**JIMMA UNIVERSITY**

## COLLEGE OF NATURAL SCIENCES

## DEPARTMENT OF BIOLOGY

# FLORISTIC COMPOSITION, STRUCTURE AND REGENERATION STATUS OF MOUNTAIN AMBARICHO NATURAL FOREST IN KACHABIRA DISTRICT, KEMBATA TEMBARO ZONE SOUTH NATION NATIONALITY AND PEOPLE REGIONAL STATE, SOUTHERN ETHIOPIA

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**A Thesis Submitted to the Department of Biology, College of Natural Sciences, and Jimma University in Partial Fulfillment of the Requirement for the Degree of Master of Science in Biology (Botanical Science Stream).**

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**APPROVAL SHEET**

This is to Certify that the thesis is prepared by: Terefe Daniel, “entitled Floristic Composition, Structure and Regeneration status of Mountain Ambaricho Natural Forest, Kachabira District, Kambata Tambaro zone Southern Ethiopia” Submitted in fulfillment of the requirements for the degree of master of science in Biology complies with the regulation of the University and meets the accepted standards with respect to originality and quality.

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## STATEMENT OF THE AUTHOR

I, the undersigned, declare that this thesis is my work and is not submitted to any institution elsewhere for the award of any academic degree, diploma or certificate and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfilment of the requirements for M.Sc. degree at Jimma University, College of Natural Sciences and deposited at the University library to be made available to borrowers under the rules of the library.

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# BIOGRAPHICAL SKETCH

The author Terefe Daniel Habebo was born on 03/05/1985, in Kachabira district, South Kambata Tambaro Zone southern Ethiopia. He attended his elementary school at Mino from 1992 to 2000, and secondary and preparatory education at Shinshicho from 2000 to 2002. Terefe Daniel attended his undergraduate study in Biology at Wolayita Sodo University from 2006 to 2012 and he has a BSc degree in biology. Right after his graduation, he was employed by HaderoTunto District Education Office and served for two years at Mugunja Elementary school (from 2010 – 2011) and for one year at Mugunja secondary school as a teacher (2012). Terefe Daniel joined Jimma University, College of Natural Sciences, and the Department of Biology in 2022 to pursue a postgraduate study in Biology and to specialize in Botanical Sciences.

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## LIST OF ACRONYMS

| | |
|---|---|
| ANF | Ambaricho Natural Forest |
| ARDO | Agricultural and Rural Development Office |
| BA | Basal Area |
| CSA | Central Statistics Agency |
| EFAP | Ethiopian Forestry Action Plan |
| FAO | Food and Agriculture Organization |
| IBC | International Biological Conservation center |
| GPS | Geographical Positioning System |
| Ln | Natural logarithms |
| MSA | Meteorological Service Agency |
| M.A.S.L | Meter above Sea Level |
| IVI | Importance Value Index |
| RD | Relative Density |
| RDO | Relative Dominance |
| SNNPR | Southern Nations, Nationalities and Peoples Regional State |
| KTZ | Kambata Tambaro Zone |
| USAID | United States Agency for international Development |
| UNEP | United Nations surroundings Programme world Conservation center |
| WCMC | World Conservation Monitoring Center |

## ABSTRACT

This study was conducted on Ambaricho Natural forest in Kachabira District; Kambata Tambaro Zone of SNNPRS .Objective of this study was to investigate the floristic composition, structure and regeneration status of plant species. Systematic sampling method was applied to collect floristic data from (35) (20 m x 20 m) sample quadrants which were established at 50 m interval elevation along the transect line, which are laid 400m apart. Within the main plots, five (four at the corner and one at the center) 1 m x 1 m sub-plots were laid to collect herbaceous, 5m x 5m sub plots were laid to collect saplings and seedlings data. A total of 61 plant species belonging to 61 genera and 42 families were recorded. Out of the collected plant species, 34(55.7%) were trees 20(32.8%) were herbs and 7(11.5%) were shrubs. The families with the highest number of species were *Asteraceae*, represented by 6 species (9.83%), followed by *Rubeaceae* 5 species (8.19%), *Lamiaceae* 4 species (6.55%), and *Solanaceae* 3 species (4.91%). Shannon -Wiener diversity index values of plant species encountered in the study sites were 3.69 while their corresponding evenness values were 0.8. Analysis of regeneration status of all plant species in study forest showed that seedling >sapling> mature trees implying the forest is at good regeneration status. But large size trees in the forest were under threat due to anthropogenic activities such as cutting of trees for fire wood, house construction and cutting of trees for preparation of charcoal all of which were negatively influenced the vegetation dynamic and tree density of the forest. To reduce this threat and to use the forest sustainably, participatory forest management is required.

**Key words:** Ambaricho Natural Forest, floristic composition, Structure, Species diversity, Regeneration Status.

# 1. INTRODUCTION

## 1.1 Background of the study

In most terrestrial parts of the world, vegetation is the maximum obvious physical representation of an ecosystem and consists of individual flora (Kent and Coker, 1992). Forest offers a wide variety of ecological, economic, social and cultural services and processes (FAO, 2007). Forests adjust water regimes/as water catchments, cultural and aesthetic services and provide surroundings services, which includes nutrient cycling, soil formation, oxygen production, carbon sequestration and prevention of air pollution (IBC,2009; FAO,2010; Senelwa *et al*.,2011). Mountain ecosystems around the world are recognized for their high biological diversity and commonly have wonderful biological groups and high level of endemism, due to their topography (Gairola *et al*., 2008). Mountain ecosystems also represent herbal, semi-natural, and plantation of trees and domesticated crop kinds that provide nourishment to different biodiversity forms and balance resilience for the fragile mountain ecosystems. Mountain forests have a high capacity for securing livelihoods by supplying non-timber forest products (Amente, 2006, Senelwa *et al*., 2011). They are also used locally to generate income and in traditional foods and medicine (IBC, 2009, Senelwa *et al.,* 2011). Ethiopia is an important regional center for biological diversity due to its wide ranges of altitude; its great geographical diversity with high and rugged mountains, flat- topped plateaus and deep gorges, incised river valleys and rolling plains (Ensermu Kelbessa *et al*., 1999; Zerihun Woldu, 1999). The country has great biodiversity resources due to the diversity in physical features, climate, topography, habitat, vegetation type and fauna (Friis *et al*., 2010). Altitude in Ethiopia range from 126m below sea level in the Dallol (Afar) depression to the highest Mountain, Ras Deshen in the Semen Mountains 4,620m above sea level (Mengistu, 2002).This helped the emergence of wide ranges of habitats that are suitable for the evaluation and survival of various plant and animal species. As a result, the country is regarded as one of the most important countries in Africa with respect to endemism of plant and animal species in tropical Africa (EFAP, 1994; EWNHS, 1996).

A substantial proportion of Ethiopian highlands were once believed to have been covered by forests having wide coverage than at present, but have gradually been cleared (Friis, 1992). Tamirat Bekele (1993) remarked that the occurrence of isolated mature trees in farmlands and patches of forests that are seen around church-yards and religious burial grounds indicates the presence of vast expanse of forest earlier. Tropical forests are deteriorating both in quality and quantity. Approximately half of tropical closed-canopy forest has already been removed and the land converted to other uses (Wright, 2005). The rapid conversion of tropical forests for agriculture, timber production and other uses has generated vast human dominated landscapes with potentially dire consequences for tropical biodiversity (Gibson *et al.*, 2011). At the moment, most of the remaining forests of the country are confined to the south and south-western parts of the country; however, nowadays the remnant forests in these areas are threatened by human activities (Tamirat Bekele, 1994). A historical document indicates that Ethiopia had experienced substantial deforestation, soil degradation and an increase in the area of bare land over the years. The need for the fuel wood, arable land and grazing areas have been indicated as the main cause of forest degradation; frequently leading to loss of forest cover and biodiversity, erosion, desertification and reduced water resources (Ensermu Kelbessa and Teshome Soromessa, 2008). The major threats to the biodiversity are unsustainable utilization of natural resources, deforestation, and conservation of natural vegetation to farmland, alien invasive species, climate exchange and shortage of right policy framework (FAO, 2010, EPA, 1997, and Schmitt *et al.*, 2010).The high degree of dependency of the local community on agriculture (more than 90% and excessive charge of population growth (EFAP, 1994; Tadesse Woldemariam, 2003; Simon Shibru and Grime Balcha, 2004; Feyera Senbeta, 2006) have additionally increased the problems. Apparently, biodiversity sources along with their habitats are rapidly disappearing in many parts of the country (Demel Tekatay, 1992; Tadesse Woldemariam and Denel Taketa, 2001; Tadesse Woldemariam *et al*, .2002; Tadesse Woldemariam, 2003; Feyera Senbeta, 2006; Feyera Senbeta and Dench, 2006).

The destruction of flora and environmental degradation has become problems of national and international issue in recent years. That is due to the reality that declining the plants cover and depletion of natural resources are closely related to drought and food shortages that have emerge as major risk affecting the life of millions of people.

The range, regeneration status, floristic composition and plant life structure are essential elements to clearly visualize the anthropogenic sports as well as environmental factors affecting the flora of an area. Hence, for forest management accurate facts on woodland useful resource is considered to be an essential requirement (FAO, 2007). Mountain Ambaricho natural forest is one of the forest of Kachabira District victimized by those anthropogenic activities as well as environmental factors. Attention and understanding on sustainable use and management are very less within the community (HDARDO, 2010).Mountain Ambaricho natural forest is highly valued for its socio-economic and ecological services, but, the assessment of floristic composition, structure, distribution, and different attributes has not been studied thus far in the study location. Consequently this study conducted to provide information on the floristic composition and structure of Mountain Ambaricho natural forest, Kachabira District, southern Ethiopia.

## 1.2 Statement of the problem

Ethiopia is one of the countries which have different varieties of plant species. Today, more woody species are endangered than ever before due to human activities. As a result different wild animals lost their homes and started to migrate and many native woody species are destructed. The farmlands are exposed to erosion and agricultural productivity is also decreasing. In a forest resource assessment of Ethiopia, it was found that within 17 years (1973–1990) high-forest cover decreased from 54,410 to 45,055 $km^2$ or from 4.75 to 3.96% of the land area (Reusing, 1998). Forest degradation has been a serious challenge to Ethiopia.

Although Mountain Ambaricho natural forest is one of the forest priority areas for conservation in Kachabira District, it obtained little attention to this point. Information on plants may be required to help to solve an ecological problem. For biological conservation and control purpose; as enter to environmental impact statements; to monitor control practices or to provide the bases for prediction of possible future changes. Forests may be visible as earth's lungs. They play a crucial position in tempering the results of weather and help protect essential water catchments. Trees provide a huge variety of products, inclusive of meals and fruit, wood, fodder for livestock, habitat for wildlife and medicines for each humans and farm animals.

Forests supply goods of commercial, cultural and sacred value, and used as numerous raw materials, which are in the main used in timber-, based totally industries and they contain a critical safety net in times of want. Mountain Ambaricho natural forests are providing the above uses. However, due to its accessibility, the plant life has been significantly and unwisely exploited. Consequently, the present conditions name for a critical mitigating manner. The plant life of this region is undamaged previously (facts from community elders) but enormously depleted at present. It has also now not been studied earlier than and therefore, the need to collect records at the ecology and composition of the forest is very crucial. Without a full assessment of the homes of various sites in a wooded area and their relation to vegetation growth, the control of the forest may be significantly handicapped.

## 1.3 Objectives of the Study

### 1.3.1 General Objective

The general objective of this study was to investigate Floristic composition, structure and regeneration status of Mountain Ambaricho Natural Forest in Kachabira District Kambata Tambaro zone, South Nations Nationalities and People Regional State, Southern Ethiopia.

### 1.3.2 Specific Objectives

The specific objectives of this study are:

1. To assess the floristic composition of Mountain Ambaricho natural forest.
2. To determine the vegetation structure of Mountain Ambaricho natural forest.
3. Assessing the regeneration status of woody plant species in Mountain Ambaricho Natural Forest

## 1.4. Basic Research Questions

In order to realize the above-mentioned research objectives, the following research questions would answer this study: -

1 What are the floristic compositions of Mountain Ambaricho natural forest?

2 What is the vegetation structure of Mountain Ambaricho natural forest looks like?

3 What is the regeneration status of plant species in Mountain Ambaricho Natural Forest?

## 1.5 Significance of the Study

This study would have great significances for many improvement programs. The outcomes of the study was provide the information to policy makers, planners, administrators, forest conservation organizations and institutions, to study their strategies and make sure their participations in forest conservation action planning and implementation program and know the seriously factors that may accelerate their uses. This could facilitate allocation of many resources for researches and other forests conservation programs. For this reason this study would attempt to discover the floristic composition and plants structure of Mountain Ambaricho natural forest, Kachabira District, Kambata Tambaro Zone, SNNPR. It would be expected that this study would serve as spring board (facilitator) to undertake targeted and comprehensive studies in another districts.

## 1.6 Scope of the study

The study was delimited to assess the floristic composition structure and regeneration status of Mountain Ambaricho natural forest, in Kachabira District, SNNPR, and State.

But not such studies have been performed so far. Hopefully, the results of this study would fill the gap and give clear insight. This study doesn’t include non-floristic pants in the study area.

# 2 LITRETURE REVIEW

## 2.1. Mountain Ecosystems

Mountain ecosystems are landscapes characterized by distinctive abiotic, biotic, social, cultural, Economic and spiritual values (Martinelli, 2007). Mountains embody fragile, topographically highly variable, often difficult environments. Mountains serve as source of water, energy and biological diversity and source of key resources such as minerals, forest, and agricultural products. Billions of people, not only living within and immediately adjacent to mountains, but also downstream and further afield, exploit the diversity of resources available in and around mountain regions. Perhaps the greatest global value of mountain areas derives from the fact that almost all of the world's major rivers rise within them (Price, 2004; Gurung, 2006). Mountains supply 80% of the world's fresh water (GEF, 2002; GMP, 2006). Twenty percent (1.2 billion) of the world's human population lives in mountains and their edges (Körner and Ohsawa, 2005).

