FLORISTIC COMPOSITION AND DIVERSITY ANALY SIS OF VEGETATION AT ABA ASRAT MONASTERY FOREST, EAST GOJJAM, ETHIOPIA

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June 2013

ADDIS ABABA UNIVERSITY

GRADUATE PROGRAMMES

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Master of Science (MSc)

Addis Ababa University, 2013

ABSTRACT

The study was conduct at Aba Asrat Monastery Forest in Debre Markos District, East Gojam Zone, Amahara Region, Northwestern Ethiopia. The objective of this study was to determine the floristic composition, plant community and regeneration status of the forest .Sixty two quadrates of 10mx10m (100m$^{2)}$ were laid along ten lines transects for vegetation data collection. In addition 1mx1m subplots wereliad with in the main plot to sample herbaceous plants. A total of 120 plant species in 96 genera and 53 families were identifeied. Family Asteraceae had eleven (9.17%) species followed by Fabaceae nine (7.5%) species, Poaceae six (5%) species and Lamiaceae five (4.17%) species. Vegetation classification following R 2.11.1 software package resulted in five communities namely: Rosa abysinica_Acacia pilispina Community type,Urera hypselodendron-Phytolacca dodeccandra community type,Allophylus abysinicus-Cluita abysinica community type, Acanthus pubescens-Combretum molle community type and Croton macrostachyus-Pavetta abysinica community type. Sorensen's similarity analysis among the communities revealed that community type 1 and 5 have the highest similarity (66%) followed by community type 3 and 5 which exhibited 57% similarity. From twelve representative woody species a total of 230 seedlings/ha, 184 saplings/ha and 63/ha mature individuals/ha were counted in the sample plots. Two population distribution patterns were revealed i.e. Inverted J -shape and bell-shaped. Moreover, there were more seedlings than saplings which could be attributed to factors that prevent the seedlings from reaching sapling stage. These factors may include expansion of farmlands, browsing by animals and prolonged dry period. On the other hand, some woody species lacked seedlings and saplings in the AAM. Based on the current study clear demarcation and raising awareness among the surrounding community are deemed necessary.

Key words/Phrases: Aba Asrat Monastery, Endemic species, Floristic composition, Plant community and Regeneration

Acknowledgments

I would like to express my deepest gratitude to my advisors Prof. Ensermu Kelbessa and Dr. Teshome Soromessa for their continuous support, guidance and providing constructive comments throughout the study. I have benefited a lot from their wealth of experiences and have been role model for my future career. I am very grateful to Department of Plant Biology and Biodiversity Management program and Addis Ababa University, which made this study possible by financing all the expenses required for the study. My sincere appreciation also goes to all staff members of the National Herbarium (ETH) for their collaboration during plant specimens' identification.

My Special thanks go to all of my friends for supporting me in all means they could. Last but not least, my special thanks are reserved for my parents for their strong moral support and good wish to my achievement.

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ACRONYMS

AAM	Aba Asrat Monastery
AAU	Addis Ababa University
BA	Basal Area
DBH	Diameter at Breast Height
EFAP	Ethiopian Forestry Action Plan
EPA	Environmental Protection Authority
EWNHS	Ethiopia Wildlife and Natural History Society
FAO	Food and Agriculture Organization
GPS	Geographical Position System
IBC	Institute of Biodiversity Conservation
IVI	Importance Value Index
M.A.S.L	Meter above Sea Level
MOA	Ministry of Agriculture
NBSAP	National Biodiversity Strategy and Action Plan
NMSA	National Meteorological Service Agency
PA	Peasant Association
RD	Relative Density
RDO	Relative Dominance
RF	Relative Frequency
SIVI	Species Important Value Index
SNNPRS	Southern Nations and Nationalities and Peoples Regional State
UNDESA	United Nations Department of Economic and Social Affairs
USAID	United States Agency for International Development
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WCMC	World Conservation Monitoring Center

CHAPTER ONE

1. INTRODUCTION

Ethiopia is found in the Horn of Africa and located between $3^{0}24^{'}$ and $14^{0}53^{'}$ North and $32^{0}42^{'}$ and $48^{0}12^{'}$ East with a total area of 1.12 million km^2 and possesses a wide range of geomorphic province with ecological and socio-cultural variations (MoA, 2000). It has a diverse ecosystem, ranging from humid forests and extensive wetlands in the west and south west to the desert of Afar depression in the northeast. The altitudinal range of the country varies from 110 m below sea level at Kobar Sink in Afar to 4620 m.a.s.l. at the highest peak of Ras Dejen (IBC, 2008).

The highland plateau of Ethiopia with an altitude of above 2500 m covers 40% of the country (EFAP, 1994; Zerihun Woldu, 1999). The topography and diverse climatic conditions of Ethiopia led to the emergence of habitats that are suitable for evolution. These have led to the occurrence of some unique plant and animal species and their assemblages. As a result, Ethiopia is one of the countries in the world with high level of biodiversity and also it is one of the most significant countries for Africa (Urban and Brown, 1971). Due to the long history of agriculture and the diversity of the environment, Ethiopia is again one of the 12 Vavilov centers of crop genetic diversity (Vavilov, 1951; Harlan, 1969).

Historical sources depict that extensive forest once covered some 35% of Ethiopia's land area. If the savanna woodland is included, two-thirds of the country was probably forested or was covered with woodland. These habitats have dramatically declined in size and quality in the last century. By the beginning of the early 1950's, high forest areas were reduced to 16% of the total land area; by the early 1980's, land area covered by forest had declined to 3.6 %; by 1989, it was reduced to about 2.7% (Million Bekele and Leykun Berhanu, 2001).

Forest reduction in Ethiopia is mostly attributable to anthropogenic factors. The most prominent ones are deforestation, expansion of agricultural land, overgrazing, unsustainable utilization and invasion of exotic species (Chaffey, 1980; Shibru Tedla, 1995; Million Bekele and Leykun Berhanu, 2001; Feyera Senbeta and Demel Teketay, 2003; Teshome Soromessa *et al.,* 2004).

The disturbances created by these activities influence the vegetation dynamics and tree density at the local and regional scales which are important in structuring plant communities (Hubbell *et al*., 1999). Reduction in forest cover has a number of consequences including soil erosion and reduced capacity for watershed protection with possible flooding, reduced capacity for carbon sequestration, and loss of biodiversity. The depletion of the natural vegetation in many parts of the country has also led to threat and decline in number and distribution of many plant species (Tesfaye Bekele, 2000). According to Ensermu Kelbessa *et al.* (1992), 120 threatened endemic plant species are known from Ethiopia, thirty five of these species were from the Dry Afromontane forests of the country.

In the face of these problems ecologists and conservation biologists have required to protect forest vegetation using different strategies from strict protection in the national parks to suitable management and other integrated conservation and development programs (Borgerhoff and Coppolillo, 2005).

Aba Asrat Monastery Forest is one of Ethiopian Monastery forest which found in Debre Markos District, Amhara Region, East Gojam Zone, North western Ethiopia. This Monastery forest has much agro ecological diversity. However, until now there is no undertaken any floristic composition documentation and other ethnobotanical and ecological study in this Monastery forest. Inlight of this, the generation of sound biodiversity and ecological data on the remaining high quality habitat area is necessary for subsequent conservation activities. Therefore, this study investigates the floristic composition and vegetation analysis of the area.

1.1. Statement of the problem

The availability of accurate data on forest resources is an essential requirement for forest management and planning within the context of sustainable development (FAO, 2007). Botanical assessments such as floristic composition and structure studies are essential in view of their value in understanding the extent of plant diversity in forest ecosystem (WCMC, 1992). Knowledge of floristic composition and structure of forest resources is also useful in identifying important elements of plant diversity, protecting threatened and endemic species (Segawa and Nkuutu, 2006). The study of floristic composition and structure of tropical forest becomes more imperative in the face of ever increasing threat to the forest ecosystem. Reduction in forest cover has a number of consequences including soil erosion and reduction capacity for carbon sequestration, loss of biodiversity and instability of ecosystems and reduced availability of various wood and non-wood forest products and services (Alemu Mekonnen and Bluffstone, 2007).

In order to maintain ecological equilibrium and to meet the forest product requirements, such information is obtained by assessing the properties of various sites in the forest. There is also low information and poor management system of the forest before and that may lead to destruction of plant species. Thus, the present study aims to add micro ledge in revealing to floristic compositio n and structure of the forest at Aba Asrat Monastery and identifying the important elements of plant diversity including an endemic plants.

1.2. Objectives

1. 2.1. General objective

- To investigate the floristic composition, structure and regeneration status of Aba Asrat Monastery Forest.

1.2.2. Specific objectives

- To document the floristic composition of Aba Asrat Monastery Forest
- To classify the vegetation in to plant community types,
- To analyze the vegetation structure of Aba Asrat Monastery,
- To determine the regeneration status of some selected species and
- To provide information for the future management of the Forest.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Background of Ethiopian forest

According to EFAP (1994), historical sources indicate that high forests might have once covered about 35-40 % of the total land area of the country. If the savannah woodlands are included, 66 % of the country was believed to have been covered with forests and woodlands. However, the country's forest and woodland resources have been declining both in size (deforestation) and quality (degradation). As a result, it has been estimated that high forests covered 16 % of the land area in the early 1950's, 3.6 % in early1980's and only 2.7 % in 1989 (EFAP, 1994). Some 5 million/ ha savannah woodlands were remaining at that time giving a total forest and woody vegetation area of 7 %. In 1994, it has been estimated that such forests cover less than 2.3 % of the country (EFAP, 1994). Various estimates of the forest cover of Ethiopia were reported, Accordingly, the forest covers in Ethiopia is declining and estimated to be less than 4% compared, for example, with an average of 20% for sub-Saharan Africa (WBISPP, 2004; Earth Trends, 2007). Reusing (1998 & 2000) using LANDSTAT/MSS showed that the extent of forest/vegetation cover of Ethiopia based on density classes, i.e., closed high forest, slightly disturbed high forest and heavily disturbed high forest. Therefore, the forest cover of Ethiopia (including all the three types) was 1.41% in 1996-1997.

2.2. Vegetation of Ethiopia

Vegetation is an assemblage of plants growing together in a particular area, or in other words the collective plant cover of an area (Jennings *et al*., 2003). The vegetation cover of a given area has a definite structure and composition, which is developed because of the long term interaction between biotic and abiotic factors. The pattern of distribution and vertical stratification of vegetation fluctuate due to different climatic zones, soil types, latitude and topography of the area. These in turn influence the distribution and type of plants and animals in the forest.

The Ethiopian highlands contribute to more than 50% of the land area with Afromontane vegetation, of which dry montane forests form the largest part (Yalden, 1983; Tamrat Bekele, 1994). The evergreen scrubland vegetation occurs in the highlands of Ethiopia either as an intact scrub, i.e. in association with the dry evergreen montane forest or usually as secondary growth after deforestation of the dry evergreen montane forest. Ethiopia, because of its geographical position, ranges of altitude, rainfall pattern and soil variability has an immense ecological diversity and a huge wealth of biological resources. This complex topography attributed from its geological formation coupled with environmental heterogeneity offers suitable environments for a wide range of life forms both flora and fauna (Zerihun Woldu, 1999; Gete Zeleke, 2003).

2.2.1. Vegetation types in Ethiopia

Various a uthors ha ve been a ttempted t o s tudy t he E thiopian f orests a nd w oody ve getation resources e mploying di fferent s ystems, a mong which) Logan (1946), Zerihun W oldu (1985), Lisanwork Nigatu (1987), Zerihun Woldu *et al.* (1989), Friis and Mesfin Tadesse (1990), Friis (1986, 1992), EFAP (1994), Tamrat Bekele (1993 & 1994), Demel Teketay and Tamrat Bekele (1995), Sebsebe Demissew *et al*., (1996), Friis and Sebsebe (2001), Kumilachew Yeshitila and Tamrat Bekele (2002) ,Tadesse Wolde Mariam (2003)and Friis *et al*., (2010), have made conside rable c ontributions t oward unde rstanding t he vegetation of t he c ountry a nd pr oposed t heir conservation strategies. Recent studies (Simon Shibru and Girma Balcha, 2004 , Genene Bekele, 2005, Abate Ayalew *et al*., 2006; Alemu Abebe, 2007 and Dereje Denu, 2007; Kitessa Hundera and Tsegaye Gadissa, 2008; Haile Yineger *et al*., 2008 and Ensermu Kelbessa and Teshome Soro messa, 2008) provided general description of the vegetation types and their floristic composition in different parts of Ethiopia. Based on the works of these and other authors the various vegetatio n types of Ethiopia have been grouped in different categories.

