

**ADDIS ABABA UNIVERSITY  
COLLEGE OF NATURAL SCIENCE  
DEPARTMENT OF ZOOLOGICAL SCIENCE**



**Diversity of Vascular Epiphytes in Chilimo Forest,  
Dendi Woreda, West Shoa Zone, Ethiopia.**

**BY: BAYISA ABDISA**

**AUGST 2019  
ADDIS ABABA**

**ADDIS ABABA UNIVERSITY**  
**College of Natural and Computational Science**  
**Department of Zoological Science**

**Diversity of Vascular Epiphytes in Chilimo Forest, West Shoa  
Zone, Ethiopia**

**By**  
**Bayisa Abdisa**

A Thesis Submitted to the school of Graduate Studies of Addis Ababa  
University in Partial Fulfillment of the Requirements for the Degree of  
Master of Science in Biology.

**Advisor: Professor Sileshi Nemomissa**

**August, 2019**  
**Addis Ababa, Ethiopia**

# **Addis Ababa University**

## **School of Graduate Studies**

This is to certify that the thesis prepared by **Bayisa Abdisa** entitled “**Diversity of Vascular Epiphytes in Chilimo Forest, Dendi Woreda, West Shoa Zone, Ethiopia**” and submitted in partial fulfillment of the requirements for the degree of Master of Science in Biology complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

Advisor: Prof. Sileshi Nemomissa

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Examiner: \_\_\_\_\_ Signature: \_\_\_\_\_ Date: \_\_\_\_\_

# Table of Contents

page

List of Table.....	1
List of Figures.....	v
List of Plates.....	vi
List of Appendix.....	vii
ACRONYMS.....	viii
ACKNOWLEDGEMENTS.....	ix
ABSTRACT.....	x
1. INTRODUCTION.....	1
1.1 Objectives of the study.....	5
1.1.1 General objective.....	5
1.1.2 Specific objectives.....	5
1.2 Research Questions.....	5
2. LITERATURE REVIEW.....	6
2.1 What is an epiphyte?.....	6
2.2 Holoepiphytes (True epiphytes).....	7
2.3 Hemiepiphytes (Half epiphytes).....	8
2.4 Humus epiphytes.....	8
2.5 Distinguishing features of epiphyte.....	8
2.6 Characteristic evolution of epiphytes.....	9
2.7 Ecology and distribution of epiphytes.....	10
2.7.1 Diversity and distribution of vascular epiphytes in Chilimo Forest.....	10
2.7.2 Distribution of vascular epiphytes on Phorophyte.....	11
2.8 Factors affecting epiphytes diversity and distribution.....	12
2.8.1 Host Morphology.....	12
2.8.2 Climate conditions.....	12
2.8.3 Disturbance.....	13

2.8.4	Dispersal syndromes.....	13
2.8.5	Elevation.....	13
2.9	Characteristic adaptation of vascular epiphytes.....	14
2.10	The role of vascular epiphyte in forest biodiversity.....	14
2.11	The effect of forest disturbance on epiphyte distribution.....	15
2.12	Epiphyte Conservation .....	16
3	MATERIALS AND METHODS .....	18
3.1	Description of the study area .....	18
3.1.1	Location.....	18
3.1.2	Population.....	21
3.1.3	Vegetation .....	21
3.1.4	Climate .....	21
3.1.5	Land use .....	23
3.2	Methods of data collection .....	24
3.2.1	Sampling Design .....	24
3.2.2	Vegetation Sampling .....	24
3.2.3	Data analysis.....	26
4	RESULTS AND DISCUSSION.....	27
4.1	RESULTS .....	27
4.1.1	Species Diversity of Vascular Epiphytes .....	27
4.1.2	Vertical distributions of vascular epiphytes on phorophytes.....	32
4.1.3	Host specificity of vascular epiphytes .....	35
4.1.4	Bark texture of phorophytes and vascular epiphytes.....	37
4.1.5	Altitudinal distribution of vascular epiphyte.....	40
4.1.6	Phorophyte species retained in agricultural matrix .....	41
4.2	DISCUSSION .....	43
5	CONCLUSIONS AND RECOMMENDATION.....	45
5.1	Conclusion.....	45
5.2	Recommendation.....	46