## 2.2 Mountain Forest as Biodiversity Reservoir

Melkania *et al.* (2006) talked about that mountains have vast relief features of the second order on the earth's surface. Globally, a huge part of mountains are covered by various flora sorts as natural excessive forests, plantations, wood and scrublands, and herbaceous vegetation. According to Kapos *et al.* (2000), mountain forests account for 26.5% of the worldwide forest region. Those forests, apart from the other uses, are important to protect fragile mountain slopes from erosion and leaching processes and as reservoirs of species for resettlement of deforested, fragmented, or newly created habitats after being affected by anthropogenic or natural disturbances (körner and Ohsawa, 2005). Mountain vegetation regularly indicates marked zonation due to environmental gradients like moisture and temperature linked with elevation. Elevation is the only and most important topographic factor other than the element and slope controlling vegetation growth (Jin *et al.,* 2008). As the result of compression of the climatic zones along an elevation gradient, exposure consequences and massive habitat diversity, species richness in mountains typically exceeds that inside the lowlands at the same scale (GEF, 2002; körner and Ohsawa, 2005; Gurung, 2006).

However, inside mountain regions, species richness generally decreases with increasing altitude (körner, 2000) while endemism regularly increases due to topographic isolation Gentry (1988) and Peterson et al, (1993) and the rapid formation and loss of corridors in geological time (Mace *et al.*, 2005).

### 2.3 Status of Ethiopia's forests

According to FAO (2015) Ethiopia lost over million hectares of forest with an annual average loss of 140,000 hectares among 1990 and 2005. Currently, the forested area is estimated to be 12.4 million hectares, which represents 11.4% of the total land area. The main reasons for deforestation are clearing of forests and woodlands for agricultural purposes, fuel timber, and charcoal manufacturing and production materials. The fact that plantation forestry has been very far from meeting the country's demand for wood indicates the inevitability of deforestation. The underlying causes of deforestations are closely linked with the vicious cycle of at the same time reinforcing factors such as poverty, population growth, poor economic growth and the country of the environment.

### 2.4 Significance of Forests

In Ethiopia the contribution of forests to local livelihoods and the national economy as a whole is significant, but is largely unrecorded and hence unrecognized. Forest resources are among natural resources that have substantial socio-economic, cultural and ecological importance in Ethiopia. There is a growing awareness of the significance of forest resources and the link between biodiversity, ecosystem service and human well-being (EFS, 2014). Forests are also source of timber and non-timber forest products (NTFP). The economic value of Ethiopian forest is not given the proper attention, even if they are sources of ecosystem services, including NTFPs that sustain rural livelihoods. The most important NTFPs that generate substantial income for rural households and foreign currency earnings in Ethiopia are coffee, honey and natural gums and resins. A study conducted on a participatory forest management concession in a southeastern city called Dodola, indicates that forest products are the most important sources of income, contributing to 34% and 53% of household per capita income and per capita cash income respectively (EFS, 2014).

## 2.5 Forests and Threats on Forest Resources of Ethiopia

Forest resources are the fruits of evolution that are developed through the combined influence of physical environment and people, and play important economic, social and cultural roles, particularly in the lives of many local communities (Regessa Feyissa, 2001).

The natural forests of Ethiopia are organized under 58 national forest priority areas. Following the regionalization of the country and the consequent devolution of power, the national regional states and their executive organs are administering most of these forest priority areas.

All of these priority areas, invariably, are under extreme pressure from settlement, land use conversion to farming and grazing, excessive extraction, and neglect in terms of forest management and protection (Yonas Yemshaw, 2002).The majority of Ethiopians are farmers for thousands of years. Highland vegetation were cleared to give way to cultivation and grazing without due consideration to soil conservation practices. People were attracted only to temporary yields obtained at the initial stage without realizing the outcome they would be facing in the long term (Alemu Abebe, 2007).

The growth of human and livestock population had caused the country to face the following problems: Environmental degradation, severe soil erosion, drought and famine and the loss of economically important indigenous tree species. Any changes in the status of these factors disturbs the vegetation composition, persistent disturbance caused by biotic exploitation regress change in vegetation that finally results in the decline of quality of vegetation and reduction in the diversity and abundance of indigenous plant species and the majority of the fauna (Tamirat Andarge, 2001).The trees and forests of Ethiopia are under tremendous pressure because of drastic decline in mature forest and continual pressures of population increase, rudimentary farming techniques, land use competition, land tenure, and forest degradation and conversion. The status of forest resources should be considered at risk. However the attention given to conservation and sustainable use of these biological resources is inadequate due to low level awareness about the role of the forests (Dereje Denu, 2007). Although deforestation is known to occur in the remaining forested areas of the country, rates of deforestation have been more difficult to estimate.

The most important reason behind the rapid deforestation rate in the country is the ever-increasing human population growth. This rapid increase in human population is associated with a very high demand for agricultural and grazing lands, forest resources for firewood, charcoal, timber, construction, and many other purposes. Fire, inappropriate investment activities, and lack of viable land use policy have also been key factors for the raid decline of forests in the country. At present, few remaining high forests are threatened by pressure from investors who are converting moist evergreen montane forests in to other land use systems such as coffee and tea plantations (Friis, 1992; Million Bekele and Leykun Berhanu, 2001; Haile Yineger *et al.,* 2008). Forest resources in the country have under gone substantial changes over the years due to competing land uses and unbalanced forest utilization. As a result it is often quoted that the closed natural forests, which were once covered more than 40% of the Ethiopian highland have now decreased to less than 3%. Ethiopian Forest Action Program (1994), indicates that the forest cover was reduced to 2.7% in 1989 and less than 2.3% in 1990. One reason for the decline of the forest is attributed to energy requirement of the country relies on biomass alone Haileleul Tebicke (2002), of which, trees and shrubs contributes the largest proportion.

According to USAID (2008), 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. These threats are largely interrelated and reinforcing, and it is therefore important not only to understand the individual threats but also to examine them in a holistic fashion that recognize their interrelation and can help to propose solutions to decrease the threats and mitigate their effects. Environmental problems such as soil degradation, erosion and decrease in biodiversity as well as the loss of potential natural resources are negative effects resulting from the destruction of these habitats. Indigenous knowledge on medicinal and other useful plants is eroded with destruction of these forests (Kitessa Hundera and Tsegaye Gadissa, 2008).

To address these threats, it is critical to raise government decision makers' awareness of importance of natural resource policies to Ethiopia; facilitate dialogue among the government, civil society, and national and international organizations; and to closely examine and revise those policies requiring clarification or harmonization. Taking the lost opportunities in to account, foresters and conservationists have to develop new initiatives to respond to the convergence of local communities and forests (Regessa Feyissa, 2001).

## 2.6 Vegetation in Ethiopia

Vegetation formation is influenced by many factors, such as climate, geology, edaphic factors and biotic factors including interference by humans in ecological succession. Vegetation is dynamic, that is constantly changing. Reasons for the changes can be ecological or evolutionary processes, climatic changes human land uses, and interaction between factors (Skarpe, 1991).

According to Sebsibe Demisew *et al.* (2004), the vegetation of Ethiopia is divided into eight major types. This vegetation classification is as follows: Desert and Semi-desert Scrubland, Small-leaved Deciduous Woodland, Moist Evergreen Montane Rainforest which can be further divided in to two sub divisions (The Afromontane-rainforest and the Transitional rainforest), Lowland Semi-evergreen Forest, Broad-leaved Deciduous Woodland and Savannah, Dry Evergreen Montane Forest and Grassland Complex, which is also divided in to four sub types (Undifferentiated Afromontane Forest, Dry Single-Dominant Afromontane Forest of the Ethiopian Highlands, Afromontane Woodland, Wooded Grassland and Grassland, Dry Single-Dominant Afromontane Forest of the East African Evergreen and Semi-evergreen Bush land), Afro-alpine and Sub-afro alpine Vegetation, and Riparian and Swamp Vegetation.

## 2.7. An Overview of Ethiopian Vegetation type

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). Vegetation types may be characterized either by their component species or by the combination of structural and functional attributes that typify them.  Vegetation structure is the organization in space of the individuals that form a community and by extension a vegetation type or plant association (Kent, M. and Coker, P. (1992).

It is the spatial pattern of growth forms in a plant community, especially in relation to their height, abundance or coverage within the individual layer (Jennings *et al*., 2003).

The vegetation of Ethiopia is one of the richest in floristic diversity in Africa and/or in the world. Most recently, the country is recognized as one of the top 20 Mega diverse countries in the world

(Abyot Berhanu, 2017).Ethiopia is endowed with wide range of vegetation formations or types ranging from afro-alpine to desert vegetation. Different authors have studied and described the vegetation types of the Country at different times (Friis *et al.* (2010).Ethiopia because of its geographical positions, range of altitudes, rainfall patterns and soil variability has an immense ecological diversity and huge wealth of biological resources. A recent study indicated that the number of higher plants in Ethiopia is estimated to be 6000 species, of which 12 percent are considered to be endemic (IBC, 2012).The vegetation resources of Ethiopia, including forests, woodlands and bush lands have been studied by several scholars. Most of the studies, including identification and descriptions of the vegetation, were undertaken by foreign travelers between the beginning of the 19th century and the mid-20th century (Mekbib Fekadu, 2012). Attempts to describe this vegetation were also conducted by many Ethiopian scholars of which, Sebsebe Demissew *et al*, (1998), (Teshome Soromessa.*et al.* 2004), and Zerihun Woldu (1999) were a few. According to Friis *et al.* (2010) the present vegetation of the country is classified into the following twelve Vegetation types:

These are: 1) Desert and semi-desert scrubland, 2) *Acacia-Commiphora* woodland and bush land, 3) Wooded grassland of the western Gambela region, 4) *Combretum- Terminalia* woodland and wooded grassland, 5) Dry evergreen Afromontane forest and grassland complex, 6) Moist evergreen Afromontane forest, 7) Transitional rain forest, 8) Ericaceous belt, 9) Afro alpine belt, 10) Reverie vegetation, 11) Salt lakes, salt-lake shores, marsh and pan vegetation and 12) Freshwater lakes, lake shores, marsh and flood plain vegetation.

## 2.8 Factors affecting vegetation distribution of the area

### 2.8.1 Environmental factors (Climate) affecting distribution of vegetation of an area

As described by (K. Soleimani *et al*., 2008), Environmental factors—light, temperature, water, and soil—greatly influence plant growth and geographic distribution. To maximize the production of any crop, it is important to understand how these environmental factors affect plant growth and development (K. Soleimani *et al*., 2008).Factors such as the climate, parent rock, topography and vital factors which determine the ecologic conditions dominant on the environment, affect the placing of a vegetation unit. Farther more, determining the range vegetation sites and the factors influencing on them are important parameters to manage the natural resources (Moradi, H, and R. Erfanzadeh, 2004). Vegetation plays an important role in the climatic zonation and can be addressed as a sign of different Climatic and topographic patterns. Therefore, climate and vegetation maps all together can be used to analyze and define bioclimatic zones (Fatemi Azarkhavarani *et al.,* 2015.

Most climatic classifications that are performed on bio climates only relied on some limited variables, like temperature, precipitation or a combination of both, while the climate is a compound Phenomenon that cannot represent the climate of a region by using some limited variable. Many researchers have studied the effect of climatic factors on the distribution and development of plant types (Sheded, 1998; Zangin *et al.,* 2010).

### 2.8.2 Anthropogenic factors affecting vegetation of an area

During the past five decades, the population growth and the expansion of economic and human activities have put enormous pressure on the world's ecosystem and biodiversity. Vegetation is the most basic part of the ecosystem (Tong, S *et al.*, 2016). Vegetation coverage has changed dynamically over time, which is of vital importance to global climate change and the creation of environmental policies. With the growing population and economy, many studies have gradually concluded that the human-induced activities are the dominant factors affecting vegetation greening and browning (Meichen Jiang *et al.,* 2017). Agricultural practices are one of the most important human activities critically affecting the present status of vegetation of an area (McLaughlin A & P Mineau, 1995) Rapid population growth, extensive forest clearing for cultivation, overgrazing, Movement of political centers, and exploitation of forests for fuel wood and construction materials without replanting reduced Ethiopia's forest area to 16 percent in the 1950s and to 3.1 percent by 1982 (Badege Bishaw, 2009)

### 2.8.3 Significance of vegetation study for conservation

Vegetation can be defined as an assemblage of plants of single to many species growing in particular areas of different sizes and different life forms. The individual vegetation layers comprise an important feature of the overall biodiversity of forest ecosystems (Mekbib F 2012). Their composition, diversity and structure constitute both important factors in the assessment of their biodiversity and also important bio-indicators of environmental changes.

Long-term study of vegetation in areas of intensive monitoring is helps to provide data for the overall study of changes in forest ecosystems in relation, for example, to the soil conditions, micro- and macroclimate, etc(V. Buriánek *et al.*, 2013).Vegetation study is very important to study the current status of our vegetation to identify the problems and threats associated with them and make useful recommendation that is helpful for planning their future conservation and sustainable management (Zerihun Tadesse, 2015).

Detailed description of vegetation resource exploitation needed analysis of floristic composition and structural complexity could contribute towards the conservation of vegetation resources.
It is additionally important to document the remaining vegetation resources for posterity (Birhanu L *et al*., 2018).
According to FAO (2007) cited by (Mulugeta Kebede and Hewan Daniel, 2017), regeneration status Floristic composition, and vegetation structure are crucial elements to clearly visualize the anthropogenic activities as well as environmental factors affecting the vegetation of an area. For the sake of conservation method, scientific studies on floristic composition and vegetation structure of a given natural forest patch is needed for determination of a forest status to take appropriate conservation measures (Dereje A and Duguma Dibbisa, 2

# 3. MATERIALS AND METHODOLOGY

## 3.1. Description of Study Area

The study was done in the Mountain Ambaricho natural forest in Kachabira district, Kambata Tambaro Zone, Southern Nations, Nationalities and People's Regional States, Ethiopia. Geographically located between 07°12'30.1" - 07°17'08.3" N and 37°47'48"– 37°50'30.6"E.

It is situated in the south western part of the zone, which is bordered with Angacha district in the north, Kedida-Gamela district in the east, Hadiya zone in south east and southwest with Wolayita zone in the south west(fig.1).. The district is found 327 Km away from the country capital, Addis Ababa and 117 km away from the regional capital, Hawassa. The district includes 21 kebeles (small administration unit) up to the end of 2019.