Accordingly, the various natural vegetation types of the Flora area of Ethiopia have been divided into eight major ecosystems which are described as follows: Desert and semi-desert scrubland, *Acacia- Commiphora woodland*, M oist M ontane r ainforest (which i ncludes the A fromontane rainforest and the Transitional rainforest), Low land semi-evergreen forest, *Combretum teminalia woodland* and Savannah, Dry evergreen montane forest and Grassland complex, which can also be divided into four subtypes namely: Undifferentiated Afromontane forest, Dry single Dominan t Afromontane of the Ethiopia Highlands, Afromontane woodland, wooded grassland and grassla nd, Afro alpine and sub-afro alpine vegetation and Riparian and Swamp vegetation (Friis, 1992;

EFAP, 199 4; N BSAP, 2005; A lemu A bebe, 2007; W oldeyohannes Enkossa, 20 08) a s i t ha s similar climatic and physical features to the southwestern parts of the country.

2.2.1.1. Dry Evergreen Montane forest of Ethiopia

The Ethiopian highlands are the largest mountain complex in Africa and comprise over 50% of the African land area covered by Afromontane vegetation, of which dry afromontane forests for m the largest part (Tamrat Bekele, 1993; Demel Teketay, 1996). Dry Evergreen Montane Forest is a very complex vegetation type occurring roughly above 1500 m and below 3200 m in altitude , with average annual temperature and rainfall of 14-25C^0 and 700-1100 mm respectively (Friis, 1992; Z erihun W oldu, 1999) . It is inhabited by t he m ajority of the E thiopian popu lation a nd represents a zo ne o f sed entary ce real-based m ixed a griculture for cen turies. T his t ype o f f orest develops in areas of relatively high humidity, but not much rain, and where there is a prolonged dry season. The forests have diminished due to human interference and replaced by grasslands in flatter areas with deep soil and by bushlands on steeper slopes with thin soil. Soils have become s hallow as a result of soil erosion that has been taking place for centuries (Ensermu Kelbessa *et al* ., 1992; Zerihun Woldu, 1999). In such type of forests, the canopy is usually dominated by *Podo carpus falcatus*; *Juniperus procera*, *Croton macrostachyus*, and *Olea europaea* subsp. *cuspidata*, true lianas, epiphytes including *Peperomia*, ferns and orchids are common. The ground cover is rich in ferns, grasses, sedges and small herbeouceous cotyledons. At the upper limits *Erica arbor ea*, *Hagenia abyssinica*, *Hypericum revolutum, Myrsine africana*, *Myrsine melanophloeos, Rosa abyssinica*, *Nuxia congesta* and clumps of *Arundinaria alpina* are also common (Friis, 1992).

The prominent features of tropical dry forests are their seasonality with respect to rainfall compar ed with the rain forests where the environment is stable throughout the year. Dry evergreen monta ne forests experience long dry seasons (4-8 months) and the rainy period is somewhat unreliable. During the dry season, not only moisture stress but also temperature increases and daytime humidity drops and watercourses either dry up or greatly diminish inflow (Demel Teketay, 1996). Degradation in this zone is very high and even severe in the northeastern Ethiopia where, forests have virtually disappeared, as a result most of the mountains sides are bare, valleys have been gullied, and springs and streams, which used to have water the whole year round are now dry in the dry season (Abate Ayalew *et al*., 2006).

The characteristic plant species in this vegetation type include; *Olea europaea* subsp. *cuspidata*, *Juniperus procera*, *Podocarpus falcatus*, *Ilex mitis* and *Erica arborea*. The shrubs occurring in th is vegetation type include; *Carissa spinarum* and *Dodonaea angustifolia* (Zerihun Woldu, 1999). Treatened endemic plant species in dry forest are *Acalypha marissima*, *Maytenus addata, Pentas concinna, Rubus aethiopicus,* and *Sedum epidendron* (Ensermu Kelbessa *et al*., 1992).

2.2.1.2. Moist Evergreen Montane forest

The moist evergreen montane forest consists of high forests of the country mainly the southwest forests, wettest and also humid forest in the southeastern plateau known as the Harenna forest (Ermias Lulekal, 2005). Many other researchers (for example, Lisanework Nigatu and Mesfin

Tadesse, 1989; Zerihun Woldu *et al*., 1989; Friis, 1992; Kumilachew Yeshitila, 1997; Woldeyoh annes Enkossa 2008, Ensermu Kelbessa and Teshome Soromessa, 2008) have also studied the composition and structure of this forest type. This forest occurs mainly in the southwestern part of the country (Wollega, Illubabor and Kafa) with altitudinal ranges of 1500-2500 m a.s.l., average annual temperature of 18-20C^0 and annual rainfall between 1500-2000 mm sometimes even higher than 2000 mm, with rain all the year round, but a maximum in April-October (Friis *et al*., 1982; Friis, 1992; Tadesse Woldemariam, 2003; NBSAP, 2005; Feyera Senbeta, 2006). The moist forest ecosystem is the most diverse ecosystem in composition, structure and habitat types (NBSAP, 2005); consequently it is rich in biodiversity with a number of endemic species.

The characteristic plant species in this vegetation type include the largest and commercially most important trees associated with broad-leaved species of which the most frequent emergent species and also the most upper canopy trees such as *Podocarpus falcatus*, *Celtis africana*, *Schefflera abyssinica*, *Mimusops kummel*, *Millettia ferruginea*, *Croton macrostachyus*, *Albiza gummifera, Ficus ovata*, *Ficus thonningii*, *Syzygium guineense* subsp. *afromontanum*, *Ekebergia capensis* and *Olea welweitschii*. The lower storey trees and shrubs include: *Maesa laceolata*, *Bersama abyssinica, Ehretia cymosa*, *Clausena anisata*, *Cordia africana*, *Matyenus gracilipes*, *Teclea nobilis*, *Trema orientalis*, *Nuxia congesta*, *Cassipourea malosana*, *Allophylus abyssinicum, Coffea arabica, Dracaena steudneri, Calpurnia aurea*, *Phoenix reclinata, Psychotria orophila, Olea capensis* subsp. *macrocarpa, Carissa spinarum* and *Rytigynia neglecta.* Lianas are common and include: *Jasmnium abyssinicus*, *Landolphia buchananii*, *Commbretum paniculatum*, *Urera hypselodendron*, *Embelia schimperii*, *Hippocratea goetzei, Periploca linearifolia, Tiliacora troupinii* and *Clematis hirsutum*. Acanthaceous species such as *Thunbergia alata*, *Hypoestes* spp., *Justicia ladanoides*, etc predominate in the herb layer within the forest and the grass species are common on the ground vegetation mainly *Oplismenus hirtellus.* Several ferns and epiphytes are found, some of which are Orchids, *Peproma abyssinica*, *Loxogramme abyssinica*, *Adiantium poi retii*, *Dryopteris* spp and *Asplenium* spp. T herefore, t he ve getation c over i n a gi ven a rea ha s definite structure and composition developed as a result of long term interaction with biotic and abiotic factors. The pattern of distribution and vertical stratification change attributed to varied climatic conditions, soil types, latitude and topography of the area which in turn influence the distribution and types of plant and animals in the forest (Mueller-Dombois and Ellenberg, 1974).

2.2.2. Threats to Ethiopian Vegetation

The Ethiopia vegetation, particularly the forest resources are under severe pressure as consequen ces of i nhabitants' n eed f or f armlands an d g razing lands. T here is a sev ere an d i ncreasing fuelwood gap in the country; which leads to depletion of the standing stock and, hence, further degradation of the remaining forest stands (EPA, 1997). The loss of forest resource is severe in the Ethiopian highlands where most of the vast mountain massifs in the heart of the country lie a bove 1500 m elevation. These highlands cover about 44% of Ethiopian land area; accommodate 88% of the total population because of their agricultural potential and low prevalence of diseases .They also contain about 95% cultivated land and more than 67% of the livestock (EFAP, 1994). The location of Ethiopian high forests on the zone of these densely populated highlands and their unique ecology make them endangered and more susceptible to strong deforestation of forest. Another threat is the conversion of high forest sites to coffee and tea plantations. Currently a nu mber of investors have filed applications for forest land with the regional authorities. In the proce ss of decision making on the requests in most cases little consideration is given to ecological imp acts in general and biodiversity conservation in particular (Taye Bekele *et al.*, 2002).

According to (FAO, 2006) the major threats to the conservation of the Ethiopian vegetation are increasingly intensive use of forestlands for agriculture and livestock, need of fuelwood and cons truction materials, forest fires and human settlement. These major causes of forest destruction are very much interrelated and most are ultimately initiated by the rapid population growth in the country.

2.3. Biodiversity in Ethiopia

Ethiopia is one of the world's richest biodiversity countries and it deserves attention regionally and globally. It has a very diverse set of ecosystems ranging from humid forest and extensive wetlands to the desert of the Afar depression. This is due to the variation in climate, topography and vegetation. Ethiopia is one of the twelve known ancient countries for crop plant diversities in the world and has valuable reserves of crop genetic diversity, of which 11 cultivated crops have their center of diversity in the country. The extensive and unique conditions in the highlands of the country have contributed to the presence of a large number of endemic species.

The flora of Ethiopia is very diverse with about 6000 vascular plant species of which about 10 pe rcent are endemic to Ethiopia (Ensermu Kelbessa, per.commun.).

2.3.1. The Status of Biodiversity in Ethiopia

The flora of Ethiopia is very heterogeneous and has a rich endemic element. It is estimated to contain about 6000 species of higher plants, of which about 10% are endemic. Endemism is particularly high in the high mountains and in the Ogaden and Borana lowlands. There is also great diversity of fauna in Ethiopia, owing to the diversity in climate, vegetation, and terrain. It is estimated that there are 281 species of mammals, 861 species of birds of which 29 species of mammals and 15 species of birds are endemic. There are about 201 species of reptiles of which 87 snakes, 101 lizards, one species of crocodile, and 13 species of tortoises and turtles and 9 of them are endemic and a total of 63 species of amphibians have also been recorded in Ethiopia of these 23 species are listed as endemic. Ethiopia has a very high genetic diversity of the world's widely grown food crops like wheat, barley, sorghum, peas, and industrial crops like linseed, castor bean and cotton and also cash crops like coffee. Ethiopians also use more than 100 medicinal plant species for their health care and plenty of indigenous knowledge related with the extraction and application of these plant resources which are the baseline for the modern pharmaceutical technologies (Ensermu Kelbessa, per.commun.).

The biodiversity of Ethiopia (and the extent to which it is currently threatened) has recently received appropriate recognition. The majority of the country now falls into one of two Biodivers ity Hotspots. Thus, the Ethiopian highlands comprise over 50% of the Eastern Afromontane Hotspot and over 40% of the Horn of Africa Hotspot falls within Ethiopia. However, the areas are among the most threatened Hotspots in the world. An estimated 97% of the natural vegetation of Ethiopian Highlands has been lost, with humans having significant impacts on an estimated 95% of the natural vegetation in the Horn of Africa (UNDP-GEF, 2005)

2.3.2. Threats on Biodiversity in Ethiopia

Ethiopia is one of the most diverse and important sources of biodiversity in the world for wild, cultivated, or domestic organisms due to its high number of endemic species, the genetic diversity of several cultivated crops, and the variety of breeds of cattle, goats, sheep, camels, horses and donkeys. However, the trees and forests of Ethiopia are under tremendous pressure because of the drastic decline in mature forest cover and the continual pressures of population increase, rudimentary farming techniques, land use competition, land tenure, and forest degradation and conversion, and the status of the forest resources should be considered at risk (USAID, 2008). In addition, due to extensive human influence on the biodiversity resource, the future fate of Ethiopia is under question with the current rapid rate of population growth and global climate change. Threats to Ethiopia's biodiversity, tropical forests, and resource base can be broadly linked to the following categories: limited governmental, institutional, and legal capacity; population growth; land degradation; weak management of protected areas; and deforestation (USAID, 2008).

