 3. Diversity of woody species in study area

Quad-rat	Richness (S)	Evenness (E)	Shannon (H)	Quad-rat	Richness (S)	Evenness (E)	Shannon (H)
1	15	0.912	2.470	40	12	0.929	2.309
2	15	0.905	2.450	41	10	0.889	2.048
3	19	0.948	2.792	42	7	0.850	1.654
4	17	0.958	2.715	43	11	0.904	2.167
5	12	0.864	2.147	44	14	0.904	2.385
6	16	0.960	2.663	45	13	0.937	2.403
7	13	0.914	2.343	46	16	0.903	2.505
8	20	0.902	2.704	47	24	0.932	2.963
9	15	0.906	2.453	48	25	0.908	2.924
10	16	0.929	2.576	49	20	0.923	2.764
11	15	0.990	2.680	50	16	0.906	2.512
12	15	0.944	2.557	51	17	0.888	2.515
13	9	0.948	2.083	52	12	0.940	2.336
14	14	0.965	2.546	53	14	0.904	2.385
15	12	0.905	2.248	54	16	0.941	2.608
16	15	0.906	2.453	55	14	0.933	2.463
17	12	0.910	2.261	56	13	0.936	2.400
18	17	0.927	2.626	57	16	0.927	2.569
19	12	0.946	2.350	58	17	0.930	2.635
20	18	0.916	2.647	59	24	0.946	3.005
21	16	0.934	2.589	60	18	0.915	2.644
22	14	0.950	2.508	61	16	0.900	2.496
23	14	0.948	2.502	62	23	0.903	2.832
24	13	0.957	2.455	63	12	0.904	2.248
25	17	0.929	2.632	64	19	0.910	2.680
26	21	0.929	2.829	65	16	0.866	2.401
27	23	0.934	2.927	66	19	0.927	2.730
28	19	0.918	2.704	67	20	0.923	2.765
29	21	0.935	2.848	68	11	0.925	2.218
30	19	0.949	2.794	69	25	0.906	2.915
31	20	0.952	2.852	70	18	0.928	2.683
32	19	0.914	2.692	71	18	0.951	2.750
33	19	0.923	2.719	72	20	0.932	2.791
34	20	0.917	2.747	73	16	0.893	2.477
35	23	0.907	2.844	74	22	0.929	2.873
36	17	0.882	2.499	75	20	0.923	2.764
37	20	0.921	2.760	Mean	17	0.922	2.57
38	16	0.909	2.520				
39	14	0.907	2.393				

Appendix 4. Altitude, latitude, longitude, aspect, location of quadrats and of transects.

Transect	Quadrats	Aspect (AS)	Latitude (E)	Longitude (N)	Altitude (m)	Transect	Quadrat	Aspect (AS)	Latitude (E)	Longitude (N)	Altitude (m)
ONE	1	W	32° 17.2'	57° 56.7'	2450	TWO	38	W	31° 58.9'	57° 55.2'	2467
	2	W	32° 19.9'	57° 57.4'	2477		39	W	32° 01.7'	57° 59.2'	2469
	3	N	32° 22.3'	57° 59.9'	2415		40	W	32° 03'	58° 01.5'	2396
	4	N	32° 25.8'	58° 00.6'	2413		41	W	32° 05.6'	58° 02.9'	2404
	5	W	32° 29.35'	57° 58.25'	2437		42	W	32° 09.2'	58° 02.9'	2414
	6	NW	32° 32.9'	57° 59.9'	2461		43	W	32° 12.8'	58° 03.3'	2424
	7	NW	32° 36.4'	58° 00.6'	2484		44	SE	32° 19.1'	58° 04'	2410
	8	E	32° 39'	58° 02.2'	2504		45	SE	32° 18.8'	58° 04.4'	2422
	9	E	32° 45.3'	58° 02.1'	2512		46	SE	32° 25.4'	58° 01.7'	2424
	10	E	32° 45.6'	58° 02.4'	2548		47	SE	32° 25.6'	58° 01.8'	2434
	11	SE	32° 45.3'	58° 02.2'	2546		48	SE	32° 28.2'	58° 02.8'	2404
	12	SE	32° 49.3'	58° 02.3'	2570		49	SE	32° 35.8'	58° 05.2'	2469
	13	S	32° 51.3'	58° 01.4'	2588		50	SE	32° 39.4'	58° 05.5'	2464
	14	S	32° 56.2'	58° 02.8'	2598		51	SE	32° 45'	58° 06.1'	2457
	15	S	33° 00.3'	58° 03.6'	2612		52	E	32° 43.6'	58° 07'	2472
	16	S	33° 06.6'	58° 50.7'	2624		53	E	32° 49.5'	58° 08.8'	2485
	17	S	33° 04.8'	58° 07.9'	2631		54	SE	32° 53.2'	58° 09.5'	2528
	18	S	33° 12.6'	58° 09.1'	2628		55	SE	32° 54.9'	58° 11.6'	2555
	19	S	33° 15'	58° 07.6'	2660		56	S	32° 59.4'	58° 11.7'	2564
	20	S	33° 17.4'	58° 07.4'	2674		57	S	33° 02.2'	58° 14.4'	2572
	21	S	33° 19.7'	58° 07.1'	2655		58	W	33° 06'	58° 16'	2584
	22	S	33° 24.1'	58° 05.6'	2723		59	W	33° 08.6'	58° 17.1'	2660
	23	S	33° 27.6'	58° 05.5'	2699		60	W	33° 18.6'	58° 17.5'	2663
	24	S	33° 31.2'	58° 02.8'	2701		61	W	33° 16.5'	58° 17.4'	2674
	25	S	33° 35.1'	58° 00.2'	2770		62	W	33° 19.8'	58° 17.5'	2637
	26	S	33° 37'	58° 00.2'	2810		63	W	33° 21.1'	58° 18.4'	2666
	27	S	33° 41'	58° 00.4'	2842		64	W	32° 53.7'	57° 53.5'	2514
	28	S	33° 47'	58° 00.2'	2863		65	W	32° 54'	57° 52.2'	2564
	29	S	33° 50.7'	58° 00'	2860		66	W	32° 57.2'	57° 51.9'	2574
	30	S	33° 54.5'	57° 59.4'	2855		67	W	32° 59.6'	57° 50.7'	2596
	31	S	33° 58.1'	57° 59.8'	2873		68	E	33° 04'	57° 55.4'	2581
	32	S	34° 01'	57° 57.8'	2875		69	E	33° 07.9'	57° 54.6'	2553
	33	S	34° 04.6'	57° 59.7'	2877		70	E	33° 11.9'	57° 53.8'	2672
	34	S	34° 06.3'	58° 01.9'	2890		71	E	33° 15.8'	57° 55.8'	2650
	35	S	34° 10.9'	58° 01.9'	2896		72	E	33° 19.2'	57° 55.2'	2667
	36	S	34° 11.7'	58° 04.3'	2910		73	E	33° 23.5'	57° 55.2'	2763
	37	S	34° 18.5'	58° 00.1'	2951		74	E	33° 26.3'	57° 54.2'	2712
					75	E	33° 28.1'	57° 54.6'	2716		

Declaration

I, the undersigned, declare that this thesis is my original work and all that sources of materials used for the thesis have been fully acknowledged. I also confirm that this work has not been submitted anywhere else for the same purpose.

Name Dinkissa Beche Benti

Signature _____

This thesis has been submitted for examination with my approval as University advisor.

Prof. Sebsebe Demissew

Signature _____

Date _____

Place and date of submission

Addis Ababa University

July, 2011