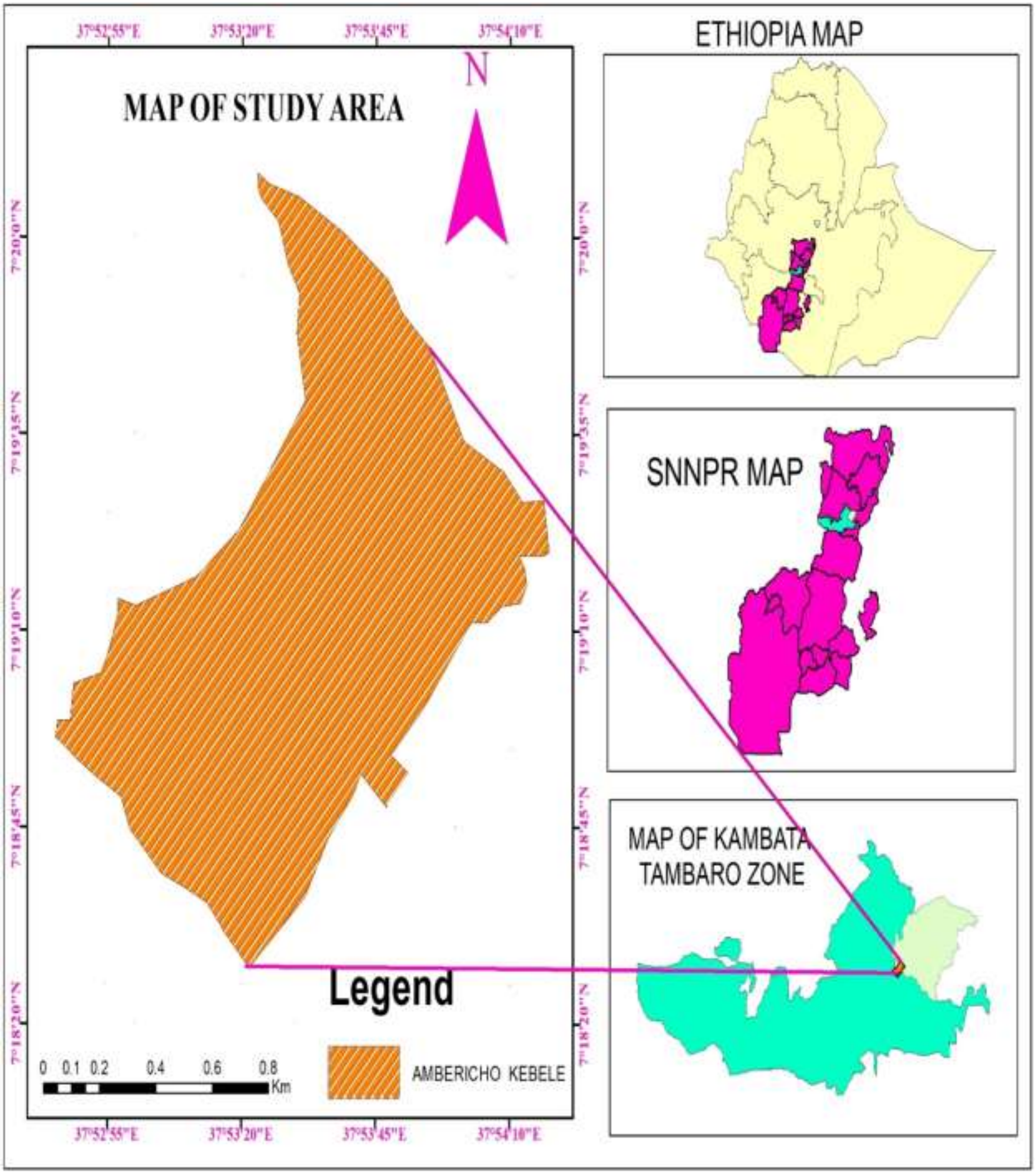
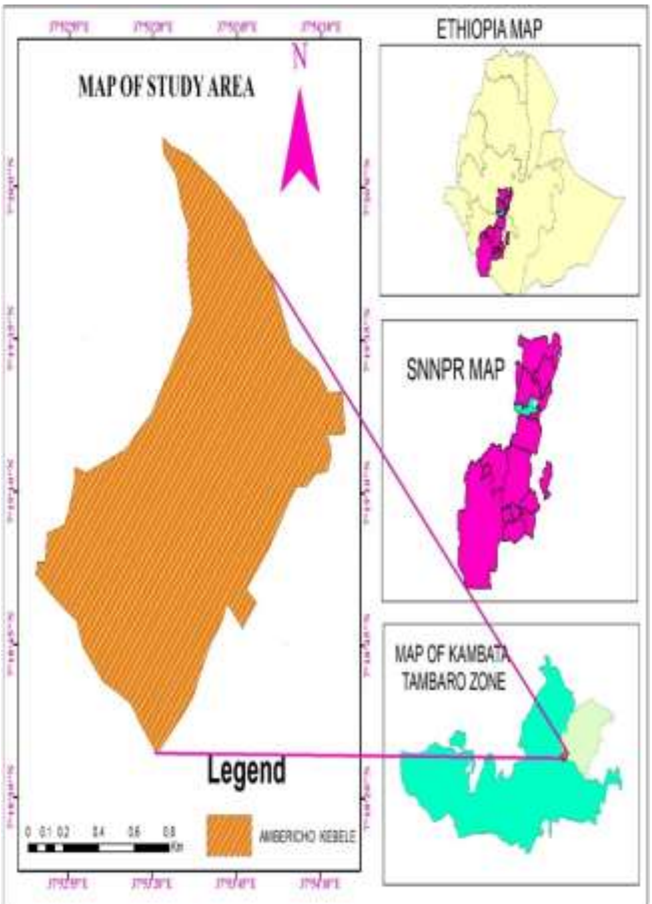
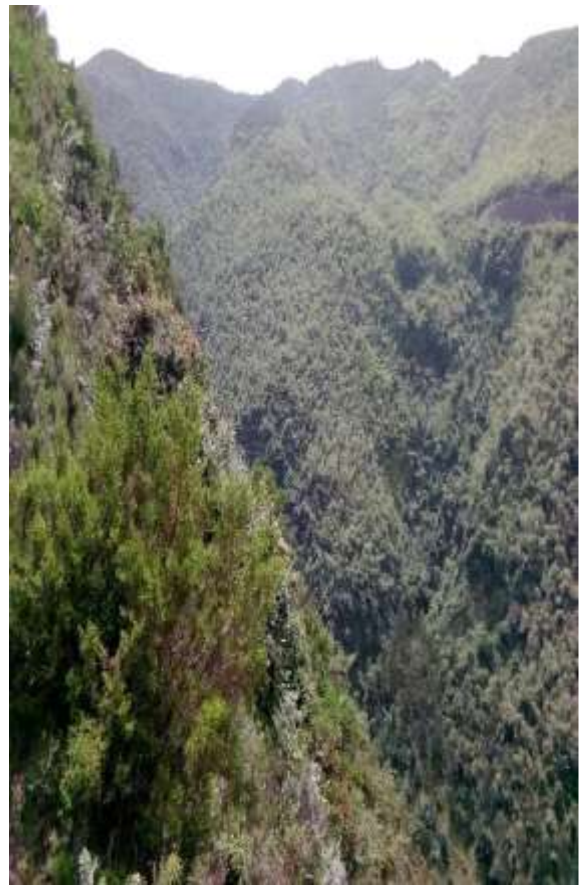



**Figure 1:** Map of study area



(A)

(B)

**Figure 2:** Map of study area (A) and Ambaricho Mountain Forest (B) photo @Terefe Daniel

The district with a total land area of 25,944 hectare and has diversified topographic features such as flat, gentle, sloping plains and undulating to rolling plains with substantial proportion of low to moderate relief hills. The altitudinal range of the area falls within 2400- 3058 m. a.s.l. Ambaricho is a source of many streams and rivers like Bazena and Korowoa and reaching the highest peak about 3058 a.s.l, is the grand mountain of the Kambati.

### 3.1.2 Soil

The soil of the study area silt soil. The hard topography (hilliness) makes the area of cultivation difficult during rainy seasons. Because soil erosion and floods are more frequent (ARDO of KATA Zone).

## 3.1.3 Climatic condition

Rain fall is bimodal distribution with the main rainy season occurring between Junes to September. The dry season lasts from November to February, following by short rainy season during the months of March and April (NMA, 2005).

There is no metrological station in the study area, but the climate data for the Kachabira district is recorded by Kambata Tambaro zone Agricultural office shows that, the area has a mean annual rainfall of 1001-1400mm and the temperature ranges from $12^0$C -$27^0$C (NMA, 2006).According to the data, the mean annual rainfall of the study area recorded was 1171mmand the mean temperature was $21.1^o$c. The lowest temperature of the area is $14.4^o$c and highest is $29.5^o$c. (Source: NMA).

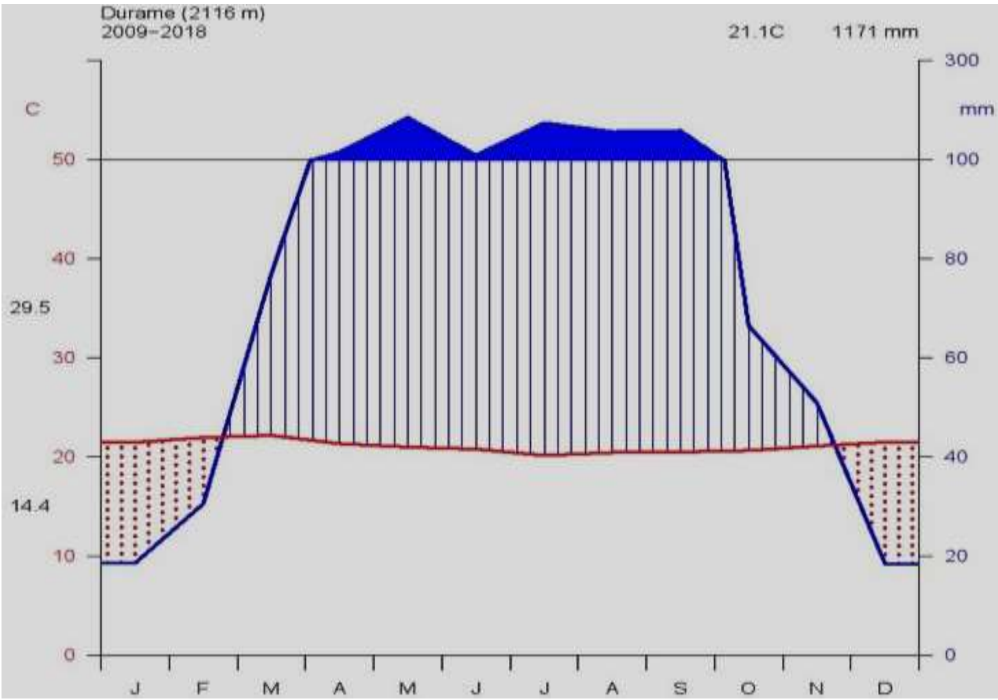


**Figure 3:** The claima diagram shows climatic condition

### 3.1.4 Vegetation

The vegetation of Ambaricho Mountain is exploited for agriculture, pasture, timber, firewood, construction, etc...The natural vegetation of the study area is sub alpine evergreen vegetation type. At the elevation between 2800-2970 m a.s.l., *Croton macrostachyus* and *Olinia rochetiana* was dominant species. At the lower zone between 2400-2750 m a.s.l. *Erica arborea* and *Maesa lancelota* were Comman tree species in association with few *Artemis afra* and *Diciliptera maculate* were dominant herbaceous species.

## 3.2 Sampling Design and Data Collection Methods

### 3.2.1 Sampling Design

A systematic sampling technique was used for the study to collect the vegetation data in the forest, A total of 35 sampling plots area of 20m x 20m (400m$^2$) were established for trees and shrubs, and 5m×5m (25m$^2$) used for seedlings and saplings and 1m x1m (1m$^2$) have been used for herbaceous plants. Sampling sites have been arranged according to the topographic nature of the study area. Along 12 belt transects were laid down with 50 meters elevation interval, 6 belt transects from North to South direction and the remaining 6 belt transects along east to west and in such a way that the various conditions encountered were represented by at least one sample.

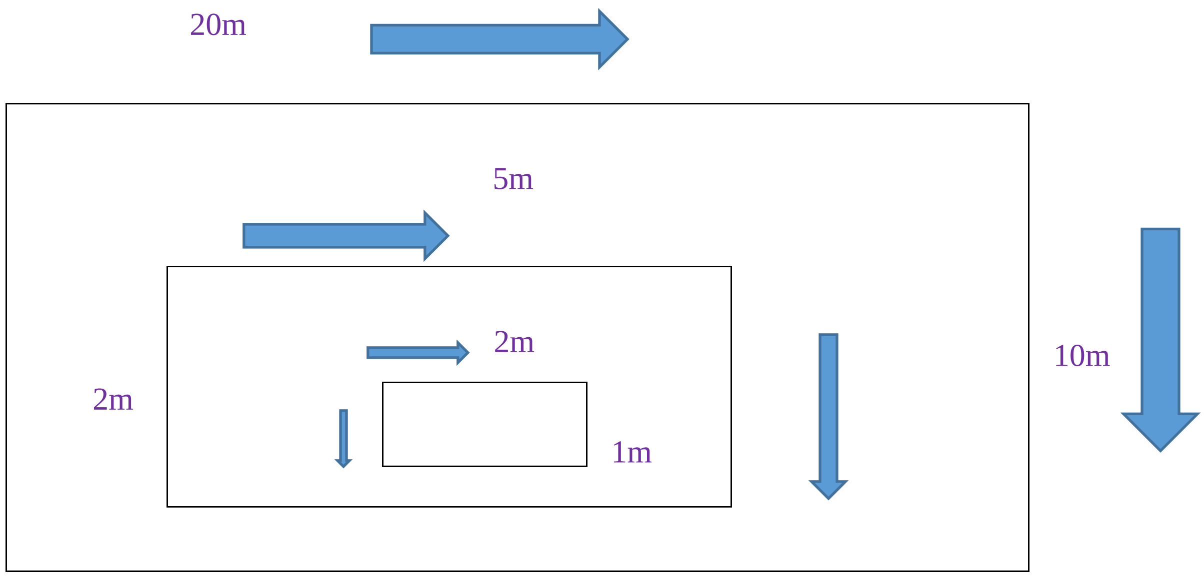



**Figure 4:** plot designs were used for data collection

### 3.2.2 Floristic Data Collection Methods

The reconnaissance survey of plants had been made on the way to make an impression of the plant life and topographic features. All plant species in every quadrat had been recorded and their boom addictions were described. Also, the real fields statistics, the plants and environmental records have been accumulated in sample quadrat located along transect lines that have been systematic laid. Quadrat had been laid at every 50m elevation alongside transect line, that have been laid 400m apart.