Tropical deforestation is considered the second largest source of anthropogenic greenhouse gas emissions (Rademaekers *et al.,* 2010) and is expected to remain a major emission source for the foreseeable future (MEA, 2005). Despite policy efforts on reducing deforestation, around 13 million hectares of forests continue to be lost every year (FAO, 2006). The reduction of greenhouse gas emissions from tropical deforestation is now recognized as an essential component of international efforts to mitigate climate change. Africa's 635 million hectares of forests account for 21.4% of its land area and 16% of the global forest area. In total, some 23 million hectares of this forest disappeared in the 1980s while another 20 million hectares gave way for other land uses in the 1990s. Recent estimations show that another 4 million hectares of forest were deforested between 2000 and 2005, which is equivalent to one-third of the total deforested area on a global level. Yet, there are some indications that net loss of forest area has slowed down and that the areas of forest designated for conservation of biological diversity has increased slightly. However, it is a fact that the permanent, rapid loss of forest area occurring in Africa is representing the highest percentage of any region during the 1980s, 1990s and early 2000s (FAO, 2006).

Ethiopian biodiversity is being increasingly threatened and reduced, making Ethiopia is one of the most degraded mega biodiversity country in the world and the threats are multiple interconnected (Lightbourne, 2006). Human population densities have increased considerably in recent times due to various reasons, at rate faster than the ability of the land to support. As a result, in order to maintain basic living standards, natural resources have been used up faster than can be naturally replenished or before new sources have been found. The consequences of this unplanned and unsustainable use of natural resources, together with alterations to the climate and natural ecological processes, have been extensive land degradation, and loss of habitat together with the loss of valuable genetic reserves. Therefore now imperative that the degradation processes be halted, and even reserved, in order to ensure the sustainable utilization of the numerous ecosystems for the Ethiopian people, both present and future generations (Teshome Ashine, 1990).

Deforestation and subsequent cultivation of the tropical dry Afromontane forest has also endangered the native forest biodiversity, not only through the direct loss of habitat but also by deteriorating the soil seed banks (Mulugeta Lemenih and Demel Teketay, 2004). The greatest threat to biodiversity is the loss of habitat as human beings develop land for agriculture, grazing livestock, draining wetlands and unwise use of pesticides. As human populations increase their encroachment on natural habitats, they are having a detrimental effect on the very ecosystems on which they depend. In Ethiopia, the most drastic damage has occurred in the natural high altitude forests and their biological resources that once covered more than forty-two million hectares (Booth, 2004). There has been progressive deforestation in Ethiopia over the last 5000 years (since the beginning of agriculture in the country), which has accelerated tremendously during the last century as the country's population has grown. As a result of population increase, increased crop cultivation in marginal areas and increased livestock grazing pressure have also contributed to increased deforestation and soil erosion in the central highlands (Badege Bishaw, 2001). In the forested areas of the south and southwest, deforestation is occurring at a sustained rate with major forestry threats including resettlement, commercial farming and fire. In the eastern and southern lowlands, commercial agricultural investments, rangeland enclosures, (re)-settlement schemes, charcoal production and the relentless expansion of very aggressive invasive alien species are having a profound and detrimental effect on the natural resources availability, the traditional rangeland management systems and institutions in place and ultimately the livestock based pastoralist livelihoods of the Afar, Somali and Borana Oromo people. In this respect, the current agro-fuel investment scramble taking place in many lowland areas does not bode well for the future and stability of pastoralist livelihoods in Ethiopia. Other major ecosystems in Ethiopia (wetlands and afro-alpine areas) are also increasingly being threatened and degraded (McKee, 2007).

The forest cover of Ethiopia has suffered severe deforestation and degradation through heavy exploitation resulting from an escalating demand for fuel wood and land for cropping and grazing (Lisanework Nigatu and Mesfin Tadesse, 1989). Because of the nutrient content of ash and mobilization of some soil nutrients, crop yields increase after slash-and-burn forest clearing (Ehui and Hertel, 1992). This may motivate farmers unable to purchase the necessary agricultura l inputs to convert forest land to agriculture every year. As a result of such activities in much of Ethiopia, deforestation has generated both an energy crisis and fears of desertification on a national level. The causes for forest decline in south central Ethiopia is considered the combined result of socio-political changes, economic activities, population growth, cultural patterns and agricultural developments. Among other events that may alter the trajectory of change is the introduction and prioritization of certain crops. Many authors have shown how the emergence of coffee, haricot beans and chat intensified changes by promoting economic activities, establishment of new markets, immigration and settlement, all of which factors have contributed ultimately to forest decline (Roundy, 1985).

2.4. Plant Community

According to Kent and Cooker (1992), plant communities are the collection of plant species which are growing together in a particular location that shows a definite association with each other. It is the combination of plants that are dependent on their environment, influence one another and modify their own environment. Plant communities are largely based on physiognom y or the growth form of the vegetation. This is because they have similar requirements for existence in terms of environmental factors such as light, temperature, water, drainage and soil (Mueller-Dombois and Ellenberg, 1974).

2.4.1. Species diversity, species richness, evenness and similarity

The description of plant community involves the analysis of species diversity, evenness and similarity. Diversity and equitability of species in a given plant community are used to interpret the relative variation between and within the community and help to explain the underlying reason for such a difference. The two main factors taken into account when measuring diversity are richness and evenness. 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 (Zerihun Woldu, 1985). Species richness refers to the total number of species in a community whereas evenness is the relative abundance of species within the sample or community making up the richness of an area (Kent and Cooker, 1992; Krebs, 1999). Species richness index is of great importance in assessing taxonomic and ecological values of habitats.

A number of indices of diversity have been devised, each of which seeks to express the diversity of a sample or quadrat by a single number. Of the various indices, the most frequently used is the simple totality of species numbers to give species richness (Magurran, 1988). Among many speci es di versity i ndices, pr obably t he m ost widely us ed t o c alculate t he di versity a nd e venness includes Shannon-Wiener diversity index, which naturally varies between 1.5 and 3.5 and rarely exceeds 4.5 (Kent and Cooker, 1992). It is a widely used index that combines richness and evenn ess (Krebs, 19 99). S pecies di versity c ould be vi ewed f rom di fferent a pproaches in t erms o f alpha, beta and gamma diversity. Alpha diversity (α) refers to the diversity of species within a particular habitat or community. Beta diversity (β) is a measure of the rate and extent of change in s pecies a long a gr adient f rom o ne ha bitat t o a nother. I t i s be tween ha bitat d iversity t hat measures turnover rates. Beta diversity is sometimes called habitat diversity (Kent and Cooker, 1992). Gamma diversity (γ) on the other hand is the diversity of species in comparable habitats along geographical gradients and is independent of the two. Similarity index measures the degree to w hich the s pecies c omposition of th e q uadrats/ s amples is a like, whereas d issimilarity coefficient assesses which two samples/ quadrats differ in composition. It can be used to assess the similarity between different habitats with reference to the composition of species. Sorensen is the most common binary similarity coefficient, because they depend on probability data, except that Sorensen gives more weight to the species that are present in both quadrats and therefore less weight to species that are present in only one quadrat (Kent and Cooker, 1992).

2.4.2. Abundance and frequency

Abundance is the number of individual plants per unit area. To measure of plant abundance it requires the counting of individual plants by species in a given area which can be used to show spatial distribution and ranges over time.

Frequency is the proportion of plots in which a species occurs. It is a measure of occurrence of a given species in a given area which indicates how the species are dispersed and is an ecological meaningful limit. This means, it gives an approximate indication of the homogeneity of the stand under consideration (Kent and Coker, 1992). Frequency of plant species was be calculated by using the following formula;

$$\text{Frequency} = \frac{\text{Number of quadrats in which a species occur x 100}}{\text{Total number of quadrats thrown in the study sits}}$$

2.4.3. Species important value index (SIVI) and dominance

SIV permits a comparison of species in a given forest and reflects the dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker, 1992). Therefore, for setting priority, it is a good index for summarizing vegetation characteristic s and ranking species for management and conservation practices. Whereas species with lower SIV need high conservation efforts, those with higher SIV need monitoring management.

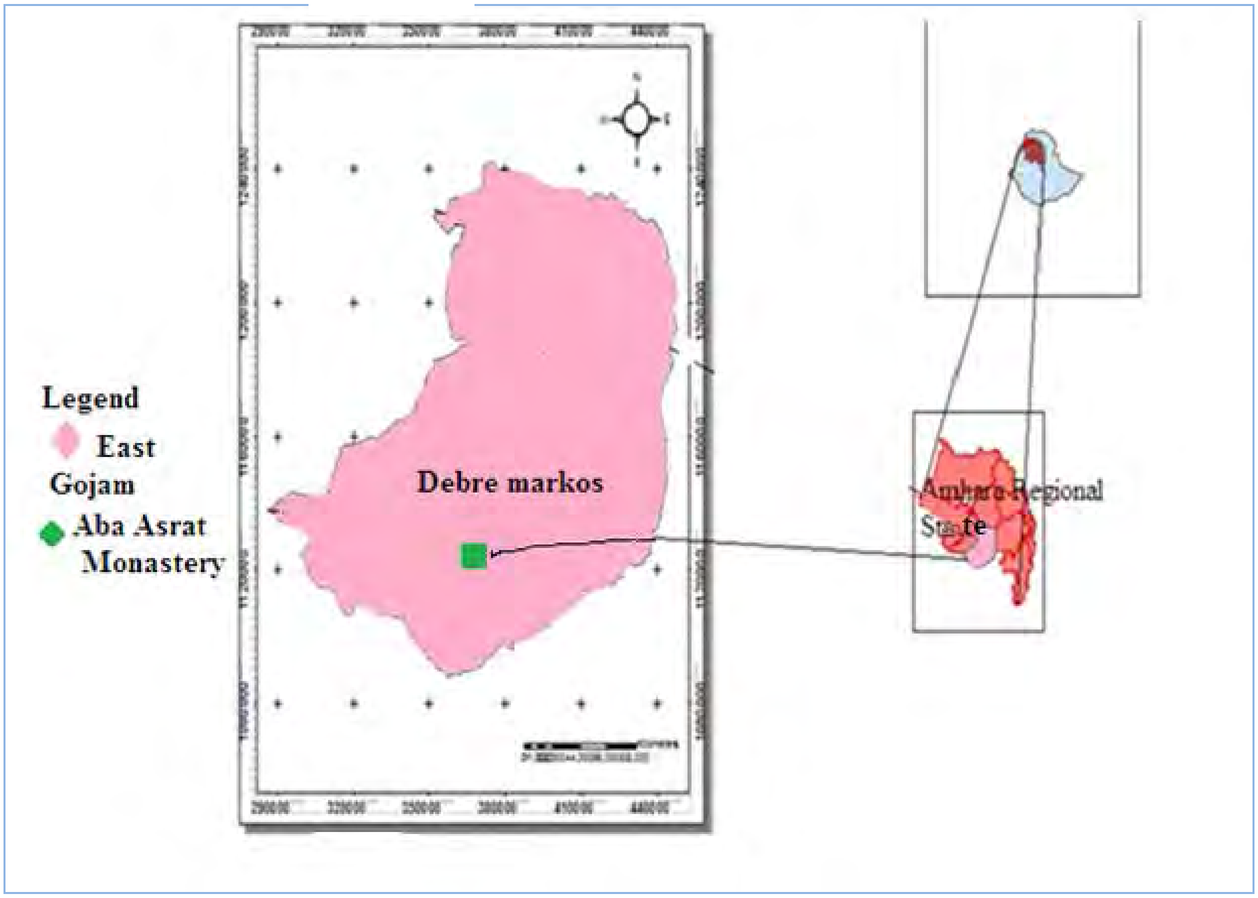
CHAPTER THREE

3. MATERIALS AND METHODS

3. 1. Description of the Study Area

3.1.1. Location

Aba Asrat Monastery is found in East Gojam Zone in Amhara Regional state, north east of Ethiopia. It is located approximately eight km north west of Debre Markos town (the capital town of the Zone) in the southeast direction and 292 km from north east of Addis Ababa, within the Chemoga River depression. It is found at the joint point of Debre Markos District at the northwest Kebi and Enechifo kebeles at the southwest and southeast respectively. The geographical coordinates of the town, Debre Markos are $10^{0}17^{'}$ latitude north and $37^{0}45^{'}$ longitude east.



3.1.2. Climate

The weather condition falls in 'Woinadega' agro ecology. Meteorological data obtained from Nat ional Meteorology Service Agency (Addis Ababa) indicates that Aba Asrat Monastery forest obtains high rainfall between May to October and low rainfall from November to February. The highest m ean a nnual r ainfall of t he s tudy a rea within t en years (1999-2008) w as 132.8 m m recorded in August whereas the lowest mean annual rainfall was 11.7 mm recorded in December.