6 REFERENCES..... 47

**LIST OF TABLES**

**PAGE**

Table 1: woreda land use classification..... 23  
Table 2: List of phorophyte species recorded from Chilimo Forest..... 28  
Table 3: List of vascular epiphytes in Chilimo forests..... 29  
Table 4: List of Vertical distributions of vascular epiphytes on host Zones. .... 33  
Table 5: Number of vascular epiphyte species existing on each sampled phorophyte. .... 36  
Table 6: List of vascular epiphyte species existing at different bark textures of phorophytes. .... 38  
Table 7: Lists of phorophyte species in Agricultural matrices..... 42

**LIST OF FIGURES**

**PAGE**

Figure 1: Map of study area ..... 19

Figure 2: Vascular epiphyte richness of some plant families in Chilimo Forest. ....30

**LIST OF PLATES**

**PAGE**

Plate 1: Partial photography of Chilimo forest.....20  
Plate 2: A local Guide climbing to pick up sighted epiphyte.....25

**LIST OF APPENDICES**

**PAGE**

Appendix 1: List of phorophyte species recorded from Chilimo Forest. ....52  
Appendix 2: List of Vertical distributions of vascular epiphytes on host Zones. ....53  
Appendix 3: Number of vascular epiphyte species existing on each sampled phorophyte.....54

## **ACRONYMS/ ABBREVIATIONS**

AAU-	Addis Ababa University
ARDO-	Agricultural and Rural Development Office
DBH-	Diameter at Breast Height
ETH-	National Herbarium of Ethiopia
M.a.s.l-	Meter above sea level
SPSS -	Statistical Package for the Social Sciences
UNEP-	United Nations Environmental Program

## **ACKNOWLEDGEMENTS**

I would like to express my deepest gratitude to my advisors Prof. Sileshi Nemomissa for their unreserved advice in selecting this interesting research topic and providing me valuable information and critical comments as well as continuous assistance and constructive suggestions throughout my study. Professor Sileshi is really genuine, punctual and fatherly throughout the research period, sharing his fruitful experiences is unforgettable.

I would like to express my gratitude to the Ministry of Education and School of Graduate Studies of Addis Ababa University for providing me with financial support, and the program unit of Biology in particular facilitating my work. I take the opportunity to thank to Mr. Deressa Shime for providing his own materials and sharing of his fruitful experiences by sacrificing his precious time and my field assistants Obo Merga Deressa who helped me in field data collection from very troublesome wet and slippery trunks high up the crown.

Special thanks go to my friends Obo Hailu Leta who gave me unreserved moral support and Digital camera. I would also like to express my thanks to my friends and colleagues, for their continued encouragement of my efforts to produce this paper.

My deepest affection is reserved for my family, my wife Ade Birke Aseffa for her carefully typing the manuscript, unreserved moral support and tolerated my selfish channel vision during my study and research time and remained supportive throughout the research period. Finally, thanks to my almighty God who kindly care and determine in all my life achievement and destiny.

## **ABSTRACT**

This study was conducted to investigate the diversity of vascular epiphytes in Chilimo forest, in Dendi woreda, west shoa zone, Ethiopia at altitude of 2000 – 3288m. Systematic sampling method was employed during data collection. Thirty four sample plots (20x20m) were laid and 400m between transect. All vascular epiphyte species found in each plot were recorded, collected, pressed and identified. A total of eighteen species of vascular epiphytes belonging to seven families were recorded from seventeen host (phorophyte) species in the study area. Orchidaceae, Polypodiaceae and Aspleniaceae are dominant from the families of vascular epiphytes in the study area. Each phorophyte zones(classes) harbored considerable number of epiphyte species, 7 species in basal zone, 10 species in trunk zone and 12 species in canopy zone. The diversity of vascular epiphyte was influenced by phorophyte and diversity increases from base to canopy. More DBH host tree carries more epiphyte. Tree bark texture has an effect on diversity of epiphytes (rough bark texture of the phorophytes has more support epiphyte than smooth barked). Rough bark texture of the phorophytes has high water retention capacity and is more convenient for vascular epiphyte species establishment than smooth ones. Increasing altitudes, decrease diversity of epiphyte due to moisture and go from lower altitude to higher altitude sparsely of forest increases. The main reason for decrease in number of epiphytes towards higher altitudes could be attributed to the low density of the forest trees, which resulted in the availability of suitable host trees (phorophyte) on which the epiphytes grew. As a result of this condition of the forest at higher altitudes, the species richness and abundance of associated epiphytes was limited. Most epiphyte was not host specific. The larger and older trees of the same offer more surface than small trees and also have been available for a longer time than younger hosts for epiphyte colonization. The changing forest structure and tree species composition at increasing altitude provide different quantities and qualities of substrate to epiphytes that resulted in decreasing number of epiphyte species with increasing elevation. Generally, the species diversity of vascular epiphytes is greatly influenced by the phorophyte biophysical factors, such as vertical gradient on individual host plants, host size, bark texture and elevation.