All woody plant species including trees and shrubs were recorded in 20m x 20m quadrat while herbaceous species have been recorded in 1m x 1m plots that have been placed subjectively in the main quadrat at the center. Plant species were counted at individual level with each main quadrat and subplots. Height and diameter at breast height (DBH) were measured for any woody plant species. A complete list of woody plant species from each quadrat (20 m × 20 m) have been recorded and percent cover values for each species have been estimated and later converted to the Braun-Blanquet 1-9 scale as modified by Van der Maarel (1979). DBH for all individuals trees and shrubs with DBH $\geq$ 2.5 cm at 1.3 m above the ground, and height $\geq$2m were measured from the 20m×20m plots.

Individual species with DBH < 2.5 cm and height < 2 m were counted as sapling. Estimation of cover/ abundance of tree, shrub and herb were performed using a 1 – 9 modified Braun Blanquet scale (van der Maarel, 1979).

### 3.2.3 Materials used

The necessary materials which are needed during the conduct of this research were:

- Global positioning system (GPS) to collect location and elevation of study area
- Digital camera to take photographic view of Mt Ambaricho vegetation
- Meter tape was used for quadrants and transect measurement
- Bag that to be used to collect plant specimen
- Newspaper, and a piece of blanket that to be used to press plant specimen

### 3.2.4 Identification of plant specimens

Plant species encountered in each quadrat have been recorded by using their vernacular names. Sample specimens of woody species have been pressed, dried and taken to Herbarium for identification and storage. The identification was done in Jimma University Herbarium using botanical keys, Flora books (Flora of Ethiopia and Eritrea volume 1-8).

## 3.2.5 Structural Data Analysis

All plant species were recorded in each plot that is laid purposively to do analysis of vegetation structure. The diameter at breast height (DBH), basal area (BA), tree density, frequency and important value index (IVI) were used for the description of vegetation structure. The structural parameters have been analyzed by using the following formula:

**Diameter at Breast Height (DBH):** the diameter is calculated from circumference (C)

$C = \pi * DBH$ Therefore,

$DBH = C/\pi$ Where: C = circumference of tree, $\pi = 3.14$

DBH = diameter at breast height of tree.

This technique is easy, quick, inexpensive and relatively accurate. There is direct relationship between DBH and basal area (Kent and Coker, 1992).

**Tree height** is a straight forward parameter used for direct measurement purposes. Height reveals something about the age of a plant. It can also say something about disturbance and re-colonization. For example, a stand comprised of a single species of tree, all of the same height could indicate vegetation removal and subsequent invasion.

**Basal area (BA):** is the area outline of a plant near ground surface. It is expressed in square m/hectare (Mueller-Dombosis and Ellenberg, 1974). Basal area is also used to calculate the dominance of species.

BA = $\pi$ $(DBH/2)^2$ where d is diameter at breast height.

**Density:** is a count of the numbers of individuals of species within the quadrat (Kent and Coker, 1992). It is closely related to abundance but more useful in estimating the importance of the species. Counting is usually done in quadrat placed several times in vegetation communities under study. Afterwards, the sum of individuals per species is calculated in terms of species density per convenient area units such as a hectare (Mueller-Dombois and Ellenberg, 1974).

**Relative density (RD)** $= \dfrac{\textbf{the number of ground stems of species counted}}{\textbf{total number of above ground stems in the sample area}} \times 100$

**Frequency**: is defined as the probability or chance of finding a species in a given sample area or quadrate. It is dependent on quadrate size, plant size, and patterning in the vegetation (Kent and Coker, 1992). It is calculated with formula:

A better idea of the importance of a species with the frequency can be obtained by comparing the frequency of occurrence of all the tree species present. The result is called relative frequency and is given by the formula:

**Relative frequency (RF)** = $\dfrac{\textbf{frequency of a species occur in plots}}{\textbf{total frequency of all speciesin all plots}} \times 100$

**Relative Dominance (RDO) =** $\dfrac{\textbf{total BA of a species}}{\textbf{some of BA of all tree species}} \times 100$

**Importance Value Index (IVI):** is useful to compare the ecological significance of species. It combines data for three parameters (relative frequency, relative density and relative abundance) or it often reflects the extent of dominance, occurrence and abundance of a given species in an area (Kent and Coker, 1992).

Importance Value Index (IVI) = RD +RF + RDO

Where, RD is Relative Density, RF is Relative Frequency, and RDO is Relative Dominance.

**Shannon-Weiner Index (Species diversity index)**

Woody species diversity would be calculated by using Shannon diversity index (H') (Kent and Coker, 1992). The Shannon diversity index would have been calculated using the following equation:

$H' = -\sum Pi \ ln \ Pi$

Where, Pi is the relative abundance of the ith species, ln is the natural logarithm.

Past software would be used in this study to determine species richness, abundance, diversity, dominance and diversity profile (Hammer *et al.*, 2001).

## Shannon evenness (E'*)*

Evenness would be calculated to compare the determined distribution with the most possible even distribution of the wide variety of species within the studied woody species.

Evenness is maximum while all of the species have same or almost identical number of species. Evenness (Shannon equitability) index could be calculated as described through (Kent and Coker 1992) to estimate the homogeneous distribution of E= Equitability (evenness) index which has values among zero.

$$\mathbf{E} = \frac{\boldsymbol{H''}}{\boldsymbol{Hmax}} = \frac{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{pilnpi}}{\boldsymbol{lns}} = \frac{\boldsymbol{H''}}{\boldsymbol{lns}}$$

Where:

E= Equitability (evenness) index which has values between 0 and 1

H' = Shannon Diversity

$H'_{max}$ = Maximum level of diversity possible within a given population

Pi= Proportion of individuals found in the $^{i}$th species

S = Total number of species (1, 2, 3…..s)

## 3.2.6 The Shannon diversity index and evenness

Species diversity and evenness of Ambaricho Natural forest were calculated using the Shannon- Wiener diversity index (Gering et al., 2003). Shannon -Wiener diversity index values of plant species encountered in the study sites were 3.69 while their corresponding evenness values were 0.8.The Shannon index represents the information statistic induces of the measures of heterogeneity. The higher the heterogeneity value, the higher is the species diversity in that ecosystem. Diversity has direct relationship with stability or health. That is disturbed and unstable ecosystems have lower heterogeneity. More stable ecosystems have higher heterogeneity value. A low value of evenness indicates that one or a few species are highly dominant while others are present with few individuals (Ambachew .2019). Due to this; the study showed that the natural forest of Ambaricho had high heterogeneity and evenness.

**Sorensen's Similarity Index**: similarities between pairs of plots or community types were calculated by using Sorenson's similarity index.

$$SSI = \frac{2a}{2a+b+c}$$

Where, a = number of common species

b = number of species unique to the first site

c = number of species unique to the second site.

Often, the coefficient is multiplied by 100 to give a percentage similarity index.

## 3.2.7 Plant Community Analysis

The plant community analysis of this study was done based on the abundance of the species Dufrene and Legendre's (1997). Plant community is defined as the collection of plant species growing together in a specific area that show a definite association of affinity with each other (Kent and Cooker, 1992).

Vegetation classification has been broadly utilized in plant as a vital instrument to create some order in to a collection of facts and enables one to communicate description and ideas on the relationship about the sort of vegetation recorded and make comparisons with similar or dissimilar samples from elsewhere. Mueller-Dombois and Ellenberg (1974) stated that plant community understood as combination of plants that are dependent on their environment, impact one another, and modify their environment.

### 3.2.8. Community's Similarity

The similarity of community 1 with community 2 was 62.2%, with community 3 it was 41.5%, but relatively shared less number of species with community 4 .The results of similarity analysis between communities revealed that the species in Ambaricho Natural forest are more or less homogeneously distributed in the forest.

### 3.2.9. Regeneration status of the forest

Regeneration status of the forest were analyzed by comparing saplings and seedlings with the matured trees according to Tiwari *et al.*,(2010); that is, the status is good regeneration, if seedlings > saplings > adults; the status is fair regeneration, if seedlings > or ≤ saplings ≤ adults; the status is poor regeneration, if the species survives only in sapling stage (saplings may be ≤ or ≥ adults); and if a species is present only in an adult form it is considered as not regeneration .

# 4. RESULTS AND DISCUSSION

## 4.1. Diversity of plant species

A total of 61 plant species, representing 42 families and 61 genera were recorded in the 35plot. Mount Ambaricho forest is floristically poor or less diversified compared with many other forest in Ethiopia like Gole Natural forest, 114 species recorded (Haile Mariam M, 2018), in Yegof dry Afromontane forest, 76 species (Mesfin Woldearegay et al. 2018), and in Belete Moist Evergreen Montane Forest, 157 species were identified *but* relatively better than Hallideghie wildlife reserve, in this area only 46 species recorded (Endris et al., 2017).The reason for variation in floristic composition of the vegetation at the different study sites could be due to excessive anthropogenic disturbances, disparity in conditions for regeneration and exploitation of some species. In addition to this, the geographical location of different study areas could also be varying from other areas.

From all 42families in Mountain Ambaricho forest, family *Asteraceae* was represented by 6 species (9.83%) followed by *Rubeaceae* 5 species (8.19%), *Lamiaceae* 4 species (6.55%), *Solanaceae* 3 species (4.91%) were the most species-rich families. These four families comprise 29.5% of all identified plant species in study area.

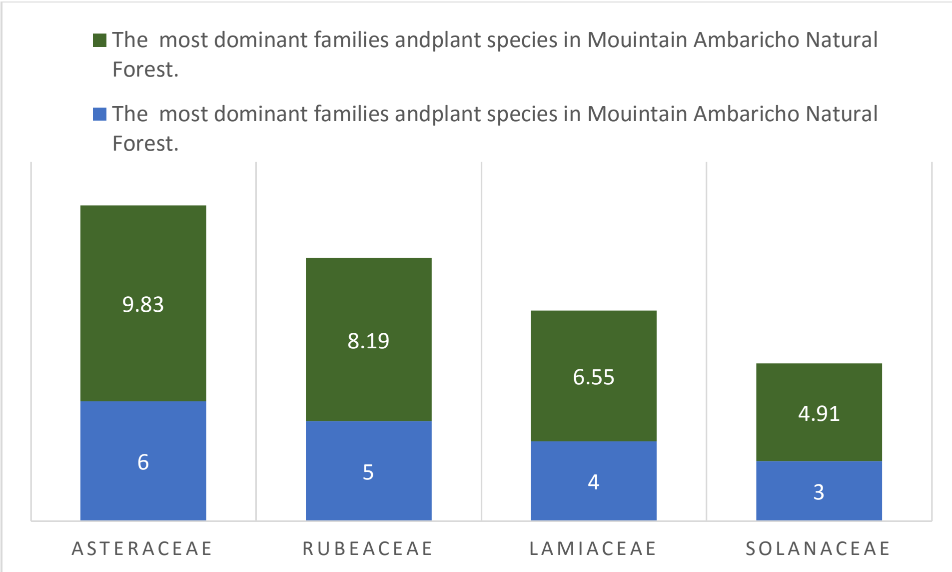



**Figure: 5** the most dominant families and number of species of Mountain Ambaricho Natural Forest.

Other families like, *Acanthaceae*, *Myrsinaceae*, *Ericaceae*, *Euphorbiaceae*, *Rosacea* and *Malvaceae* were the second most species-rich families represented by two species each (3.27%). All the other 32families were represented only by single species each. Of the all recorded species, 34(55.7%) were trees, 20(32.8%) were herbs and 7(11.5%) were shrubs (Fig.6).

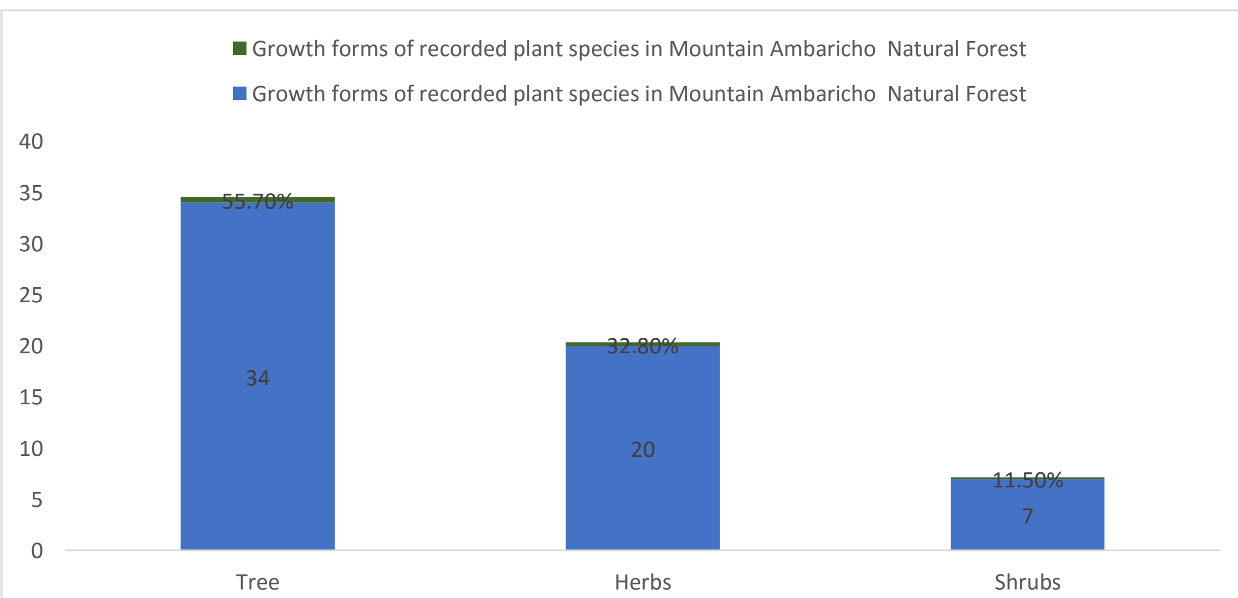



**Fig: 6.** Growth forms of recorded plant species in Mountain Ambaricho.

## 4.2. Plant Community Types

The plant community types were recognized using Agglomerative hierarchical cluster analysis. Communities were Agglomerative hierarchical cluster analysis revealed that there were 4 community types,

These community groups were identified from the hierarchical cluster analysis using the computer software program R for windows version 3.0.2. The computer program was used for determining the optimal number of clusters used to decide the number of plant community types. Ward method and Euclidean distance were used to draw the diagram showing dissimilarity among the four clusters (Fig7). The description and altitudinal distribution of these plant community types is given below.