The lowest mean annual temperature over ten years was 8.7^{0}C recorded in December, whereas the highest mean annual temperature was 26.0^{0}C recorded in February (Figure.2).

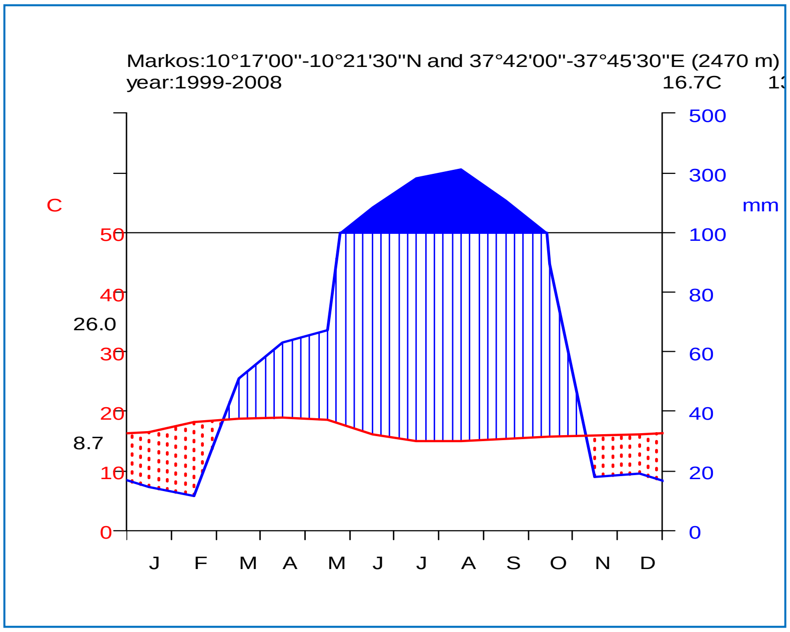


Figure 1: Climadiagram of Aba Asrat Monastery

Data source: Ethiopian National Meteorological Service Agency of Ethiopia (NMSA, 2013).

3.1.3. Vegetation

Typical dry evergreen montane forests in Ethiopia are situated on highlands and mountains occur ring at altitudinal range of 1,500 to 3,200 m.a.s.l. Since Aba Asrat Monastery is one of the highlands, which ranges from 2100 m to 2479 m.a.s.l., it has dry evergreen montane forest ecosystem. The presence of species like; *Olea europea* subsp. *cuspidata*, *Juniperus procera*, *Prunus africana*, *Celtis africana*, *Euphorbia* spp. *Carissa spinarum*, *Rosa abyssinica*, *Acacia abyssinica* etc. are good indications that a given vegetation type belongs to dry evergreen montane ecosystem (Zerihun Woldu, 1999), Tamrat Bekele (1993) and Sebsebe Demissew and Friis (2009). Some species like; *Olea europea* subsp. *cuspidata, Juniperus procera*, *Prunus africana*, *Euphorbia* spp. *Carissa spinarum*, *Rosa abyssinica*, *Acacia abyssinica* and *Albizia schimperiana* (cover most part of the monastery) are found in Aba Asrat Monastery forest. So Aba Asrat Monastery forest is grouped under dry evergreen montane forest.

Figure 2: Vegetation of Aba Asrat Monastery

3.2. Materials

The equipment required for plant data collection were presses (straps, ventilators, blotters and flimsies), Secateurs, field note book, plastic bag, photographic camera, GPS, Calibrated stick and Rolling meter.

3.3. Methods

3.3.1. Reconnaissance Survey

Reconnaissance survey was made in September, 2012 in and around Aba Asrat Monastery forest to gather relevant information concerning the study area, observe vegetation distribution, get an impression of the site conditions, and to identify the possible sampling sites. During the visit additional information and relevant literature for the study was collected from the concerned governmental office (Gozamin and East Gojjam Zone Agricultural Office and East Gojjam Zone Cultural and Heritage Office) and from non-governmental authority (Ethiopian Orthodox Church in East Gojjam Zone District), and also from the local people living in and around the study area. The topographical feature, vegetation coverage and an overview of the species in the habitat was assessed.

3.3.2. Sampling design

Systematic sampling was used to collect vegetation data, Following Muller-Dombois and Ellenberg (1974). Ten line transects were laid at every 100 m distance perpendicular to the Chemoga River. The first line transect was laid systematically from the top of farmland of the Monastery. Sixty two main plots having an equal size of 10 m x 10 m (100 m^2) were laid out to collect the data on woody species. Within the main plot 1 m x 1 m sub-plots were laid, four at the corners and one in the middle, for herbaceous data collection. The distance between the main plots was 100 m along each of the line transects. The latitude and longitude were taken from the center of each main plot and measured using GPS.

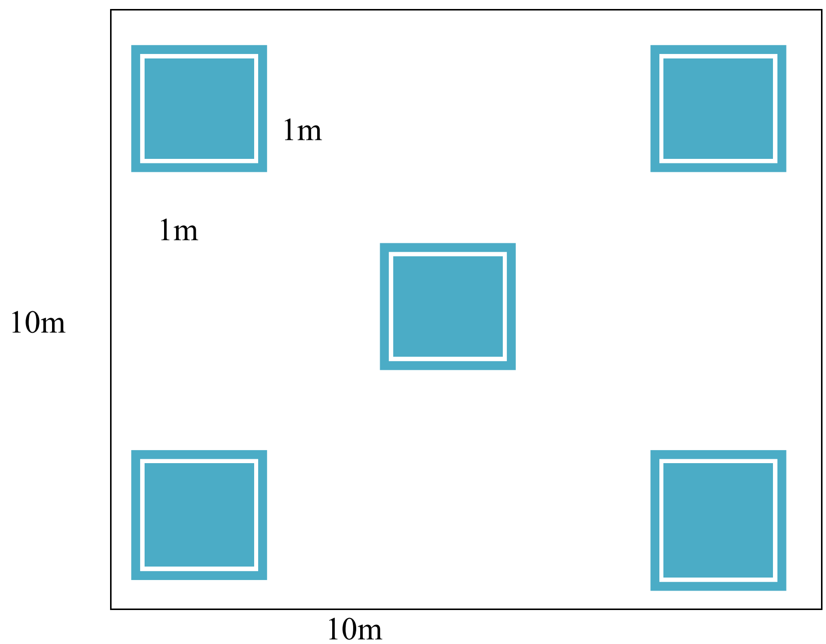


Figure 3 : Sampling plot design of the study area (Aba Asrat Monastery).

In each plot, the diameter and height of all woody species was recorded. Diameter was measured for all individual woody species having DBH greater than 2.5 cm using rolling meter. Height was measured for any individual tree and shrub using a calibrated stick. In places where topographic features made it difficult to measure the height of trees and shrubs was estimated visually. The presence-absence and cover abundance data, defined here as the proportion of area in a quadrat covered by a given species, was recorded and gathered from each quadrat.

Seedling and sapling density and regeneration status of the woody species were recorded. In each of these quadrats, the numbers of all seedlings that were less than1m hight were recorded. Individuals that had attained 1m and above but DBH less than 2.5 cm were considered as Saplings and counted.

3.3. 3. Floristic data collection

All plant species including herbs, shrubs, trees and climbers in each quadrat were recorded. The local names of the species were recorded and included in the list of taxa. During the study, physiographic variables such as altitude, and latitude were measured for each quadrat using GPS. The plant specimens were assigned by tentative field identifications and then brought to the National Herbarium (ETH) of Addis Ababa University, Ethiopia for further identification where voucher specimens are deposited. Taxonomic identification was made following the Flora of Ethiopia and Eritrea and Honeybee Flora of Ethiopia, by consulting experts, and by using authenticated herbarium specimens.

3.4. Data Analysis

3.4.1. Vegetation data analysis

Hierarchical cluster analysis is one of the most commonly used multivariate techniques to analyze community ecological data. It helps to group a set of observations (vegetation samples) together, based on their attributes or floristic similarities (Kent and Coker 1992). For this study, agglomerative hierarchical classification using similarity ratio cluster analysis was performed using R for windows version 2.11.1 (Venables *et al.*, 2010) to classify the vegetation into plant community types based on abundance data of the species in each quadrat.

3.4.2. Measurement of species diversity and similarity indices

Biological diversity can be calculated in various ways. In this study, the Shannon-Wiener diversity index, species richness and Shannon's evenness were computed to describe species diversity of the plant community types (Shannon and Wiener, 1949). The Shannon-Wiener diversity index was calculated as follows:-

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where; H: Shannon-Wiener Index

Pi: proportion of individual tree species

S: number of species

Species richness of the study woody species would be expressed as number of species per unit area and was be calculated as follows;

R=S-1/ln N

Where; S=the number of species of that taxonomic group observed

N=total individuals of the observed

Density of plant species was be calculated by using the following formula;

$$\text{Density} = \frac{\text{Number of individuals}}{\text{Sum of all plot areas}}$$

$$\text{Relative density} = \frac{\text{Total no. of individuals of species A} * 100}{\text{Total no. of individuals of all species}}$$

Frequency (F) of plant species was be calculated by using the following formula;

$$F = \frac{\text{Number of quadrats in which a species occur} \times 100}{\text{Total number of quadrats thrown in the study site}}$$

$$\text{Relative frequency} = \frac{\text{Frequency of species A} * 100}{\text{Frequency of all species}}$$

Basal area of the woody species was be calculated by using a diameter at breast height as used by (Kent and Cooker, 1992).

Basal Area= $\pi d^2/4$, Where; d=diameter at breast height, π= 3.14

Following Kent and Coker (1992), Sorensen's similarity index was be used to determine the pattern of species turnover between the communities.

It will be calculated as follows

Ss= 2a/2a+b+c,

Where; **Ss=** Sorensen's similarity coefficient;

a = Number of species common to both samples;

b = Number of species in sample 1 only;

c = Number of species in sample 2 only.

Importance Value Index (IVI) = RD + RF + RDO, Where RD is Relative density, RF is Relative frequency and RDO is Relative Dominance;

3.4.3. Structural data analysis

The structure of the vegetation in this study was described using the frequency of distribution of DBH, Plant height and IVI. Species Importance Value Indices (SIVI) were computed for dominant woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF) to determine dominance following Kent and Coker (1992).

The different formulas that are important in conducting structural analyses are described below;

SIVI = Relative Density (abundance) + Relative Frequency + Relative Dominance (basal area),

where: Relative Density of a species (RD) = $\dfrac{\text{Number of individuals of a species X 100}}{\text{Number of individuals of the sample}}$

Relative Frequency of a species (RF) = $\dfrac{\text{Number of sample plots containing a species X 100}}{\text{Sample units for all species of the sample}}$

Relative Dominance of a species (RDO) = $\dfrac{\text{Basal area of a species X 100}}{\text{Total basal area of the sample}}$

Basal Area (BA) was calculated using DBH as follows:-

Basal Area (BA) = $\pi d^2/4$, where, $\pi = 3.14$; d = DBH (cm)

CHAPTER FOUR

4. RESULTS

4.1. Floristic composition of the study area

A total of 120 plant species that belong to 96 genera and 53 families were identified from Aba Asrat Monastery (Appendix. 1). Families Asteraceae, Fabaceae Solanaceae, Rosaceae and poace ae contributed eleven (9.17%), eight (6.67%), seven (5.83%) and six (5% each) respectively. Moreover; Euphorbiaceae, Lamiaceae and Polygonaceae contributed four (13.3%), Verbenaceae, Myrtaceae, Malvaceae and Acanthaceae contributed three species each (12.5%). Loganiaceae, R anunculaceae, Sapindaceae, Cyperaceae, Myrsinaceae, Moraceae, Rubiaceae, Celastraceae, Olea ceae, Urticaceae, Amaranthaceae and Boraginaceae contributed two species each (23.2%). The re maining 36 families contributed one species each (29.99%). Among the total species 48 (40.5%) are shrubs, 39 (32%) are herbs, 27 (22.5%) trees and 6 (5%) are climbers (Figure 4). The present finding indicated that herbs and shrubs were found to be more dominating than trees and climber (Figure 5).