**Key words:** Chilimo forest, Diversity, Phorophyte, vascular epiphyte

## 1. INTRODUCTION

Epiphytes are those species which normally germinate on the surface of another living plant and pass the entire life cycle without becoming connected to the ground (Kress, 1989). They derive their nourishment from atmospheric sources. Epiphytes are defined as plants rooting on the surface of tree trunks or branches without harming the host tree (Benzing, 2004). The term *epiphytic* derived from the Greek words (epi = upon; phyton = plants). In forest ecosystem, epiphytes play useful roles in nutrient cycles, provide shelter and nesting materials for some insects and bird species, and are important sources of food for some foraging animals (Coxson and Nadkarni, 1995; Stuntz et al., 2002). Epiphytes constitute an important bio-indicator group of species that can be monitored to provide useful information on overall ecosystem health and productivity, because of their arboreal lifestyle and sensitivity to environmental stress (Fattland, 1996; McCune, 2000). Since they are useful climatic indicators, they can be used as a warning system for changing conditions in microclimate and even as indicators of global climatic change (Benzing, 1998). Epiphytes are extremely important elements of the flora representing about 10% of all plant species globally (Neider and Barthlott, 2001).

Vascular epiphytes are also plants that grow on trees or shrubs without directly harming them, are the life form most restricted to and typical of humid tropical forests (Hietz, 1999). Similarly, Schubert (1990) defined phorophyte as a host plant used by an epiphyte for physical support. Most vascular epiphytes are limited to tropical and subtropical forests, where they may be the most diverse life form in very humid formations (Madison, 1977; Benzing, 1987). However, their large scale diversity patterns are still discussed on the base of results from a few, local epiphyte inventories. This shows that their floristic composition and contribution to total forest flora is known for only a very few forests (Ingram et al., 1996).

Documenting the epiphyte flora of epiphyte-rich tropical forests will enhance our knowledge of these communities. However, the sampling of epiphytes is fraught with methodological difficulties (Burns and Dawson, 2005; Wolf et al., 2009). Thus they are comparatively poorly studied,

probably due to their hardly accessible habitat (Ku'per, 2004). However, plants fallen to the ground and local tree-climbers have provided voucher collections (Wolf et al., 2009). Although these techniques seem primitive compared with those used by modern canopy scientists, much of our knowledge of epiphyte distribution is based on this types of data (Johansson, 1974). These methods were also best employed in collecting specimens for the current study of epiphyte diversity in Chilimo forests.

On the other hand, complete inventories of host trees are usually only possible with specialized equipment and intensive sampling effort (Lowman, 2001). Therefore, complete inventories of epiphyte diversity on large numbers of trees are often not logistically feasible. As a result, detailed investigations concerning vegetation, ecology and diversity of tree canopies are especially rare (Biedinger and Fischer, 1996). Today in general the innovation of canopy access techniques such as rope climbing, walkways, platforms, cranes and hot air balloons to gain access to the forest canopy resulted in a burgeoning of interest in canopy research (Laman 1995). Recently, Hylander and Nemomissa (2009) have conducted a study on 'Home garden coffee as a repository of epiphyte biodiversity in Ethiopia'. It indicates that still there is lack of enthusiasm to study the diversity of epiphyte species in Ethiopian forests. The cause may be inaccessibility of their canopy habitat and the lack of modern method of sampling epiphytes. However the present beginnings may help as the stepping-stone for the future studies of epiphyte flora in other forests of the country.