**Community 1: *Croton macrostachyus-Olinia rochetiana* community type:** This community type was found at the altitude ranging between 2565 to 2900 m a.s.l. This community resulted from 12 plots and 66 species. The tree layer was highly dominated by *Croton macrostachyus* and *Olinia. Rochetiana, Galiniera saxifraga, Dovyalis abyssinica* and *Rhamnus prinoides* were the common tree species. The herbaceous species dominating this community was *Argemone mexicana* and *Clematis hirsuta.*

**Community *2 Olea europea -Olinia rochetiana* community type:** This community type was found at the altitude ranging between 2540 to 2850 m a.s.l. This community resulted from 10 plots and 48 species. The tree layer was highly dominated by *Juniperus procera* and *Olea europea. Celtis africana, Ehretia cymosa* and *Dodonea viscosa* were the common tree species. The herbaceous species dominating this community was *Physalis peruviana* and *Echinops longisetu.*

**Community 3 *Juniperus procera –Olea europea* community type:** This community type was found at the altitude ranging between 2420 to 2670 m a.s.l. This community resulted from 8 plots and 44 species. The tree layer was highly dominated by *Myrica salicifolia* and *Olinia rochetiana. Canthium oligocarpum, Myrsine africana, Protea gaguedi* were the common tree species. The herbaceous species dominating this community was *Thymus vulgaris* and *Girardinia bullosa.*

**Community 4 *Erica arborea –Maesa lanceolata* community type:** This community type was found at the altitude ranging between 2400 to 2780 m a.s.l. This community resulted from 5 plots and 25 species. The tree layer was highly dominated by *Erica arborea* and *Maesa lanceolata***.** *Scolopia salicifolia*, *Acokanthera schimperi* and *Euphorbia dumali* were the common tree species. The herbaceous species dominating this community was *Artemisia afra and Dicliptera maculata.*

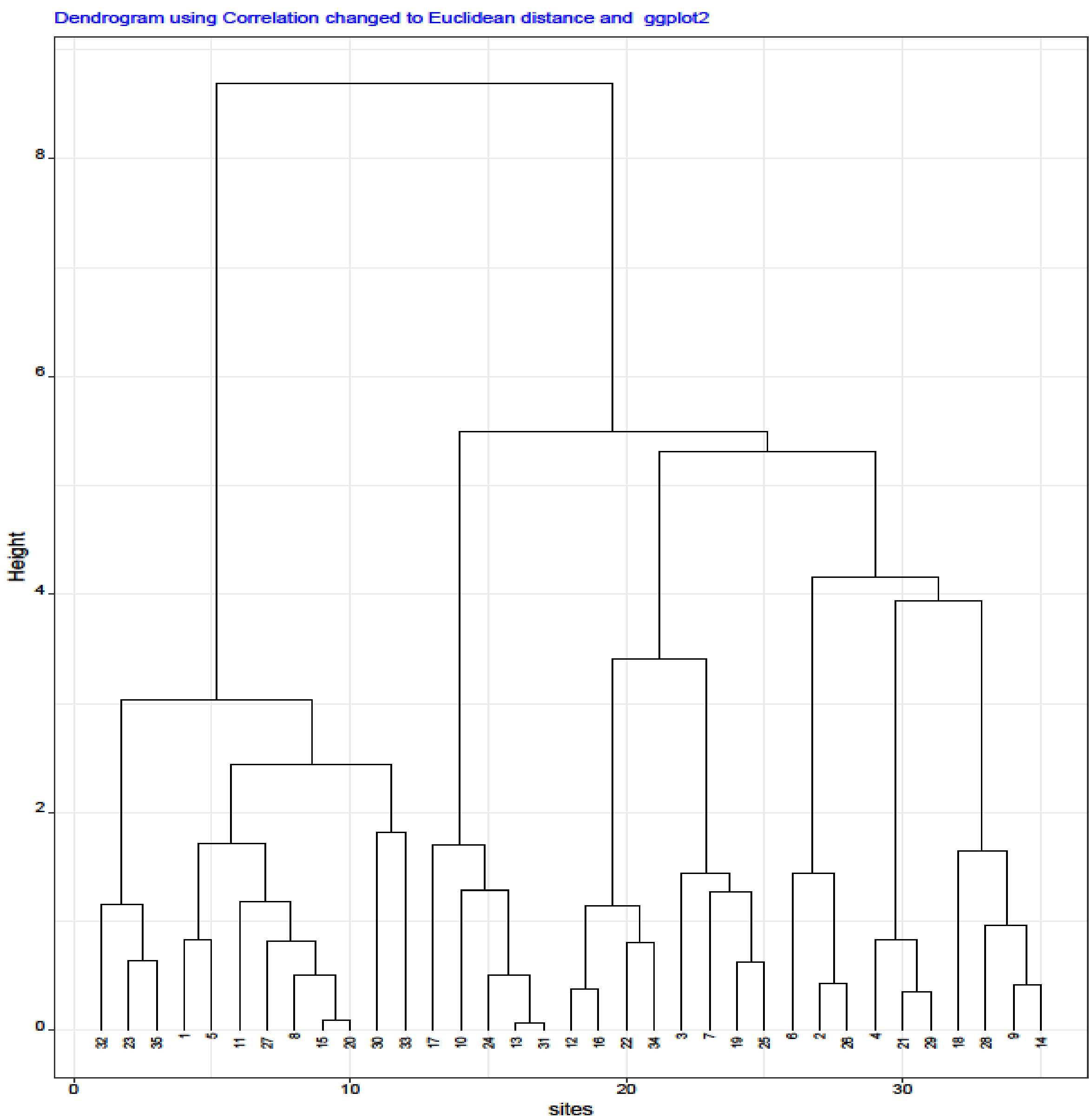



**Figure: 7.**Dendrogram showing four plant communities in Mountain Ambaricho Natural Forest.

### 4.3. Species Diversity and Evenness of collected plant species in study area

Diversity to be high if the species distributed evenly and, only a few species dominate the area, the diversity would be low (Rosenzweig, 1995). In Ambaricho natural forest 61 plant species and 42 families' were recorded.

**Table 1: Species richness, Shannon-Weiner diversity index and evenness of the plant community types in Mountain Ambaricho Natural forest.**

| Community | Species richness | Diversity index(H) | Shannon-Evenness (H'/H max) |
|---|---|---|---|
| 1 | 23 | 2.086683 | 0.665504 |
| 2 | 23 | 2.261298 | 0.721193 |
| 3 | 28 | 2.51225 | 0.75393 |
| 4 | 20 | 2.088196 | 0.697057 |

### 4.4. Vegetation structure of Mountain Ambaricho natural forest

#### 4.4.1 Stem density

Density can be expressed as the number of individuals present per hectare of an area .The total density of all plant species in Mount Ambaricho Forest was 3511 stems ha-1.

The results of this study shown that, the density of plant species of Mountain Ambaricho Natural forest is greater than, Belete forest (1066 individuals/ha) (Kflay Gebrehiwot et *al*.2013), Sire Beggo Forest (1845 individuals/ha) (Abiyou Tilahun et al, 2014). But its density was found to be nearly lower than the density of Weiramba forest (3547 individuals per hectare) (Zelalem Tshager et al, 2018) and Farley lower than the density of Dirki and Jato woodland forest (5145 individuals /ha) by (Zerihun Tadesse 2015).

From the recorded plant species in study area, the five most abundant species were *Erica arborea* (9.66%), *Myrsine africana* (8.44%), *Arundinaria alpina* (7.32%), *Hagenia abyssinica* (6.41%) and *Juniperus procera* (4.98) which in total constitute 36.81 % of the total abundance of the forest.

The densest species in the study forest were *Erica arborea* (339.28 individuals per hectare), followed by *Myrsine africana* (296.43 individuals per hectare), *Arundinaria alpina* (257.14 individuals per hectare),*Hagenia abyssinica* (225 individuals per hectare) and *Juniperus procera* (175 individuals per hectare) (Table 3).In opposite to these, the least dense woody species recorded in study area were *Povetta oliveriana* (15.3 individuals per hectare), *Euphorbia dumali* (14.6 individuals per hectare), *Phallanthus emblica* (13.6 individuals per hectare), *Scolopia theifolia* (11.5 individuals per hectare), *Dovyalist abyssinica* (10.7 individuals per hectare) and *Ecuclea divinorum* (8.42 individuals per hectare) respectively.

**Table: 2** Density of five dominant tree species of Mountain Ambaricho Natural Forest with their percentage coverage.

| No | species | Family | Density | % |
|---|---|---|---|---|
| 1 | *Erica arborea* | *Ericaceae* | 339.28 | 9.66 |
| 2 | *Myrsine africana* | *Myrsinaceae* | 296.43 | 8.44 |
| 3 | *Arundinaria alpina* | *Poaceae* | 257.14 | 7.32 |
| | | | | |
| 4 | *Hagenia abyssinica* | Poaceae | 225 | 6.41 |
| 5 | *Juniperus procera* | *Cupressaceae* | 175 | 4.98 |
| Total | | | 1292.85 | 36.81 |

### 4.4.2. Diameter at breast height (DBH) Class distribution

A total of 2147/ha individuals whose DBH >2.5cm were recorded and seven DBH classes were established for DBH analysis. DBH class 1(2.5-5), 2(5.01-10),3(10.01-15),4(15.01-20),5(20.01-25),6(25.01-30) and 7(>30).

The total number of individuals in each DBH class decreased with increasing DBH. The highest density of the populations, 722 were found in the lower DBH class 1(2-5cm), while the rest 502, 373, 252, 160, 118and 20 were found between DBH class 2, 3,4,5,6 and 7 respectively.

This show inverted-J shape population distribution (Fig 8).This pattern shows a good regeneration potential of the forest in area.

**DBH of woody species>2.5cm in Ambaricho Mountain were recorded under seven classes**

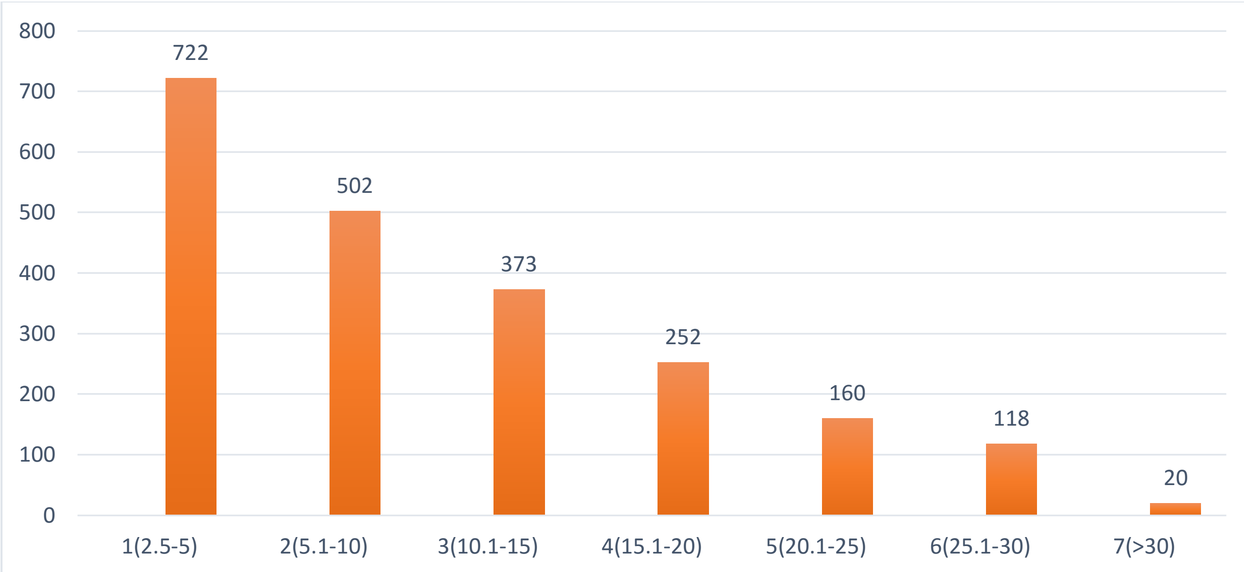



**Figure: 8** DBH classes of woody species >2.5cm were recorded of Mountain Ambaricho under seven classes.

### 4.4.3 Height class distribution

Most of the woody species in the study area belonging to the lower height class. The height distribution patterns of Ambaricho natural forest was characterized by high number of individuals in lower height class than higher class.

Woody species <2.5cm in Mountain Ambaricho Natural Forest Categorized under five height Classes.

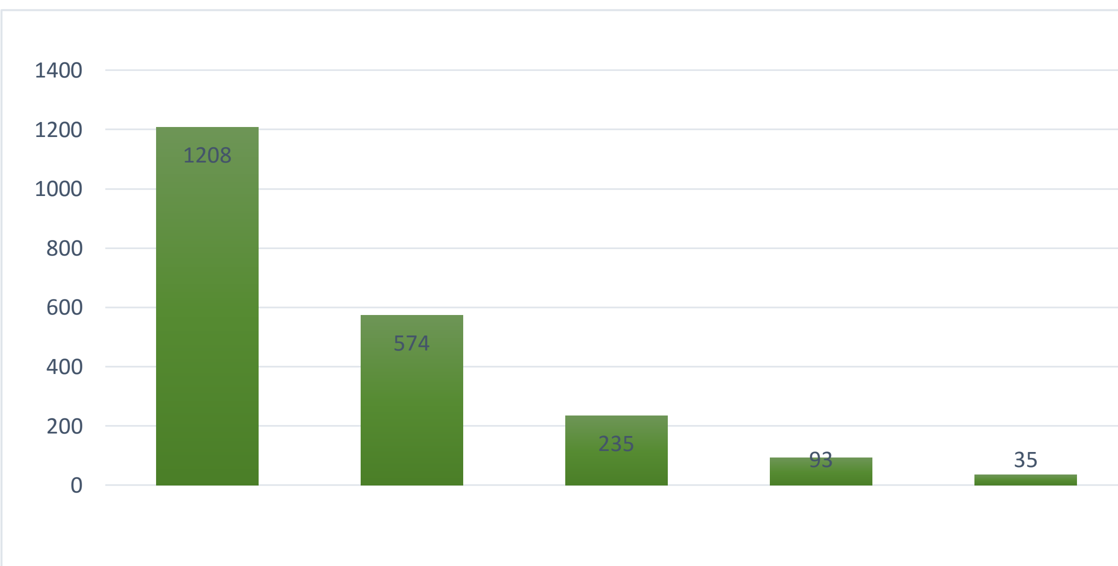



**Figure 9** Height class distributions of woody species <2.5 in Mountain Ambaricho natural forest.

As height increases from one class to the other, the density of individuals decrease dramatically. This clearly reveals the dominance of small sized individuals than large sized ones. This pattern represents good reproduction status and regeneration potential, but lower recruitment and absence of matured individuals. It might be due to the area was disturbed by anthropogenic factors like bigger tree species are selectively removed or exploited by humans. Abate Ayalew et al (2006) also stated that the density of individuals decreasing with increasing height could be attributed to a high rate of regeneration but irregular recruitment potential. Similar result was observed by Dagne and Tamiru (2016) in Zerat Forest.