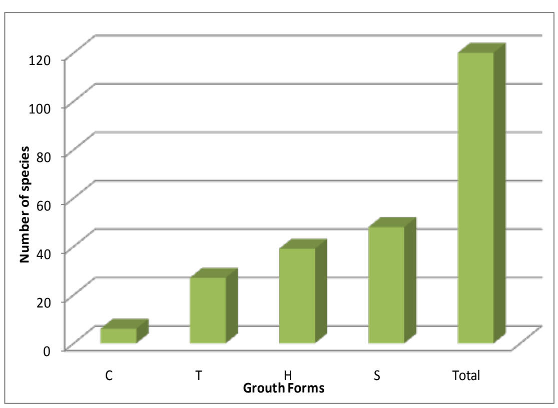


Figure 4: Growth forms habits of taxa of the study Area

4.1.1. Endemic Plants in Aba Asrat Monastery Forest

Six endemic plant species were registered in the study area as endemic to Ethiopia. Two species (*Kalanchoe petitiana* and *Lippia adoensis*) are called near endemic taxa as they are also found in Eritrea. These endemic species are distributed in six genera and three families (Table2).

This indicated that Aba Asrat Monastery is place where one can find a range of plant species including endemic and near endemic ones.

Table 1: Lists of endemic and near endemic plant taxa with their families and growth forms

No	Scientific Name	Family	
1	*Cynoglossum coeruleum* Subsp *Coeruleum* (endemic)	Boraginaceae	H
2	*Echinops kebericho* Mesfin. (endemic)	Asteraceae	S
3	*Erythrina brucei* Schweinf. (endemic)	Fabaceae	T
4	*Gomphocarpus purpurascens* A. Rich. (endemic)	Asclepiadaceae	S
5	*Kalanchoe petitiana* A. Rich. (near endemic)	Crassulaceae	H
6	*Lippia adoensis* Hochst. ex Walp. (near endemic)	Verbenaceae	S
7	*Millettia ferruginea* (Hochest).Back. (endemic)	Fabaceae	T
8	*Solanecio gigas* (Vatke) C.Jeffrey. (endemic)	Asteraceae	S

4.2. Plant Communities in Aba Asrat Monastery Forest

Results from cluster analysis as imputed in the software R- 2.11.1 statistical data analysis output showed five different communities (clusters) for Aba Asrat Monastery (Figure 6). The communit ies were described based on their synoptic cover values. Dominating species in this case is a species having a synoptic cover-abundance value (mean frequency x mean cover abundance) (van der Maarel *et al.*, 1978) of at least five, and characteristics species having a high frequency in the type and a lower frequency in most other within the cluster (Table 3). In accordance with this principle the five community types are discussed in detail in the subsequent sub topics.

4.2.1. *Rosa abyssinica- Acacia pilispina* Community Type I

Rosa abyssinica is dominant species and *Acacia pilispina* is characteristic species of the community. This community is also distributed within the altitudinal range of 2315to 2345 m.a.s. l. and contains 21 plots and 53 species which are situated near the Chemoga River. *Euclea racem osa, Calpurnia aurea*, *Pterolobium stellatum*, *Carissa spinarum*, *Podocarpus falcatus*, *Ageratum conyzoides*, *Galium asparinoides, Kalanchoe petitiana* and *Stephania abyssinica* are associated species found in this Community.

4.2.2. *Urera hypselodendron- Phytolacca dodecandra* Community Type II

Urera hypselodendron dominant species and *Phytolacca dodecandra* are characteristic species found in this community. It contains 16 plots and 56 species and distributed between the altitudinal range of 2287 and 2334 m a.s.l. Associated shrub and herb species of the community are; *Justicia schimperiana*, *Vernonia amygdalina*, *Urera hypselodendron*, *Leonotis ocymifolia* and *Vernonia adoense* and *Achyranthus aspera* and *Bidens Prestiaria* respectively.

4.2.3. *Allophylus abyssinicus- Clutia abyssinica* Community Type III

Allophylus abyssinicus is dominant species and *Clutia abyssinica* is characteristic species of t he community. The Community contains six plots and 40 species which distributed between the altitudinal ranges 2345 to 2368 m.a.s.l. *Artemisia abyssica, Epilobium hirsutum, Chenopodium ambrosioides,* and *Ocimum lamiifolium* are common herb species in the community. Tree species like *Hagenia abyssinica* and *Allophylus abyssinicus* as well as shrub species such as *Caylusea abyssinica, Clutia abyssinica* and *Sida schimperiana* are also associated species in the community.

4.2.4. *Acanthus pubescens -Combretum molle* Community Type IV

This community covers 11 plots and 50 species distributed within the altitudinal range from 2308 to 2324 m a.s.l. Dominant species in th is c ommunity is *Acanthus pubescens* and *Combretum molle* is ch aracteristic species f ound in this community. The he rb l ayer o f th is c ommunity is riched by *Hypoestes forskaolii*, *Echinochloa pyramidalis* and *Medicago polymorpha.*

4.2.4. *Croton macrostachyus-Pavetta abyssinica* Community type V

This c ommunity c onsists of s even plots and 35 s pecies w ithin t he a ltitudinal range of 2230 t o 2326 m.a.s.l. The tree species which were found in this community are *Allophylus abyssinicus* and *Juniperus procera* but the indicator species for this community is *Croton macrostachyus* and *Pavetta abyssinica*. The dominant herb species in this community is *Girardinia diversifolia* and *Tagetes minuta.*

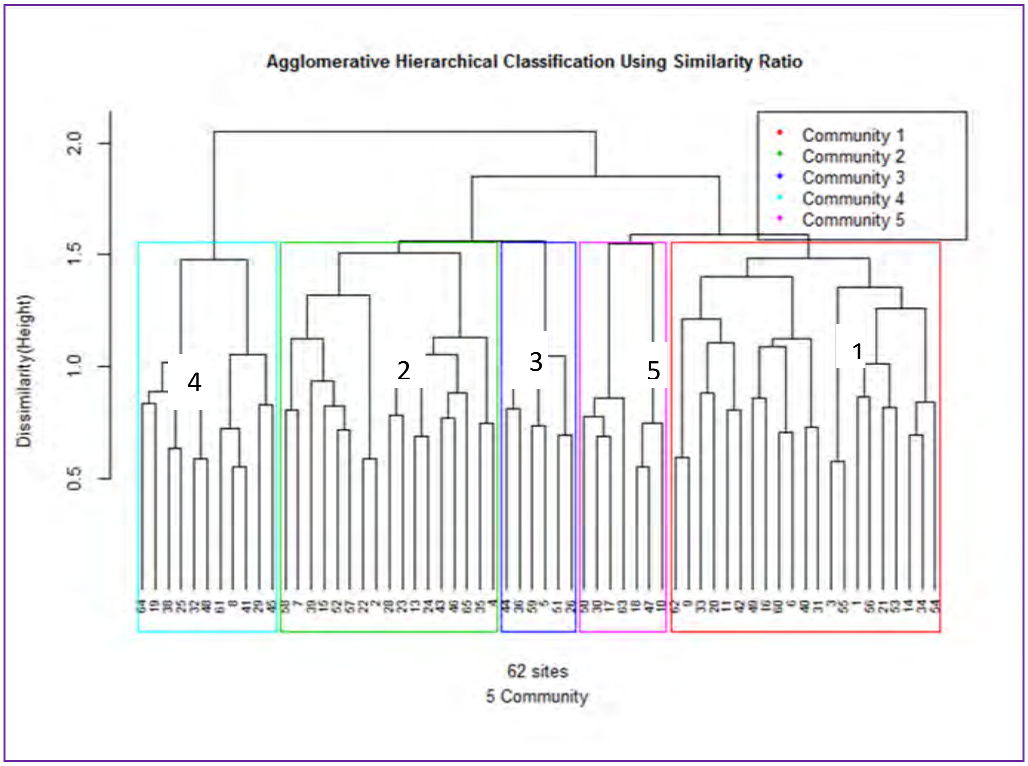


Figure 5: Community types of Aba Asrat Monastery Forest

The communities contain the following plots

C-I; 1, 3, 6, 9, 11, 14, 16, 20, 31, 33, 34, 40, 42, 49, 53, 54, 55, 56, 60, 62, 21

C-II; 4, 7, 12, 13, 15, 22, 23, 24, 28, 35, 38, 39, 43, 46, 57, 15

C-III; 5, 26, 36, 44, 51, 59, 6

C-VI; 8, 19, 25, 29, 32, 38, 41, 45, 48, 61, 10, 15

C-V; 10, 17, 18, 30, 47, 50, 7

Table 2: Synoptic table of the community Types

Species name	C.1	C.2	C.3	C.4	C.5
Acacia pilispina	**4.23**	1.8	2.3	1.11	3.33
Pterolobium stellatum	**3.02**	0	0	0	0
Carissa spinarum	**4.12**	1.32	0	0.78	0
Ageratum conyzoides	**3.11**	0	0	0	0
Calpurnia aurea	**4.12**	1.12	0	0.46	0
Euclea racemosa	**2.45**	0	0.11	0	0
Galium asparinoides	**2.53**	0	0	0	0
Juniperus procera	**3.29**	0.89	0	0.42	0.64
Kalanchoe petitiana	**2.01**	0	0	0	0
Plantago lanceolata	**2.29**	0	3	0.5	1
Rosa abyssinica	**6.29**	0	0	0	0
Podocarpus falcatus	**3.88**	1.7	0	0.32	0
Stephania abyssinica	**2.12**	0	0	0	2
Achyranthes aspera	0	**3.33**	0.54	0	0
Cordia africana	0.43	**5.33**	0	0.3	0
Urera hypselodendron	0	**9**	0	0	0
Justicia schimperiana	0.54	**5.67**	0.32	0.98	0
Leonotis ocymifolia	0	**7.33**	0	0	0
Phytolacca dodecandra	0.59	**4.67**	0.69	3.55	1.24
Bidens prestinaria	0	**4**	0	0	0
Vernonia amygdalina	0	**4.67**	0	0	1
Allophylus abyssinicus	0	0	**11**	3	0
Caylusa abyssinica	0.75	0	**6**	0	1
Chenopodium ambrosiodes	0	0	**9**	0	0
Clutia abyssinica	1.76	2	**7**	1.24	3.5
Epilobium hirsutum	0	0	**4**	0	0

Hagenia abyssinica	0	0	**6**	0.87	0
Ocimum lamiifolium	0.9	0	**4**	0	2
Sida schimperiana	0	0	**3**	0	0
Combretum molle	2.9	3	2	**10**	1.33
Acacia abyssinica	0	0	0	**5.45**	0
Arundo donax	0	0	0	**5.45**	0
Artemisia abyssinica	1.02	0	2	**0.91**	1
Hypoestes forskaolii	0	0	0	**5.27**	0
Acanthus pubescens	2	0.87	0	**17.45**	3
Echinochloa pyramidalis	0	0	0	**4.55**	0
Medicago polymorpha	0	0	0	**3.64**	0
Nuxia congesta	0	0	0	0	**6.67**
Paveta abyssinica	3	1.9	2.11	0.92	**5.89**
Rhamnus prinoides	0	0	1.78	0	**3.67**
Tagetes minuta	0	0.34	0	0	**2.67**
Eucalyptus camaldulensis	4	0	0	2	**5.56**
Croton macrostachyus	0	0	0	0	**9.67**
Solanum adoense	1	0.65	0	0.03	**1.89**
Girardinia diversifolia	0	0	0	0	**4.44**
Vernonia adoensis	2	0	1	0	**3.78**

4. 2. 6. Species richness, diversity and evenness of the Plant communities

From the five community types, community type two has the highest species richness, diversity and species evenness. Community type one is the second least in species richness and Community type five has the lowest species richness but second in species evenness.

Table 3: Species Richness, Diversity and Evenness of the communities

Communities	Richness	Diversity(H)	Shannon Evenness
1	53	3.76	0.93
2	56	3.81	0.96
3	40	3.42	0.93
4	50	3.52	0.90
5	35	3.53	0.94

4.2.7. Similarity between the community types

The Sorensen's similarity coefficient of the five communities' shows that, communities 1 and 5 have the highest similarity (66%) followed by communities three and five and one and four which have similarity ratios of 57% and 49% respectively. From the five communities, communities one and three show highest dissimilarity between them, have similarity ratio (9%).

Table 4: The Sorensen's similarity of the communities

Community types	1	2	3	4	5
1	*				
2	0.36	*			
3	0.09	0.27	*		
4	0.49	0.13	0.40	*	
5	0.66	0.30	0.57	0.17	*

4.2.8. Species Importance Value index (SIV)

The SIV of the tree species is given in Table 6. Tree species with the highest SIV (*Calpurnia aurea*, *Acacia pilispina*, and *Juniperus procera*) contributed 53.89% SIV. The first two species are found in the family Fabaceae and the last one Cuppressaceae. *Calpurnia aurea* has the highes t SIV of 104.76 or 34.92 % followed by *Juniperus procera* (52.83 or 17.61%) and *Cordia africa na* (43.12 or 14.7%). The lowest SIV was recorded for *Croton macrostachyus* and *Podocarpus falcatus*.