### 4.4.4. Basal area

The total basal area of woody species in Ambaricho forest was 19.67 $m^2$/ha. About 12.25$m^2$/ha (62.22%) of the total basal area was contributed by six woody species like; *Hagenia abyssinica* (20.3*%), Juniperus procera* (11.18%), *Celtis africana* (10.16%), *Podocarpus falcatus* (9.15%), *Ehretia cymosa* (7.62%) and *Olea europea* (3.81%) (Table 4). Species like *Arundinaria alpina*, *Erica arborea*, and *Myrsine africana* although they have high density; their basal area is not as high as their density. This is due to the nature of the plants not to grow to higher basal area and the level of exposure to human activities. This also indicates that species with the highest basal area do not necessarily have the highest density (Berhanu Kebede et al.2014).

The basal area of Ambaricho Forest is greater than Yegof dry Afromontane forest it is about 15.85 $m^2$ ha-1(MesfinWoldearegay et al. 2018), Achera natural forest (3.61 $m^2$ ha-1)( Habtam G and Ali S , 2015) and it is also much greater than Hallideghie wildlife reserve (it was about was 0.997 $m^2$ per ha) (Endris et al, 2017). However, basal area of Ambaricho Natural Forest is less than from basal area of, Denkoro forest; it is about 45$m^2$/ha. (Abate Ayalew ET al.2006), Alemsaga Forest/75.3$m^2$/ha (Getinet Masresha et al, 2015) and Belete forest/103.5$m^2$/ha (Kflay, Gadissa and Kitessa, Hundera, 2014).

**Table 3:** The six top Basal area of selected woody species in Mountain Ambaricho forest

| NO | Species | *Basal area in* $M^2$*/ha* | % |
|---|---|---|---|
| 1 | *Hagenia abyssinica* | 4 | 20.3 |
| 2 | *Juniperus procera* | 2.2 | 11.18 |
| 3 | *Celtis africana* | 2 | 10.16 |
| 4 | *Podocarpus falcatus* | 1.8 | 9.15 |
| 5 | *Ehretia cymosa* | 1.5 | 7.62 |
| 6 | *Olea europea* | 0.75 | 3.81 |
| | *Total* | 12.25 | 62.22% |

**Table 4:** Comparison of the Basal Area of Mountain Ambaricho Natural Forest with Basal Areas of other Forests in Ethiopia in m2 ha-

| **Forest** | **BA** | **AUTHOR** |
|---|---|---|
| Doodle | 129.0 | Hundera et al., (2007) |
| Belete | 103.5 | Kflay et al., (2014 |
| Alemsaga | 75.3 | (Masresha et al., 2015) |
| Bibita | 69.9 | Denu (2006) |
| Magada | 68.52 | Bekele (2005) |
| Wof-Washa | 64.32 | Fisaha et al., (2013) |
| Dindin | 49.0 | Shibru and Balcha (2004) |
| Denkoro | 45.0 | Ayalew et al., (2006) |
| Ambaricho | 19.67 | Present study |
| Yegof dry Afromontane | 15.85 | (MesfinWoldearegay et al. 2018), |

### 4.4.5 Frequency

Frequency is defined as the probability or chance of finding a species in a given sample area or quadrate. It is dependent on quadrate size, plant size, and patterning in the vegetation (Kent and Coker, 1992).It is also defined as the number of quadrants in which a particular species occurs in a study area. It is obtained by dividing the number of quadrants in which the species occurred by the total number of the quadrants from which all the species sampled in the area under the study (Zerhun Tadesse.2015). Based on the findings, relatively most frequently observed plant species in the Ambaricho forest (Table6) were *Erica arborea* with relative frequency of (12.78%), *Myrsine africana* (11.74%), *Arundinaria alpina* (10.88%), *Hagenia abyssinica* (4.83%) and *Juniperus procera* (4.83%).

In contrary to this the lowest percentage frequency species were *Canthium oligocarpum* (1.5%), *Dolonix elata* (1.47%), *Acokanthera schimperi* (1.46%), *Rhamnus prinoides* (1.38%), *Hypercum* quatinianum (0.9%) and *Bersama abyssinica* (0.8%) were occurred in the study area

**Table 5:** The five top frequented plant species in Mount Ambaricho natural forest.

| No | Scientific Name | Family of species | Relative Frequency (%) |
|---|---|---|---|
| 1 | *Erica arborea* | *Ericaceae* | 12.78 |
| 2 | *Myrsine africana* | *Myrsinaceae* | 11.74 |
| 3 | *Arundinaria alpina* | Poaceae | 10.88 |
| 4 | *Hagenia abyssinica* | *Rosaceae* | 4.83 |
| 5 | *Juniperus procera* | *Cupressaceae* | 4.83 |

### 4.4.6. Importance Value Index (IVI)

Importance value index (IVI) is a useful parameter that helps to determine the ecological importance of species. Importance Value Index combines data from three parameters which include RF, RD and RDO (Kent and Coker, 1992). It is a good measure for summarizing vegetation characteristics of a given habitat and is useful to compare the ecological significance of species and for conservation practices.

It was also stated that species with the greatest importance value are the leading dominant of specified vegetation (Berhanu Kebede et al.2014).

In the present study, total IVI of woody species in Ambaricho natural forest was 279.64. In this regard, the 8 leading dominant and ecologically most significant trees with top IVI in Mountain Ambaricho forest are *Hagenia abyssinica*(11.69.%),*Erica arborea* (8.63%), *Juniperus procera* (7.82%), *Myrsine africana* (7.73%), *Arundinaria alpina* (6.99%), *Celtis africana* (5.59%), *Podocarpus falcatus* (4.87%) and *Ehretia cymosa* (4.52%) respectively (Table7). They contribute 161.88(57.87%) from a total of 279.64 IVI value. The reason for these species have higher IVI value is that they have higher relative density, relative frequency and relative dominance than other species in the forest. In contrary side the woody species, which exhibited the lowest IVI values in the study forest were, *Dolonix elata* (0. 94%), *Myrica salicifolia* (0.93%), *Lannea schimperi* (0.92%), *Euphorbia dumali* (0.7%), *Hypercum quatinianum* (0.68%), *Lantana camara* (0.66%) and *Scolopia* the folia (0.49%) respectively; they contribute only 14.87(5.32%) total IVI values in studied forest.

**Table 6:** The eight top ecologically important woody species with highest Important Value Index (IVI) values, RDO, RD and RF in Ambaricho natural forest. Note: RD = Relative density, RF =Relative frequency, RDO =Relative dominance and IVI = Important value index

| No | Scientific Name | RDO | RD | RF | IVI |
|---|---|---|---|---|---|
| 1 | *Hagenia abyssinica* | 20.41 | 7.47 | 4.83 | 32.71 |
| 2 | *Erica arborea* | 0.1 | 11.26 | 12.78 | 24.14 |
| 3 | *Juniperus procera* | 11.25 | 5.81 | 4.83 | 21.89 |
| 4 | *Myrsine africana* | 0.05 | 9.84 | 11.78 | 21.63 |
| 5 | *Arundinaria alpina* | 0.15 | 8.54 | 10.88 | 19.57 |
| 6 | *Celtis africana* | 10.17 | 2.09 | 3.4 | 15.64 |
| 7 | *Podocarpus falcatus* | 9.17 | 2.06 | 2.41 | 13.64 |
| 8 | *Ehretia cymosa* | 7.67 | 2.06 | 2.93 | 12.66 |

## 4.5. Population structure of selected Woody species in Mount Ambaricho forest

### 4.5.1 DBH class distribution of structural patterns of selected woody species

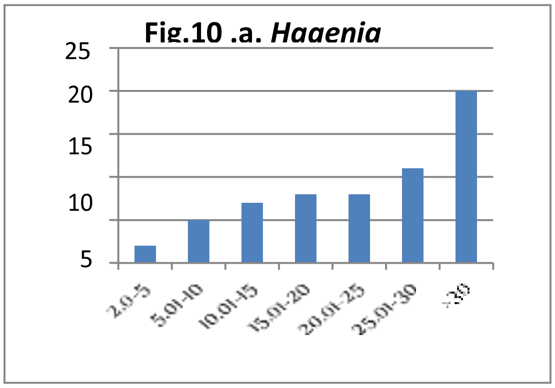
Analysis of the DBH class distribution of five selected woody species in terms of their density in Ambaricho forest revealed four general distribution patterns .The first population pattern was represented by low number of individuals in first diameter class followed by increasing number of individual in higher diameter class. In this population pattern there was high number of individuals in higher diameter classes. This is due to the fact that male and female individuals of *Hagenia abyssinica* were found on separate plant, which affects the reproductive capacity of the species, which in turn lowers reproduction. The other probable reason could be *Hagenia abyssinica* is one of the most useful medicinal plants in the area.

The female parts are used as a remedy for tapeworm infestation, which affects the production of viable seeds to germinate and enhance seedling and young population. This pattern shown J-shaped population distribution. *(*Fig.10a*)*The second pattern was represented by *Juniperus procera.*

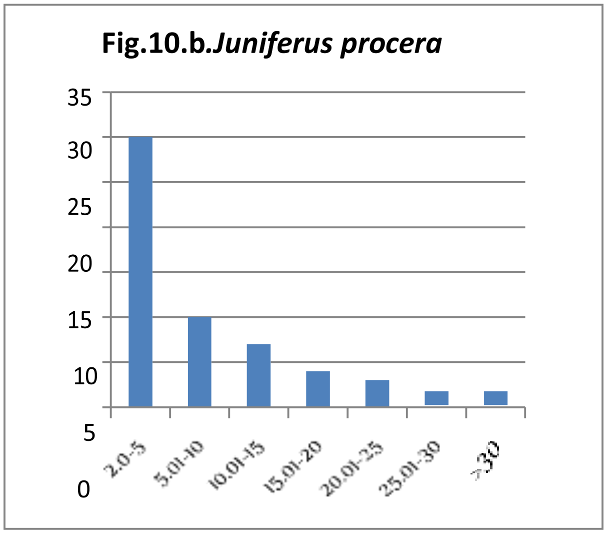
In this pattern, high number of individuals in the lower diameter classes and decreasing the number of individuals towards higher diameter (DBH) classes (Fig 10b).

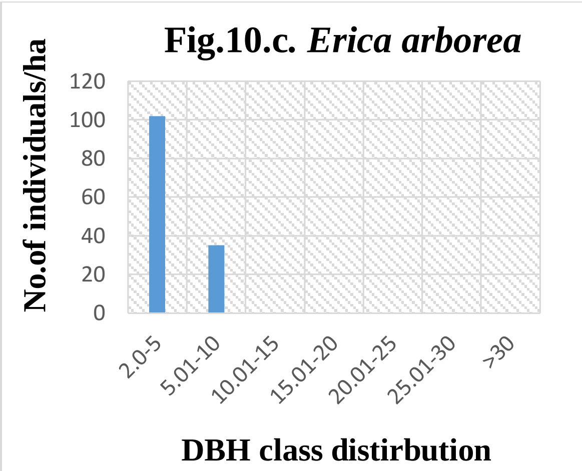
It depicted in the inverted J-shape population pattern. This type of population structure suggests good regeneration status but discontinuous recruitment in to larger size. One of the possible reasons for the discontinuity could be selective cutting of a particular size of this tree for different purpose. The local people use medium size of these trees for roof cover of their huts and for making fence and the highest class for timber production as a result the density of these classes was lowered. And also species like, *Podocarpus falcatus, Ehretia cymosa* and *Celtis africana* show this kind of population pattern. The third population pattern was represented by *Erica arborea* and *Myrsine africana*. In this population pattern, higher number of individuals in first diameter class followed by very low number of individual in the second diameter class and absence of individuals in the successive higher diameter classes. This is due to the nature of plants are not necessarily to grow in higher diameter class. This type of population structure suggests good reproduction and bad recruitment status (Fig.10c and d). And also species like, *Euphorbia dumali* and *Dovyalis abyssinica* show this kind of population pattern.

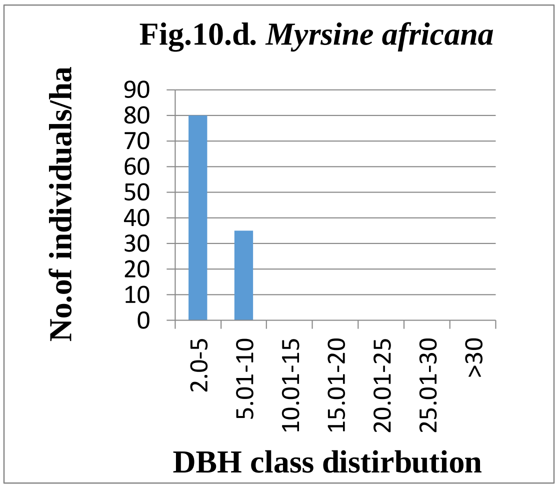
The fourth pattern was represented by *Arundinaria alpina*. In this pattern, high number of individuals in the middle diameter classes and low number of individuals in lower and higher diameter (DBH) classes (Fig 9.e). It depicted in the Bell-shape population pattern.

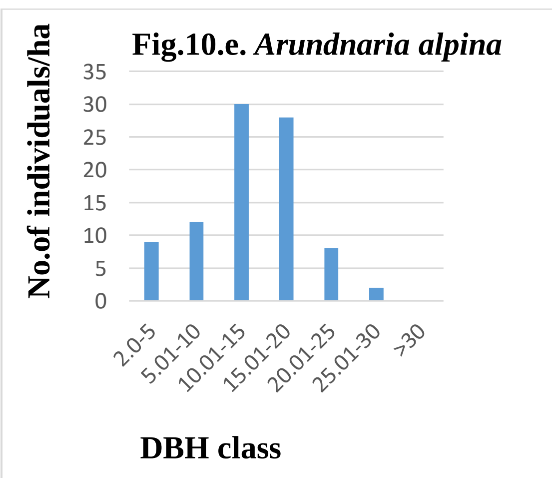



**DBH classes**






### 4.5.2 Height class distribution of structural patterns of selected woody species

Analysis of the height class distribution of five selected woody species in terms of their density in Ambaricho forest revealed two general distribution patterns.

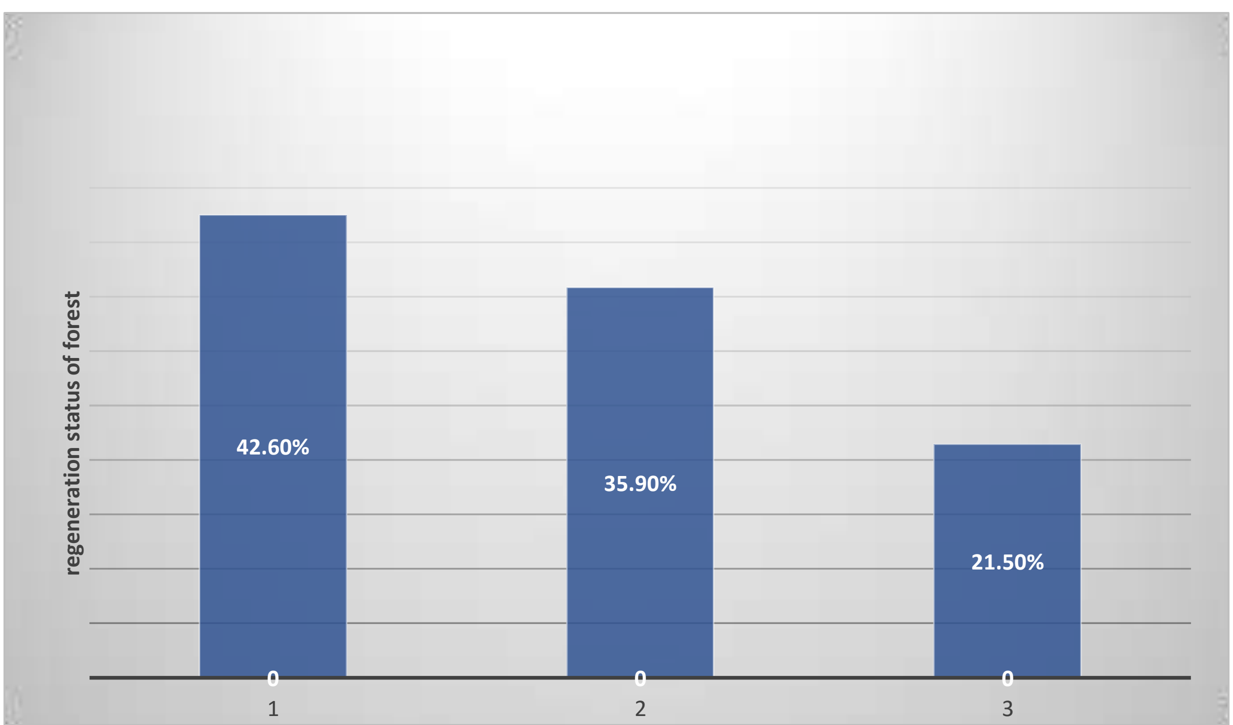
The first pattern was represented *by Hagenia abyssinica*, *Juniperus procera* and *Arundinaria alpina*. In this pattern, high number of individuals in the middle height classes and low number of individuals in lower and higher height classes (Fig 10). It depicted in the Bell-shape population pattern. This type of population structure suggests poor reproduction and recruitment status.

The second population pattern was represented by higher number of individuals in first height class followed by very low number of individual in the second height class and absence of individualsintheotherhigherheightclasses.ItdepictedintheLshapedorinvertedFshapedpopulationpattern.This type of population structure suggests good reproduction and bad recruitment status. This pattern was represented by the species *Erica arborea* and *Myrsine africana*. And also species like, *Euphorbia dumali*, *Dovyalis abyssinica* and *Olinia rochetiana* show this kind of population pattern.

### 4.6. Regeneration status of the Mountain Ambaricho natural forest

Accordingly, the regeneration status of the woody species in Ambaricho natural forest was determined. The forest is dominated by small sized woody species. This indicating that the large sized forest was affected by human disturbance, but vegetation is under good regeneration status. **Figure: 11** the proportion of seedling, Sapling and mature plant species were recorded in 35

Sampled plot in Mountain Ambaricho Natural Forest. Regeneration status of the vegetation in any forest was described by comparing saplings and seedlings with the matured individuals



(Simon Shibru and Girma Balcha, 2004).

The findings of Present study shows the presence of more seedlings than saplings and mature woody species and more saplings than mature woody species in Ambaricho forest, it indicates that the vegetation has a good regeneration potential.

**Conclusion and Recommendation**

## 5.1 Conclusion

From the study area 61plant species belonging to 61 genera and 42 families were identified. Mount Ambaricho forest is floristically poor or less diversified .Of these families the four species rich families were *Asteraceae, Rubaceae,Lamiaceae* and *Solanaceae.* This study indicated that Ambaricho Natural Forest consists of species like *Hagenia abyssinica, Juniperus procera, Celtis africana, Podocarpus falcatus, Ehretia cymosa* and *Olea europea* which are characterized by high basal area. The total basal area calculated for the study area was19.67m2 /ha and the basal area of six top selected woody species was 62.22%.The result of this study revealed that the total density per hectare of all trees/shrubs with height ≥2m and DBH ≥ 2.5 cm were 2147/ha. Analysis of the DBH class distribution of five selected woody species in terms of their density in Ambaricho forest revealed four general distribution patterns .The first population pattern was represented by low number of individuals in first diameter class followed by increasing are not necessarily to grow in higher diameter class. The fourth pattern was represented by ***Arundinaria alpina***. In this pattern, high number of individuals in the middle diameter classes number of individual in higher diameter class. This pattern shown J-shaped population distribution, represented by the species ***Hagenia abyssinica***. The second pattern was represented by ***Juniperus procera*** in this pattern, high number of individuals in the **lower diameter classes** and **decreasing the number of individuals towards higher diameter** (DBH) classes. The third population pattern was represented by ***Erica arborea*** and ***Myrsine africana***. This is due to the nature of plants and low number of individuals in lower and higher diameter (DBH) classes. In the present study the general distribution of diameter (DBH) classes of the woody species recorded in Ambaricho forest indicates the density of woody species decreases with increasing DBH size, indicating the predominance of small-sized individuals in the area. Thus, the finding of this study reveals that the regeneration status of Ambaricho Natural forest was good.

## 5.2 Recommendation

Based on the effects of the present have a look at, the subsequent statements had been encouraged;

- There is a need to in the wooded area with a purpose to permit the natural regeneration of woody species inside the forests create focus of neighborhood groups and the government about the price of conserving the wooded area resources and ecological consequences of wooded area degradation
- Developing participatory woodland control by using which human impacts can be minimized thru discussion and session with the neighborhood groups.
- Sustainable protection and management of the forests wished thru the collaborative effort of the authorities, NGO and nearby network for reduction of tree reducing and manufacturing of charcoal.
- Non-stop woodland stock must be conducted.
- Comprehensive studies need to be initiated to record the plant aid utilization pattern. Since the present study was limited to document the floristic composition, structure and natural regeneration status of woody plants species, further ethnobotanical studies are required to explore proper forest management systems sustainable use of natural vegetation resources, and the development of proper conservation mechanisms of vegetation regeneration potential is a crucial option.

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## APPENDICES

Appendix 1: List of plant species of Mountain Ambaricho Natural Forest in Kachabira District South Nation Nationality State.

T = Tree, S= Shrub H =Herb

| No | Scientific name | Family name | Local name | Growth habit |
|---|---|---|---|---|
| 1 | *Artemisia afra* | *Asteraceae* | Ceecichua | Herb |
| 2 | *Arundinaria alpina* | *Poaceae* | Lenchua | Tree |
| 3 | *Agarista salicifolia* | *Ericaceae* | Adichu | Tree |
| 4 | *Acokanthera schimperi* | *Apocynaceae* | Karchuta | Shrub |
| 5 | *Argemone mexicana* | *Papaveraceae* | Cuuichua | Herb |
| 6 | *Amaranthus caudatus* | *Amaranthaceae* | Laliraasuta | Herb |
| 7 | *Abutilon hiatus* | *Malvaceae* | Wojifiitaanchua | Tree |
| 8 | *Apodytes dimidiata* | *Icacinaceae* | Dongichuta | Tree |
| 9 | *Bersama abyssinica* | *Melianthaceae* | Bitansichua | Tree |
| 10 | *Bidens pilosa* | *Asteraceae* | Qeccebichua | Herb |
| 11 | *Canella asiatic* | *Apiaceous* | Sharafichua | Herb |
| 12 | *Celtis africana* | *Ulamaceae* | Sutichua | Tree |
| 13 | *Canthium oligocarpum* | *Rubiaceae* | Samagituligchua | Tree |
| 14 | *Croton macrostachyus* | *Euphorbiaceae* | Masanchua | Tree |
| 15 | *Clematis hirsuta* | *Ranunculaceae* | Calagiichuta | Herb |
| 16 | *Clauson anisate* | *Rosacea* | Gambalaqqichua | Tree |
| 17 | *Dicliptera maculata* | *Acanthaceae* | Yamemachata | Herb |
| 18 | *Dovyalis abyssinica* | *Salicaceae* | Heqagalichua | Tree |
| 19 | *Dolonix elata* | *Fabaceae* | Canace | Tree |
| 20 | *Dodonea viscosa* | *Sapindaceae* | Kitikitichua | Tree |
| 21 | *Dossinia marmorata* | *Orchidaceae* | Raasichuta | Herb |
| 22 | *Datura stramonium* | *Solanaceae* | Macharaqichua | Herb |
| 23 | *Erica arborea* | *Ericaceae* | Sata | Tree |

| | | | | |
|---|---|---|---|---|
| 24 | *Euphorbia dumali* | *Euphorbiaceae* | Hurumaza | Shrub |
| 25 | *Ehretia cymosa* | *Boragnaceae* | Ulagichua | Tree |
| 26 | *Eculea divinorum* | *Ebenaceae* | Meegarichua | Tree |
| 27 | *Echinops longisetu* | *Asteraceae* | Harrecuua | Herb |
| 28 | *Ekebergia capensis* | *Meliaceae* | Oloonchuta | Tree |
| 29 | *Galiniera saxifraga* | *Rubiaceae* | Gonowasa | Tree |
| 30 | *Girardinia bullosa* | *Urticaceae* | Doobeechuta | Herb |
| 31 | *Galiumthunbergianum* | *Rubiaceae* | Xamadoot | Herb |
| 32 | *Hypercum quatinianum* | *Hypercaceae* | Hebeta | Shrub |
| 33 | *Hagenia abyssinica* | *Rosaceae* | Xeenchuta | Tree |
| 34 | *Juniperus procera* | *Cupressaceae* | Hoonchua | Tree |
| 35 | *Justicia schimperiana* | *Acanthaceae* | Gulibaanichua | Shrub |
| 36 | *Eucalyptusglobuls* | *Myrtaceae* | Barzaafichua | Tree |
| 37 | *Lannea schimperi* | *Anacardiaceae* | Duukechuta | Tree |
| 38 | *Lantana camara* | *Verbanaceae* | Uliworisinchua | Shrub |
| 39 | *Myrsine africana* | *Myrsinaceae* | Gexeenchuta | Tree |
| 40 | *Myrica salicifolia* | *Myricaceae* | Tataba | Tree |
| 41 | *Maesa lanceolata* | *Myrsinaceae* | Gawaadichua | Tree |
| 42 | *Malva neglecta* | *Malvaceae* | Lagaanchua | Herb |
| 43 | *Noitalicx piperita* | *Lamiaceae* | Zebinehitichuta | Herb |
| 44 | *Olea europea* | *Oleaceae* | Weerchua | Tree |
| 45 | *Olinia rochetiana* | *Oliniaceae* | Shoimolichuta | Tree |
| 46 | *Ocimum sanctum* | *Lamiaceae* | Basoblichua | Herb |
| 47 | *Parthneium hysterophorus* | *Asteraceae* | Natiraguda | Herb |
| 48 | *Povetta oliveriana* | *Rubiaceae* | Miiqichuta | Tree |
| 49 | *Plantato lanceolata* | *Plantagnaceae* | Erbeete | Herb |
| 50 | *Podocarpus falcatus* | *Podocarpaceae* | Zagiishua | Tree |
| 51 | *Protea gagued* | *Proteaceae* | Danshichuta | Tree |
| 52 | *Prunus africana* | *Rosaceae* | Garbichua | Tree |

| | | | | |
|---|---|---|---|---|
| 53 | *Physalis peruviana* | *Solanaceae* | Daaxichuta | Herb |
| 54 | *Phallanthus emblica* | *Phallanthaceae* | Qanchuta | Tree |
| 55 | *Rhamnus prinoides* | *Rhamnaceae* | Geshiichua | Tree |
| 56 | *Scolopia theifolia* | *Flacourtiaceae* | Mishilichua | Shrub |
| 57 | *Solanum incanum* | *Solanaceae* | Homboororiichuta | Shrub |
| 58 | *Thymus vulgaris* | *Lamiaceae* | Tosinichuta | Herb |
| 59 | *Verbascum thapsus* | *Scrophulariaceae* | Qesitichaguda | Herb |
| 60 | *Vernonia myriantha* | *Asteraceae* | Reejichua | Tree |
| 61 | *Vernonia amygdalina* | *Asteraceae* | Heebiichua | Tree |