Table 5 : Species Importance Value index of the selected tree species

No	Name of species	RD (%)	RF (%)	BA	RDO (%)	SIV	IVI (%)
1	*Calpurnia aurea*	50.00	46.15	43.79	8.61	104.76	34.92
2	*Cordia africana*	13.33	10.9	95.99	18.89	43.12	14.37
3	*Juniperus procera*	10.60	12.6	150.66	29.63	52.83	17.61
4	*Podocarpus falcatus*	7.33	8.9	69.59	13.69	29.92	9.98
5	*Acacia pilispina*	9.17	9.5	78.5	16.00	34.67	11.56
6	*Acacia abyssinica*	6.50	5.33	19.63	4.2	16.03	5.34
7	*Croton macrostachyus*	3.07	6.62	50.24	10.77	20.46	6.82
	Total	100	100	508.4	100	300.00	100

4.3. Vegetation structure of Aba Asrat Monastery Forest

4.3.1. DBH class of Aba Asrat Monastery

The general pattern of the DBH class distribution of the tree species was calculated based on the sampled a rea. A t otal of 112 i ndividuals were counted w ith D BH > 2 .5 cm within s ampled plots. The total DBH density between 12.1-22.0 c m i s 55 (45.8%) in dividual /h a, t hose w ith DBH density between 22.1– 32.0 cm is 21 (17.5%) individuals/ha and those with DBH density between 32.1–42.0 cm is 4 (3.33%) individuals/ha, 42.1-52.0 cm 2 (1.67%), 1 (0.83%). It shows an inverted J-shape; with many small stems compared with large ones (Figure .7)

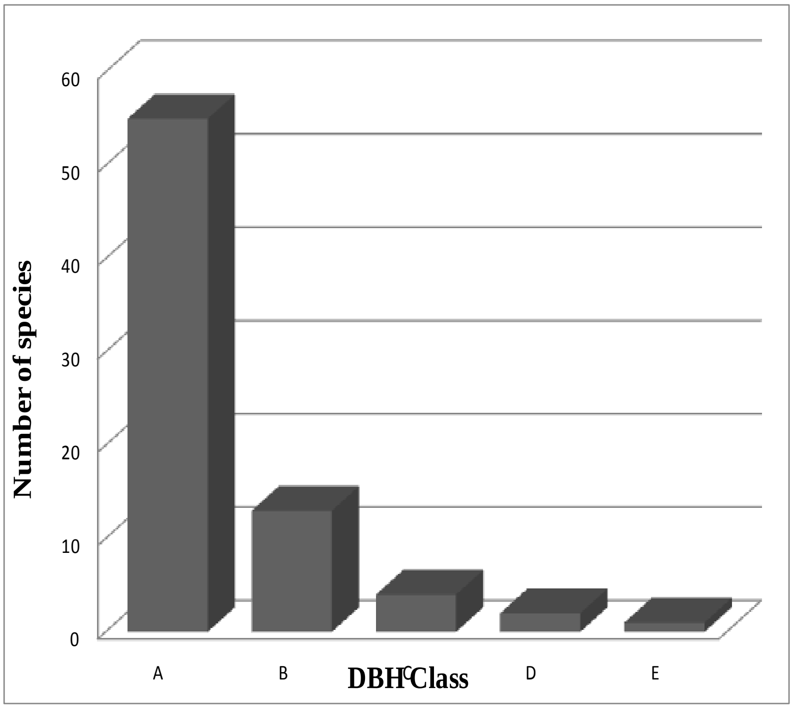


Figure 6: DBH Class distribution of Aba Asrat Monastery

Legend; A=12.1-22.0 cm, B=22.1–32.0 cm, C=32.1–42.0 cm, D=42.1-52.0 cm, E=52.1-62.0 cm

4.3. Height

The woody species in the study area are categorized into six height classes; <5 m, 5.01-10 m, 10.1-15 m, 15.01-20 m, 20.1-25 m, >25-30 m. Most of the species (70%) are found in class A. Whereas 2 5% are found in class B and t he r emaining 5% includes i n other c lass. A s he ight increases from one class to the other the density of individuals falls dramatically.

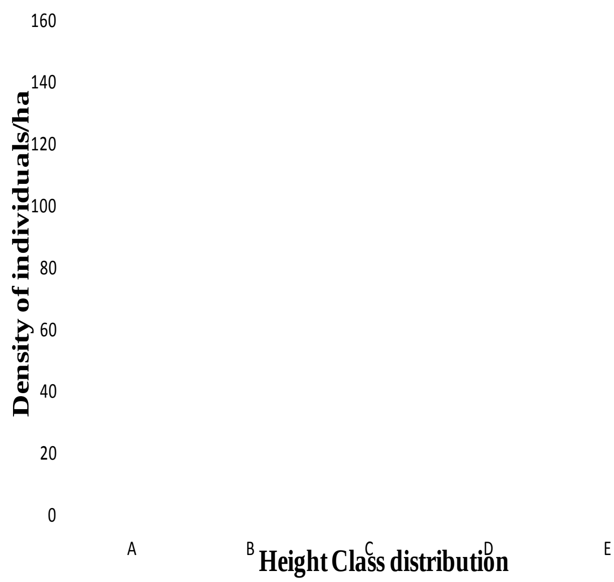


Figure 7 : Height Class

Legend; A= <5 m, B= 5.01-10 m, C= 15.01-20 m, D= 20.1-25 m, E= >25-30 m.

4.3.3. Population structure

The patterns of diameter class distribution indicate the general trends of population dynamics and recruitment processes for a given species. Analysis of six tree species in the study site revealed two g eneral p atterns (F igure 8). The f irst p attern w as pos itively s kewed shape or i nverted J-shape, which has a high number of species in the lower DBH classes and the number of individuals in the species showed a gradual reduction at the highest DBH classes. This pattern was exhibited by the species, *Croton macrostachyus, Podocarpus falcatus*, *and Acacia pilispina*.

The seco nd t ype o f p opulation p attern w as b ell sh aped a nd i s ch aracterized b y t he sp ecies *Juniperus procera, Ficus sur* and *Cordia africana.* It shows a fairly high number of individuals of the species in the middle DBH classes but lower numbers of individuals of the species in the lower and higher DBH classes.

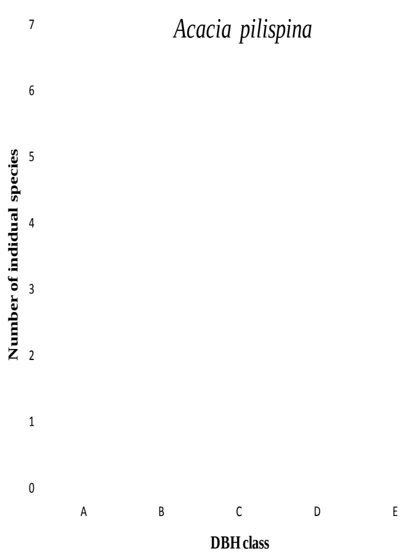


Figure: 8a **DBH class**

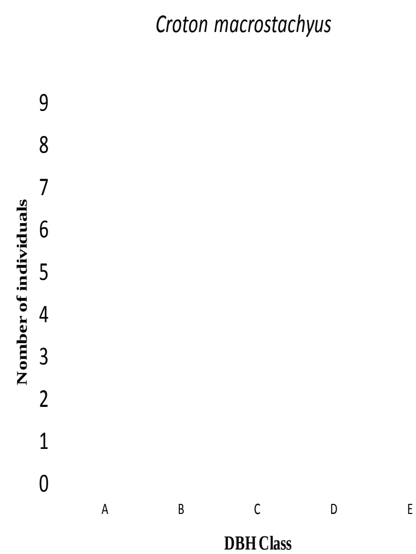
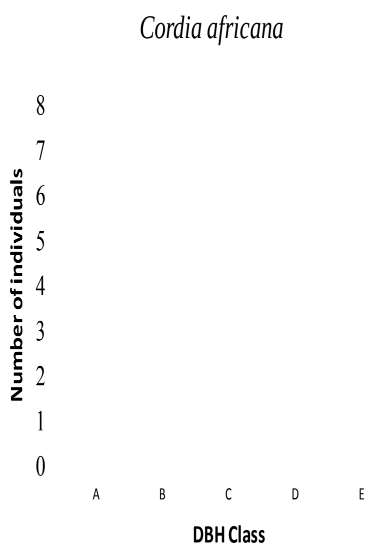


Figure:8b **DBH class**



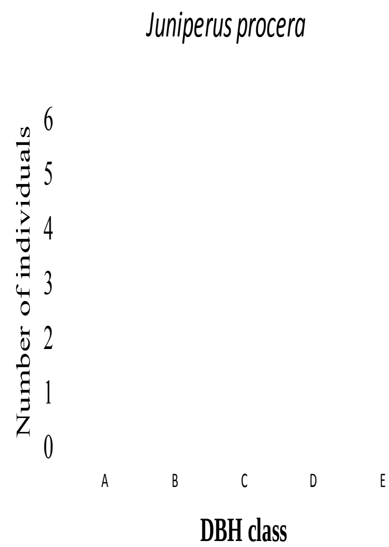


Figure: 8c DBH class

Figure: 8d DBH class

Figure 8: Population structure of some selected tree species

Legend; A=2.6-12.5, B=12.6-22.5, C=22.6-32.5, D=32.6-42.5, E=42.6-52.5.

3.3.4. Regeneration status

The regeneration status of the woody species in Aba Asrat Monastery Forest was determined. From eleven representative woody species a total of 176 seedlings/ha and 153.8 saplings/ha and 63/ha mature individuals/ha were recorded (Table 7).

Table 6: List of selected tree species used to determine the regeneration status

Name of the species	**No. Seedling**	**No. Sapling**	**Mature**	**Abundance**
Acacia abyssinica	13	9	8	30
Acacia pilispina	28	35	16	79
Calpurnia aurea	23	22	9	54
Allophylus abyssinicus	129	98	85	312
Buddleja polystachya	87	64	21	172
Cordia africana	72	59	9	140
Croton macrostachyus	46	38	16	100
Nuxia congesta	51	48	14	113
Prunus africana	36	34	7	77
Salix mucronata (S.subserrata).	43	37	3	83
Total	528	461	189	1160
/ha	176	153.8	63	392.5

CHAPTER FIVE

5. DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1. DISCUSSION

5.1.1. Floristic composition

From the total of 120 plant species found in Aba Asrat Monastery high number of species (Eleve n (9.17%)) are found in Asteraceae family. This might be due to the fact that Asteraceae family is mostly herbs and weeds or due to well developed strategies and adaptations that helped them successfully to survive in the area. The dominance of Asteraceae was reported from similar veget ation study by Birhanu Kebede, (2010) from Gedo Dry Evergreen Montane Forest, Feyera Abde na (2010) from Chato Natural forest and Lemessa Kumsa (2010) from Gura-Lopho Moist Afro montane Forest. This implies that Asteraceae family is the most dominant family in different pla ces which also the cas e i n the flora of Ethiopia and Eritrea. Generally A ba A srat Mo nastery forest h as least species (120 s pecies) c omposition relative t o ot her f orest s tudied by a bove authors, which are Gedo Dry Evergreen Montane Forest (235 species), Chato Natural forest (154 Species) and Gura Lopho Moist Afromontane Forest (168 species).

The Monastery forest also contains eight endemic species. This indicated that Aba Asrat Monast ery Forest is a place where a range of plant species including endemic ones are found. The appea rance of high species diversity and some endemic species could initiate further study and better management on the Monastery forest.

Five community types were identified from the classification strategies. These include Community types I, II, III, IV, and V.

Community type I, which is dominated by *Rosa abyssinica* and characterized by *Acacia pilispina* species. *Euclea racemosa, Calpurnia aurea*, *Pterolobium stellatum*, *Carissa spinarum* are shrub associated species found in the community. *Podocarpus falcatus* and *Juniperus procera,*

Ageratum conyzoides, *Galium asparinoides, Kalanchoe petitiana* and *Stephania abyssinica* are a ssociated tree and herb species found in this. In this community cattle grazing and other human impacts are low, because it is found on the mountain and undulating land parts of the Monastery. This community is the second richest community in the study area ne xt to c ommunity t ype I I, which contains 21 plots and 53 species.