Appendix 2: List of 40 woody plants species recorded from Mount Ambaricho natural forest with their Relative Dominance, Relative Density, Relative Frequency and Important Value Index

| **No** | **Species name** | **Family name** | **RDO (%)** | **RD (%)** | **RF (%)** | **IVI** |
|---|---|---|---|---|---|---|
| 1 | *Acokanthera schimperi* | Apocynaceae | 0.059 | 1.8 | 1.46 | 3.31 |
| 2 | *Agarista salicifolia* | Ericaceae | 1.02 | 1.1 | 0.9 | 4.02 |
| 3 | *Abutilon hiatus* | Malvaceae | 1.07 | 0.95 | 0.97 | 2.99 |
| 4 | *Apodytes dimidiata* | Icacinaceae | 3.99 | 1.04 | 0.8 | 5.83 |
| 5 | *Arundinaria alpina* | Poaceae | 0.15 | 8.54 | 10.88 | 19.57 |
| 6 | *Bersama abyssinica* | Melianthaceae | 3.63 | 1.01 | 0.8 | 5.44 |
| 7 | *Canthium oligocarpum* | Rubiaceae | 0.61 | 1.8 | 1.5 | 3.91 |
| 8 | *Celtis africana* | Ulamaceae | 10.17 | 2.09 | 3.4 | 15.64 |
| 9 | *Clauson anisate* | Rosacea | 1.12 | 1.04 | 1.47 | 3.63 |
| 10 | *Crotonmacrostachys* | Euphorbiaceae | 2.35 | 1.01 | 1.38 | 4.74 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | *Dolonix elata* | Fabaceae | 0.1 | 1.07 | 1.47 | 2.64 |
| 12 | *Dodonea viscosa* | Sapindaceae | 3.58 | 1.09 | 0.8 | 5.47 |
| 13 | *Dovyalis abyssinica* | Flacourtiaceae | 0.61 | 0.35 | 1.89 | 2.85 |
| 14 | *Eculea divinorum* | Ebenaceae | 1.58 | 0.26 | 1.97 | 3.81 |
| 15 | *Ehretia cymosa* | Boragnaceae | 7.67 | 2.06 | 2.93 | 12.66 |
| 16 | *Ekebergia capensis* | Meliaceae | 4.2 | 0.9 | 1.5 | 6.6 |
| 17 | *Erica arborea* | Ericaceae | 0.1 | 11.26 | 12.78 | 24.14 |
| 18 | *Euphorbia dumali* | Euphorbiaceae | 0.52 | 0.48 | 0.98 | 1.98 |
| 19 | *Galiniera saxifraga* | Rubiaceae | 1.53 | 1.09 | 0.86 | 3.48 |
| 20 | *Hagenia abyssinica* | Rosaceae | 20.41 | 7.47 | 4.83 | 32.71 |
| 21 | *Hypercumquatinianum* | Hypercaceae | 0.005 | 1.01 | 0.9 | 1.91 |
| 22 | *Juniperus procera* | Cupressaceae | 11.25 | 5.81 | 4.83 | 21.89 |
| 23 | *Justicia schimperiana* | Acanthaceae | 0.001 | 0.95 | 1.9 | 2.85 |
| 24 | *Lannea schimperi* | Anacardiaceae | 0.1 | 1.1 | 1.38 | 2.58 |
| 25 | *Lantana camara* | Verbanaceae | 0.153 | 0.9 | 0.8 | 1.85 |
| 26 | *Maesa lanceolata* | Myrsinaceae | 1.53 | 0.9 | 1.89 | 4.32 |
| 27 | *Myrsine africana* | Myrsinaceae | 0.05 | 9.84 | 11.74 | 21.63 |
| 28 | *Myrica salicifolia* | Myricaceae | 0.01 | 1.6 | 0.98 | 2.59 |
| 29 | *Olea europea* | Oleaceae | 3.84 | 1.4 | 1.47 | 6.71 |
| 30 | *Olinia rochetiana* | Oliniaceae | 0.5 | 1.7 | 1.97 | 4.17 |
| 31 | *Povetta oliveriana* | Rubiaceae | 1.21 | 0.5 | 1.96 | 3.67 |
| 32 | *Podocarpus falcatus* | Podocarpaceae | 9.17 | 2.06 | 2.41 | 13.64 |
| 33 | *Protea gagued* | Proteaceae | 4.1 | 1.09 | 1.72 | 6.91 |
| 34 | *Prunus africana* | Rosaceae | 2.45 | 1.04 | 1.38 | 4.84 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 35 | *Phallanthus emblica* | Phallanthaceae | 2.15 | 0.45 | 0.86 | 3.46 |
| 36 | *Rhamnus prinoides* | Rhamnaceae | 0.67 | 1.01 | 1.38 | 3.06 |
| 37 | *Scolopia theifolia* | Flacourtiaceae | 0.15 | 0.37 | 0.86 | 1.38 |
| 38 | *Solanum incanum* | Solanaceae | 0.0005 | 1.01 | 1.96 | 2.97 |
| 39 | *Vernonia myriantha* | Asteraceae | 1.17 | 1.01 | 0.8 | 2.98 |
| 40 | *Vernonia amygdalina* | Asteraceae | 1.38 | 1.01 | 1.5 | 3.89 |

Appendix 3: Shannon-wiener index (H') and Evenness (E)

| No | Plant species | Family | Pi | lnPi | Pi*lnpi |
|---|---|---|---|---|---|
| 1 | *Artemisia afra* | *Asteraceae* | 0.03 | -3.5 | -0.1 |
| 2 | *Arundinaria alpina* | *Poaceae* | 0.07 | -2.6 | -0.18 |
| 3 | *Agarista salicifolia* | *Ericaceae* | 0.017 | -4.07 | -0.069 |
| 4 | *Acokanthera schimperi* | *Apocynaceae* | 0.016 | -4.13 | 0.06 |
| 5 | *Argemone mexicana* | *Papaveraceae* | 0.009 | -4.71 | -0.042 |
| 6 | *Amaranthus caudatus* | *Amaranthaceae* | 0.0091 | -4.69 | -0.042 |
| 7 | *Abutilon hiatus* | *Malvaceae* | 0.01 | -4.6 | -0.046 |
| 8 | *Apodytes dimidiata* | *Icacinaceae* | 0.01 | -4.6 | -0.046 |
| 9 | *Bersama abyssinica* | *Melianthaceae* | 0.0087 | -4.74 | -0.041 |
| 10 | *Bidens pilosa* | *Asteraceae* | 0.0093 | -4.68 | -0.043 |
| 11 | *Canella Asiatic* | *Apiaceous* | 0.008 | -4.8 | -0.04 |
| 12 | *Celtis africana* | *Ulamaceae* | 0.013 | -4.34 | -0.056 |
| 13 | *Canthium oligocarpum* | *Rubiaceae* | 0.015 | -4.19 | -0.063 |
| 14 | *Croton macrostachyus* | *Euphorbiaceae* | 0.0087 | -4.74 | -0.041 |
| 15 | *Clematis hirsuta* | *Ranunculaceae* | 0.0081 | -4.81 | -0.038 |
| 16 | *Clauson anisate* | *Rosacea* | 0.008 | -4.82 | -0.039 |
| 17 | *Dicliptera maculata* | *Acanthaceae* | 0.02 | -3.9 | -0.08 |
| 18 | *Dovyalis abyssinica* | *Salicaceae* | 0.009 | -4.7 | -0.04 |
| 19 | *Dolonix elata* | *Fabaceae* | 0.0091 | -4.69 | -0.043 |

| | | | | | |
|---|---|---|---|---|---|
| 20 | *Dodonea viscosa* | *Sapindaceae* | 0.0093 | -4.68 | -0.043 |
| 21 | *Dossinia marmorata* | *Orchidaceae* | 0.0091 | -4.69 | -0.042 |
| 22 | *Datura stramonium* | *Solanaceae* | 0.008 | -4.8 | -0.04 |
| 23 | *Erica arborea* | *Ericaceae* | 0.09 | -2.4 | -0.21 |
| 24 | *Euphorbia dumali* | *Euphorbiaceae* | 0.1 | -2.3 | -0.23 |
| 25 | *Ehretia cymosa* | *Boragnaceae* | 0.01 | -4.6 | -0.05 |
| 26 | *Eculea divinorum* | *Ebenaceae* | 0.0093 | -4.67 | -0.043 |
| 27 | *Echinops longisetu* | *Asteraceae* | 0.0081 | -4.81 | -0.038 |
| 28 | *Ekebergia capensis* | *Meliaceae* | 0.0081 | -4.81 | -0.038 |
| 29 | *Galiniera saxifraga* | *Rubiaceae* | 0.0093 | -4.68 | -0.043 |
| 30 | *Girardinia bullosa* | *Urticaceae* | 0.019 | -3.96 | -0.075 |
| 31 | *Galium thunbergianum* | *Rubiaceae* | 0.01 | -4.6 | -0.046 |
| 32 | *Hypercum quatinianum* | *Hypercaceae* | 0.0087 | -4.74 | -0.041 |
| 33 | *Hagenia abyssinica* | *Rosaceae* | 0.064 | -2.75 | -0.17 |
| 34 | *Juniperus procera* | *Cupressaceae* | 0.049 | -3.01 | -0.15 |
| 35 | *Justicia schimperiana* | *Acanthaceae* | 0.0081 | -4.81 | -0.038 |
| 36 | *Eucalyptusglobuls* | *Myrtaceae* | 0.009 | -4.71 | -0.042 |
| 37 | *Lannea schimperi* | *Anacardiaceae* | 0.0093 | -4.68 | -0.043 |
| 38 | *Lantana camara* | *Verbanaceae* | 0.0081 | -4.81 | -0.038 |
| 39 | *Myrsine africana* | *Myrsinaceae* | 0.08 | -2.52 | -0.2 |
| 40 | *Myrica salicifolia* | *Myricaceae* | 0.014 | -4.27 | -0.059 |
| 41 | *Maesa lanceolata* | *Myrsinaceae* | 0.0081 | -4.81 | -0.038 |
| 42 | *Malva neglecta* | *Malvaceae* | 0.0081 | -4.81 | -0.038 |
| 43 | *Noitalicx piperita* | *Lamiaceae* | 0.0091 | -4.69 | -0.04 |
| 44 | *Olea europea* | *Oleaceae* | 0.01 | -4.6 | -0.05 |
| 45 | *Olinia rochetiana* | *Oliniaceae* | 0.023 | -3.7 | -0.086 |
| 46 | *Ocimum sanctum* | *Lamiaceae* | 0.0087 | -4.74 | -0.041 |
| 47 | *Parthneium hysterophorus* | *Asteraceae* | 0.008 | -4.82 | -0.038 |
| 48 | *Povetta oliveriana* | *Rubiaceae* | 0.0093 | -4.68 | -0.043 |

| | | | | | |
|---|---|---|---|---|---|
| 49 | *Plantato lanceolata* | *Plantagnaceae* | 0.0087 | -4.74 | -0.041 |
| 50 | *Podocarpus falcatus* | *Podocarpaceae* | 0.013 | -4.34 | -0.056 |
| 51 | *Protea gagued* | *Proteaceae* | 0.0093 | -4.68 | -0.043 |
| 52 | *Prunus africana* | *Rosaceae* | 0.0089 | -4.72 | -0.042 |
| 53 | *Physalis peruviana* | *Solanaceae* | 0.01 | -4.6 | -0.05 |
| 54 | *Phallanthus emblica* | *Phallanthaceae* | 0.0089 | -4.72 | -0.042 |
| 55 | *Rhamnus prinoides* | *Rhamnaceae* | 0.0087 | -4.74 | -0.039 |
| 56 | *Scolopia theifolia* | *Flacourtiaceae* | 0.017 | -4.07 | -0.069 |
| 57 | *Solanum incanum* | *Solanaceae* | 0.0087 | -4.74 | -0.041 |
| 58 | *Thymus vulgaris* | *Lamiaceae* | 0.032 | -3.44 | -0.11 |
| 59 | *Verbascum thapsus* | *Scrophulariaceae* | 0.0091 | -4.69 | -0.042 |
| 60 | *Vernonia myriantha* | *Asteraceae* | 0.0087 | -4.74 | -0.041 |
| 61 | *Vernonia amygdalina* | *Asteraceae* | 0.01 | -4.6 | -0.05 |
| Shannon-wiener diversity index (H’) = H′== - Σ Pi ln Pi= 3.69 | | | | | |
| Evenness (E) = H′ / H′ max= 0.75 | | | | | |

Appendix 4**:** Species richness and Shannon-Weiner diversity index and, evenness from Plot to Plot of Mount Ambaricho natural forest in Kachabira district.

| Plot | Species richness | Diversity index (H’) | Shannon evenness (H’/Hmax) |
|---|---|---|---|
| 1 | 9 | 1.68599 | 0.767327 |
| 2 | 5 | 1.241692 | 0.771507 |
| 3 | 5 | 1.424717 | 0.885227 |
| 4 | 5 | 1.184696 | 0.736093 |
| 5 | 5 | 1.302164 | 0.80908 |
| 6 | 5 | 1.47576 | 0.916941 |
| 7 | 8 | 1.786007 | 0.858888 |
| 8 | 5 | 1.320515 | 0.820482 |
| 9 | 4 | 1.205451 | 0.869549 |
| 10 | 5 | 1.116689 | 0.693838 |
| 11 | 6 | 1.451376 | 0.810029 |
| 12 | 6 | 1.445001 | 0.80647 |
| 13 | 4 | 0.994914 | 0.717679 |
| 14 | 5 | 1.302397 | 0.809225 |
| 15 | 6 | 1.369421 | 0.764288 |
| 16 | 4 | 1.29354 | 0.933092 |
| 17 | 6 | 1.449623 | 0.80903 |
| 18 | 5 | 1.230354 | 0.764462 |
| 19 | 6 | 1.214321 | 0.677723 |
| 20 | 5 | 1.171354 | 0.727803 |
| 21 | 5 | 1.177321 | 0.73151 |
| 22 | 5 | 1.009441 | 0.627201 |
| 23 | 5 | 1.243228 | 0.772461 |
| 24 | 6 | 1.58557 | 0.884923 |
| 25 | 6 | 1.152421 | 0.643179 |

| | | | |
|---|---|---|---|
| 26 | 5 | 1.071976 | 0.666056 |
| 27 | 6 | 1.293972 | 0.722179 |
| 28 | 5 | 1.091034 | 0.677897 |
| 29 | 4 | 1.261318 | 0.909848 |
| 30 | 4 | 1.179606 | 0.850906 |
| 31 | 4 | 1.029106 | 0.742343 |
| 32 | 4 | 1.277404 | 0.921452 |
| 33 | 4 | 0.954638 | 0.688626 |
| 34 | 4 | 1.232152 | 0.888809 |
| 35 | 7 | 1.779879 | 0.914677 |

Appendix 5: The Four Community types, their sample plots and Altitude

| **Community types** | **plots** | **Total plots** | **Altitudinal range (m)** |
|---|---|---|---|
| Community 1 | 1,5,8,11,15,20,23<br>27,30,33,35,32 | 12 | 2565 to 2900 |
| Community 2 | 2,4,6,9,14,18,21<br>26,28,29, | 10 | 2540 to 2850 |
| Community 3 | 3,7,12,16,19,22,25,34 | 8 | 2420 to 2670 |
| Community 4 | 10,13,17,24,31 | 5 | 2400 to 2780 |

Ambaricho Forest photo was taken by (Mulatu Markos).