Community type II: Community type I I is found ne ar t he Monastery church (Medihanialem church). Because of this location the community is less grazed by cattle and its human impact is low. This m eans t hat p eople w ho l ive i n and a round t he Monastery restrain t hemselves from applying any negative impacts in areas close to the church. The community is characterized by medium a nd hi gh s ized t rees w ith m ore or l ess interlocked c anopies. M osses are common epiphytes in this community.

Community type III: This is rich in shrub layer which contains six plots and 40 species. *Allophyl us abyssinicus* is dominant species in this community and found near the bushland habitats which had little disturbance by human and cattle when compared to the other community types. So, relatively good number of species diversity is found in this community.

Community type IV: The community is found in the bushland habitat which is dominated by *Acanthus pubescens* and characterized by *Combretum molle* species. In general the community is covered by small and medium sized plant species and rich in shrub layer species. The Community contains 11 plots and 50 species which are grouped under the third richest community in the Monastery Forest.

Community type V: This community type is found near the farm land habitats. This makes the community suitable by cattle grazing and exposed to human impact for collecting firewood, charcoal making and cutting plants for fence. Because of this the community has least species richness, with seven plots and 35 species.

Species richness, diversity and evenness between the communities show, Community type 5 has the lowest species richness but second in species evenness.

This might be because of anthropologic disturbance for different purpose. But all the communiti es have broadly similar evenness values. This might be attributed to the relatively small variation in altitudinal ranges between the communities.

The Sorensen's similarity coefficient shows that Communities 1 and 5 have the highest similarity (66%) followed by communities three and five and one and four which have similarity ratios of 57% and 49% respectively. From the five communities, community one and community three sh ow highest dissimilarity between them with similarity ratio (9%). This might be due to the fact that many of the species are not distributed throughout the communities and due to the altitudinal proximity.

5.1. 2. Structural Description

The p redominance o f s mall si zed woody sp ecies i n A ba Asrat Mo nastery f orest might be t he result of excessive cutting. This is witnessed by the subsequent structural analysis based on tree h eight and DBH classes. As height increases from one class to the other the density of individuals falls dramatically. This clearly tells the dominance of small sized individuals and the presence of high regeneration but lower recruitment and absence of matured individuals. It might be due to the presence of competition among the species and the area was disturbed by anthropogenic facto rs. The study by Feyera Senbeta and Demel Teketay (2003) revealed that the dominance of small trees and shrubs in the forest suggests that the bigger tree species are selectively removed or exp loited. However, selective removal and cutting is absent in this study site.

The forest has more than half its total number of individuals in the lowest DBH classes (<32 cm) and very few in the highest DBH classes.

The patterns in the population structure of some species are suggestive of the past occurrence of disturbance. In cases of trees with inverted J-Shaped population structure (figure7), which shows a good reproduction and regeneration potential of the area.

An inverted J-shape is observed in natural undisturbed montane forest, which has mainly small sized st em d ensity co mpared w ith t he l arger o nes (Nebel *et al*., 2 001). S imilar re sults w ere observed by Feyera Senbeta and Demel Teketay (2001), Abate Ayalew *et al*. (2006); Feyera Senbeta (2006), Haile Yinger *et al*. (2008), Fekadu Gurmessa (2010), Feyera Abdena (2010) and Lemessa Kumsa (2010).

The second type of population pattern was bell shaped which shows a fairly high number of individuals of the species in the middle DBH classes but lower numbers of individuals of the species in the lower and higher DBH classes. This species has poor recruitment potential which might be due to intense competition between the other species found in its surroundings.

The ratio of seedlings and saplings to mature individuals was 2.79: 1 and 2.44: 1 respectively. This consequence shows the presence of more seedlings than saplings and mature individuals. The numbers of saplings are even more than the number of mature individual plants which show s that the Monastery Forest is under regeneration. In this study, different species have different densities of seedlings and saplings. The highest density of seedlings and saplings was found in the species *Allophylus abyssinicus, Nuxia congesta, Prunus africana* and *Croton macrostachyus.* The species *Cordia africana, Salix mucronata, Buddleja polystachya, Acacia pilispina, Calpurni a aurea* and *Acacia abyssinica* showed the lowest seedling and sapling densities.

5.2. Conclusion and Recommendations

5.2.1. Conclusion

The analysis of floristic data at altitudinal range of 2100 and 2479 m in Aba Asrat Monastery Forest showed the presence of higher species diversity. A total of 120 species belonging to 96 genera and 53 families were recorded. Shrubs, herbs, trees and climbers species comprised 35%, 40%, 2.5% and 22.5% respectively. Family Asteraceae was found to be the most dominant followed by Fabaceae and Solanaceae. The dominance of these families might be due to well-developed strategies and adaptations that would help them successfully to survive in the area. Among the species recorded from the forest, five of them are endemic species while one is an endemic subspecies to Ethiopia. Two are near endemic species, occurring in both Ethiopia and Eritrea.

The vegetation of the Monastery was grouped into five community types that had varying degrees of species richness, diversity and evenness. Plant community type two has the highest species richness (56 species), diversity and species evenness while the least diversity was observ ed in community type five. The variation among communities could be due to different factors (a nthropogenic, altitude, soil moisture and other factors), of which anthropogenic is expected to be greater.

The DBH analysis for woody species revealed variations in the population structure. The density of woody species decreases with increasing DBH, indicating the predominance of small-sized individuals in the area. Analysis of vegetation structure showed different population patterns that indicate relatively medium variation among species population dynamics within the study site. Accordingly, two population patterns have been observed; inverted J and bell shaped.

Analysis of regeneration of some selected woody species revealed that tree species such as *Calpu rnia aurea*, *Acacia abyssinica, Salix mucronata (S. subserrata)* and *Acacia abyssinica* have low re generation potential whereas *Allophylus abyssinicus* and *Cordia africana* have good recruitment status of seedling and sapling in the study site. The finding implies the need for conservation and management of economically and ecologically important plant species; particularly those plants where low regeneration was obtained.

5.2.2. Recommendations

Aba Asrat Monastery Forest provides important economic and social value to the rural communit ies living in and around the area. To minimize the present human influence on this unique area and for the future management of the study area in a sustainable manner, the following recommendations are made:

- Participatory forest management programme should be introduced and implemented so that local communities are able to develop sense of ownership and responsibility for the manage ment and conservation of the Forest.

- Attention and priority should be given for in-situ conservation through collaboration of local communities, relevant sectors and stakeholders.

- Raising public awareness, on the multiple uses of forest resources an d e cosystem ser vices need to be strengthened so as to safeguard the biodiversity of the Monastery Forest.

- Understanding forests of church yards and Monasteries as potential sources of biodiversity and gazetting them by the state after a clear demarcation is required to stop further encroachment and disturbances.

- Training and awareness raising is essential for the church scholars about scientific tree propagation (seed collection, storage and nursery techniques), silvicultural and forest management technique in order to diversify and enhance their level of knowledge on top of traditional conservation knowledge.

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APPENDICES

Appendix 1 : List of plant species collected from Aba Asrat Monastery Forest

No	Botanical name	Family name	Local name	H	Coll.
1	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae	Cheba	T	GB43
2	*Acacia pilispina* Pic.Serm.	Fabaceae	Girar	T	GB55
3	*Acanthus pubescens* (Oliv.) Engl.	Acanthaceae	Kosheshla	S	GB70
4	*Achyranthes aspera* L.	Amaranthaceae	Teleng	H	GB27
6	*Ageratum conyzoides* L.	Asteraceae	Bicha ab eba	H	GB10
8	*Allophylus abyssinicus* Hochst.) Radlkofer	Sapindaceae	Embis	T	GB72
9	*Cyathula uncinulata* (Schrad.)Schinz	Amaranthaceae	Aluma	H	GB47
10	*Argemone mexicana* L.	Papaveraceae	Aremo	H	GB11
11	*Artemisia abyssinica* Sch.Bip. ex. A. Rich	Asteraceae	Chikugn	H	GB62
12	*Arundinaria alpina* K. Schum	Poaceae	Kerkeha	S	GB42
13	*Arundo donax* L.	Poaceae	Shenbeko	S	GB73
14	*Bersama abyssinica* Fresen.	Melianthaceae	Azamir	S	GB64
16	*Buddelja polystachya* Fresen	Loganiaceae	Nech anfar	S	GB54
17	*Calpurnia aurea* (Ait.) Benth	Myrtaceae	Ligta	S	GB53
18	*Carduus leptacanthus* (Fresen.)	Asteraceae	Eshoh	H	GB6
19	*Carex steudneri* Bock.	Cyperaceae	Filla	H	GB38
20	*Carissa spinarum* (Forssk.) Vahl	Apocynaceae	Agam	S	GB33
21	*Caylusea abyssinica* (Fresen.) Fisch. & Mey.	Resedaceae	Rench	H	GB59
21	*Passiflora caerulea* L.	Passifloraceae	Areg mesay	H	GB11
22	*Chenopodium ambrosioides* L.	Chenopodiaceae	abayasie	H	GB12
23	*Clausena anisata* (Willd.) Benth.	Rutaceae	Midib	S	GB71
24	*Clematis simensis* Fresen	Ranunculaceae	Azoareg	H	GB95
25	*Clematis hirsutum* Perr. & Guill.	Ranunculaceae	Nechhareg	H	GB20
26	*Clerodendrum myricoides* (Hochst) Vatke.	Lamiaceae	Misroch	H	GB15
27	*Clutia abyssinica* Jaub. & Spach	Euphorbiaceae	Fyelefeg	S	GB51
28	*Combretum molle* R.Br.ex.G.Don.	Combretaceae	Aballo	S	GB66

29	*Cordia africana* Lam.	Boraginaceae	Wanza	T	GB2
31	*Crotalaria retusa* L.	Fabaceae	Bakellalike	H	GB6
32	*Croton macrostachyus* Del.	Euphorbiaceae	Bisana	T	GB19
33	*Cynoglossum coeruleum* Hochest ex.A.DC.in.	Boraginaceae	Shingug	H	GB56
34	*Cyperus dichroostachyus* A. Rich.	Cyperaceae	Giramta	H	GB34
35	*Cyperus fischranus* A.Rich.	Cyperaceae	Engicha	H	GB10
36	*Datura stramonium* L.	Solanaceae	Astenager	H	GB46
37	*Dodonaea angustifolia* L.f.	Sapindaceae	Kitkita	T	GB10
	Dombeya torrida (J.F.Gmel.) P.Bamps	Sterculiaceae	Wulkfa	T	GB97
38	*Dovyalis abyssinica* (A.Rich.) Warb.	Flacourtiaceae	Koshim	S	GB10
39	*Echinochloa pyramidalis* (Lam.) H itchc an d	Poaceae	Sindedo	H	GB1
40	*Echinops kebericho* Mesfin.	Asteraceae	Kebericho	H	GB40
41	*Eleusine floccifolia* (Forssk.) Spreng.	Poaceae	Acrima	H	GB10
42	*Embelia schimperi* Vatke.	Myrsinaceae	Enkoko	S	GB2
43	*Epilobium hirsutum* L.	Onagraceae	Yelamchew	H	GB3
44	*Erythrina brucei* Schweinf.	Fabacae	Korch	T	GB91
45	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	key barzaf	T	GB4
46	*Eucalyptus citriodora* Hook.	Myrtaceae	white barzaf	T	GB50
47	*Euclea racemosa* murr.	Ebenaceae	Dedeho	T	GB98
48	*Ficus sur* Forss .K.	Moraceae	Sholla	T	GB89
50	*Galium asparinoides* Forssk.	Rubiaceae	Ashkit	H	GB10
51	*Gomphocarpus purpurascens* (A. Rich.)	Asclepiadaceae	-	S	GB23
52	*Guizotia scabra* (Vis.) Chiov.	Asteraceae	Mech	H	GB6
53	*Hagenia abyssinica* (Bruce) J.F. Gmel.	Rosaceae	Kosso	T	GB19
54	*Heteromorpha arborescens* (Spreng.) Cham.	Apiaceae	Yejidimrkus	T	GB83
55	*Hyparrhenia anthistirioides* (Hochst.ex .A.Rich.). Stapf.	Poaceae	Senbelet	H	GB52
56	*Hypoestes forskaolii* (Vahl) R. Br.	Acanthaceae		H	GB13
57	*Hypoestes triflora* (Forssk.) Roem & Schult.	Asteraceae	Aremo	H	GB22
58	*Ipomoea indica* (Burm.f.) Merrill	Convolvulaceae	abeba	H	GB74
59	*Juniperus procera* L.	Cuppressaceae	Tid	T	GB92
60	*Jusminium abyssinica* Hochst.ex DC.	Oleaceae	Tenbelel	C	GB17
61	*Justicia schimperiana* (Hochst.ex Nees) T .	Acanthaceae	Simiza	S	GB10
62	*Kalanchoe petitiana* A. Rich.	Crassulaceae	Andawlla	H	GB1

63	*Leonotis ocymifolia* (Bunn. f.) Iwarsson,	Lamiaceae	Raskimr	H	GB49
64	*Lippia adoensis* Hochst. ex Walp.	Verbenaceae	Kessie	H	GB48
66	*Maesa lanceolata* Forssk.	Myrsinaceae	Kelewa	T	GB11
67	*Malva parviflora* Hojer.	Malvaceae	Lut	H	GB45
68	*Maytenus gracilipes* Welw. ex Oliv.)	Celastraceae	Atat	S	GB12
69	*Maytenus obscura* (A.Rich.) Cuf.	Celastraceae	Koba	T	GB11
71	*Milletia ferruginea* (Hochest).Back.	Fabaceae	Birbira	T	GB96
72	*Bidens prestinaria* (Sch, Bip.) Cufod.	Asteraceae	-	H	GB78
73	*Myrica salicifolia* A.Rich	Myricaceae	Shinet	T	GB7
74	*Nicandra physaloides* (L.) Gaertn.	Solanaceae	Roza abeba	S	GB4
	Nuxia congesta R. Br. ex. Fresen	Loganiaceae	Atkuar	T	GB67
75	*Ocimum lamiifolium* Hochst. Ex Benth	Lamiaceae	Damakese	H	GB65
76	*Olea europaea* .subsp. *cuspidata* (Wall.ex G. D	Oleaceae	Woira	T	GB63
77	*Osyris quadripartita* Decne.	Santaleceae	Keret	S	GB77
78	*Pavetta abyssinica* Hochst. Ex A. Rich	Rubiaceae	Dingayseber	S	GB60
79	*Pavonia urens* Cav.	Malvaceae	Shiget	S	GB75
80	*Persicaria lapathifolia* (L).S.F.Gray.	Polygonaceae	arem	H	GN16
81	*Peucedanum winkleri* Wolff.	Apiaceae	Karshbimbo	H	GB44
82	*Phoenix reclinata* Jacq.	Arecaceae	Zenbaba	S	GB41
83	*Phytolacca dodecandra* L'Herit	Phytolaccaceae	Endod	S	GB21
84	*Plantago lanceolata* L.	Plantaginaceae	Gorteb	H	GB8
85	*Plectranthus caninus* Roth.	Lamiaceae	zikakibe	H	GB76
86	*Podocarpus falcatus* (Thunb.) Mirb.	Podocarpceae	Zigba	T	GB93
87	*Premna schimperi* Engl.	Lamiaceae	Chocho	T	GB94
88	*Prunus africana* (Hook. f.) Kalkm.	Rosaceae	Homa	T	GB90
89	*Prunus persica* (L.) Batsch.	Rosaceae	Kok	T	GB5
90	*Pterolobium stellatum* (Forssk)) Brenan	Fabaceae	Gumero	S	GB28
91	*Rhamnus prinoides* L'Herit.	Rhamnaceae	Gesho	S	GB36
92	*Ricinus communis* L.	Euphorbiaceae	Chakma	S	GB12
93	*Rosa abyssinica* Lindley	Rosaceae	Kega	S	GB26
94	*Rosa richardii* Rehd..	Rosaceae	Tsigereda	S	GB27
95	*Rubus apetalus* Poir.	Rosaceae	Enjori	S	GB25
96	*Rumex abyssinica* Jacq.	Polygonaceae	Mekmeko	H	GB21
97	*Rumex nepalensis* Spreng.	Polygonaceae	Tult	H	GB22
98	*Rumex nervosus* Vahl	Polygonaceae	Emboacho	S	GB24
99	*Salix mucronata Thumb*. (S.*subserrata*). (Willd.)	Salicaceae	kiya	T	GB30

101	*Senna septemtrionalis* (Viv.) Irwin & Bameby.	Fabaceae	-	S	GB27
102	*Sida schimperiana* Hochst. ex A. Rich	Malvaceae	Chifrg	H	GB37
104	*Solanecio gigas* (Vatke) C.Jeffrey	Asteraceae	Kitle dabo	S	GB35
105	*Solanum adoense* Hohst. ex. A.Rich	Solanaceae	Mutiy	S	GB69
106	*Solanum incanum* L.	Solanaceae	Imbway	S	GB10
107	*Solanum marginatum* L.f.	Solanaceae	_	S	GB11
108	*Solanum anguivi* Lam.	Solanaceae	Ebuway	S	GB12
110	*Stephania abyssinica* (Dill. & A. Rich.) Walp.	Menispermaceae	Kelala	H	GB88
111	*Tagetes minuta* L.	Asteraceae	Dejamuk	H	GB3
112	*Thymus schimperi* Ronnign.	Lamiaceae	Tosign	H	GB84
113	*Teclea nobilis* Del.	Rutaceae	-	T	GB14
114	*Urera hypselodendron* (A.Rich.) Wedd.	Urticaceae	Lankuso	S	GB78
115	*Girardinia diversifolia* (Link) Friis.	Urticaceae	Sama	H	GB79
116	*Verbascum sinaiticum* Benth.	Scrophulariaceae	Ketetina	S	GB10
117	*Vernonia amygdalina* Del.	Asteraceae	Grawa	S	GB18
118	*Vernonia auriculifera* Hiern.	Asteraceae	Gengerita	S	GB29
120	*Zehneria scabra* (Linn. f.) Sond.	Cucurbitaceae	Areg Resa	C	GB87

Legend: (T= Tree, H= Herb, S= Shrub, C= Climber).

Appendix 2: List of families and genera.

No	Family name	Number of species	Number of genera
1	Acanthaceae	3	3
2	Amaranthaceae	2	2
3	Apiaceae	2	2
4	Apocynaceae	1	1
5	Arecaceae	1	1
6	Asclepiadaceae	1	1
7	Asteraceae	11	9
8	Boraginaceae	2	2
9	Celastraceae	2	1
10	Chenopodiaceae	2	1
11	Combretaceae	1	1
12	Convolvulaceae	1	1
13	Crassulaceae	1	1
14	Cucurbitaceae	1	1
15	Cuppressaceae	1	1
16	Cyperaceae	3	2
17	Ebenaceae	1	1
18	Euphorbiaceae	3	3
19	Fabaceae	9	8
20	Flacourtiaceae	1	1
21	Lamiaceae	5	5
22	Loganiaceae	2	1
23	Malvaceae	3	3
24	Melianthaceae	1	1
25	Menispermaceae	1	1
26	Moraceae	2	1
28	Myricaceae	1	1
29	Myrsinaceae	2	2
30	Myrtaceae	3	2
31	Oleaceae	2	2

32	Onagraceae	1	1
33	Papaveraceae	1	1
34	Passifloraceae	1	1
36	Phytolaccaceae	1	1
37	Plantaginaceae	1	1
38	Poaceae	6	6
39	Podocarpaceae	1	1
40	Polygonaceae	4	2
41	Ranunculaceae	2	1
42	Resedaceae	1	1
43	Rhamnaceae	1	1
44	Rosaceae	6	3
45	Rubiaceae	2	2
46	Rutaceae	2	2
47	Salicaceae	1	1
48	Santaleceae	1	1
49	Sapindaceae	2	2
50	Scrophulariaceae	1	1
51	Solanaceae	6	3
52	Urticaceae	2	2
53	Verbenaceae	3	2
Total		120	96

Appendix 3: Sample Plots together with the corresponding altitude and location

Transects	Quadrats	Altitude(M.a.s.l.)	Latitude	Longitude
1	1	2333 m	10^{0} 17.186’N	37^{0}45.504’E
	2	2341 m	10^{0} 17.420’N	37^{0} 45.296’E
	3	2298 m	10^{0} 17.220’N	37^{0} 45.299’E
	4	2315 m	10^{0}17.237’N	37^{0}45.294’E
	5	2338 m	10^{0}17.413’N	37^{0}45.295’E
	6	2318 m	10^{0}17.382’N	37^{0}45.301’E
	7	2332 m	10^{0}17.308’N	37^{0}45.250’E
	8	2345 m	10^{0}17.341’N	37^{0}45.251’E
2	9	2329m	10^{0}17.173’N	37^{0}45.467’E
	10	2308m	10^{0}17.258’N	37^{0}45.311’E
	11	2285m	10^{0}17.296’N	37^{0}45.303’E
	12	2301m	10^{0}17.242’N	37^{0}45.283’E
	13	2312m	10^{0}17.278’N	37^{0}45.288’E
	14	2317m	10^{0}17.359’N	37^{0}45.306’E
3	15	2313m	10^{0}17.386’N	37^{0}45.313’E
	16	2219m	10^{0}17.403’N	37^{0}45.330’E
	17	2278m	10^{0}17.387’N	37^{0}45.318’E
	18	2330m	10^{0}17.341’N	37^{0}45.225’E
	19	2337m	10^{0}17.166’N	37^{0}45.209’E
	20	2355m	10^{0}17.190’N	37^{0}45.213’E
4	21	2329m	10^{0}17.216’N	37^{0}45.224’E
	22	2336m	10^{0}17.325’N	37^{0}45.330’E
	23	2324m	10^{0}17.228’N	37^{0}45.301’E
	24	2316m	10^{0}17.304’N	37^{0}45.283’E
	25	2285m	10^{0}17.294’N	37^{0}45.296’E
5	26	2298m	10^{0}17.264’N	37^{0}45.266’E
	27	2307m	10^{0}17.227’N	37^{0}45.292’E
	27	2331m	10^{0}17.391’N	37^{0}45.285’E
	28	2311m	10^{0}17.305’N	37^{0}45.285’E
6	30	2326m	10^{0}17.315’N	37^{0}45.317’E
	31	2338m	10^{0}17.413’N	37^{0}45.295’E
	32	2340m	10^{0}17.211’N	37^{0}45.227’E
	33	2344m	10^{0}17.194’N	37^{0}45.218’E
	34	2342m	10^{0}17.189’N	37^{0}45.220’E

	35	2337m	10^{0}17.187’N	37^{0}45.219’E
	36	2335m	10^{0}17.183’N	37^{0}45.218’E
7	37	2355m	10^{0}17.190’N	37^{0}45.213’E
	38	2345m	10^{0}17.174’N	37^{0}45.191’E
	39	2334m	10^{0}17.179’N	37^{0}45.193’E
	40	2328m	10^{0}17.235’N	37^{0}45.273’E
	41	2312m	10^{0}17.241’N	37^{0}45.280’E
	42	2307m	10^{0}17.225’N	37^{0}45.289’E
8	43	2319m	10^{0}17.284’N	37^{0}45.288’E
	44	2336m	10^{0}17.302’N	37^{0}45.241’E
	45	2340m	10^{0}17.214’N	37^{0}45.230’E
	46	2353m	10^{0}17.223’N	37^{0}45.240’E
	47	2360m	10^{0}17.304’N	37^{0}45.316’E
	48	2366m	10^{0}17.310’N	37^{0}45.322’E
9	49’	2350m	10^{0}17.208’N	37^{0}45.335’E
	50	2348m	10^{0}17.196’N	37^{0}45.309’E
	51	2370m	10^{0}17.320’N	37^{0}45.331’E
	52	2383m	10^{0}17.342’N	37^{0}45.228’E
	53	2378m	10^{0}17.338’N	37^{0}45.212’E
	54	2362m	10^{0}17.314’N	37^{0}45.203’E
	55	2358m	10^{0}17.297’N	37^{0}45.300’E
	56	2350m	10^{0}17.263’N	37^{0}45.275’E
10	57	2341m	10^{0}17.186’N	37^{0}45.217’E
	58	2332m	10^{0}17.164’N	37^{0}45.203’E
	59	2337m	10^{0}17.168’N	37^{0}45.210’E
	60	2346m	10^{0}17.181’N	37^{0}45.223’E
	61	2352m	10^{0}17.201’N	37^{0}45.243’E
	62	2364m	10^{0}17.221’N	37^{0}45.250’E