Vascular epiphytes are the main component of forests in tropical regions. But the studies carried out in the past few decades have not concentrated on the epiphytes. Much of studies have been concentrated on the tree components of vegetation. Schnitzer and Carson (2000) have been published that in the past decades, most studies carried out on vascular plant were focused on the tree components, despite the fact that the non- tree vegetation is responsible for high percentage of the total biodiversity in the tropical forests.

The diversity and distribution of vascular epiphytes are determined by many factors. The biophysical environment of phorophytes such as host size, bark texture, vertical stratification as well as elevation above sea level are among the major factors discussed in the current study. Large

trunks have more surface area to be colonized by epiphytes (Zotz, 1997) than small trees. Rough bark texture of the phorophytes is similarly more convenient for vascular epiphyte species establishment than smooth ones (Nadkarni, 2000). Vertical distribution of epiphyte indicated that diversity increases from the base of the host plants through trunk to the crown. However, species richness was thought to decrease with increasing elevation (Stevens, 1992).

As the result of high deforestation rates and various degrees of disturbances made by human activities, vascular epiphytes are more diversified in primary forests than in the secondary and disturbed forests (Barthlott et al. 2001). The same author has published that the increase in species numbers, abundance, and species composition of primary forests are mainly due to highly diverse phorophyte structures and highly differentiated microclimates. The fact that epiphytes are surviving on the substratum raised above the ground, the properties of the substrate influence their distribution. Epiphytes are mostly abundant on forks, horizontal branches and rough barks of the host trees, but least abundant on vertical and smooth branches (Hietz and Hietz-Seifert, 1995; Hietz, 1999). These sites are the place where soil is easily collected and anchored is easier for them. The ages, chemical compositions of the barks, like bark PH, and size of the host trees are important for the abundance and diversity of the vascular epiphytes (Hietz, 1999).

As epiphytes are relying on other plants for support, they face several stressful conditions. In order to overcome these unfavorable conditions, they evolved different adaptation mechanisms (physiological morphological). Besides these structural and physiological modifications, the tropical areas provide suitable environment for the survival of the epiphytes. The warm temperature, high precipitation, large tree size, and enough solar radiation are conditions best suitable for the survival of epiphytes (Johansson, 1974).

Epiphytes are extremely important element of the flora (they represent about 10% of all plant species globally) are responsible for much of the biotic diversity that makes humid tropical forests the most complex of all worlds terrestrial ecosystems (Madison 1977; Benzing 1987). Establishment of epiphyte communities will enhance energy capture, moisture capture and retention, and biotic community diversity in restoration plantings, continuing the process of

returning agricultural pasture to a complex forest (Cummings et al., 2006). This makes the current study of the diversity of vascular epiphytes in Chilimo forest, interesting.

Vascular epiphytes provide specialized services to the ecosystem functioning. The ecological services include: substrate and food for many canopy dwelling animals, indicator for conservation initials and indicator of air quality and water cycling bio indicator to assess forest continuity maintenance of the moisture of the environment of ecological damage and contribute for plant species richness (biodiversity). Epiphytes have also been used extensively for medical, agricultural and horticultural purposes for human.

The high diversity of vascular epiphytes is one of the most striking characteristics of tropical rain forests and humid montane forests. These organisms are of major significance for a great number of reasons: 1) they contribute substantially to ecosystem diversity, production and nutrient cycles; 2) they provide appreciable nutrient and energy sources to associated organisms such as pollinating birds, bats and mutualistic ants; 3) they act as global indicators for climate change; 4) they are of major horticultural and, hence, of economic value; and 5) they create an arena for observational and experimental studies on a wide range of biological questions including diversity patterns, systematics, plant interactions, ecophysiology and mechanisms of evolutionary change. This study was intended to assess the composition and diversity of epiphytes in Chilimo Forest. Along with these, the impact of altitude, host tree dbh and height, nature of host bark and host plant species on the distribution of vascular epiphytes were assessed.

## **1.1 Objectives of the study**

### **1.1.1 General objective**

- To identify and document the species diversity of vascular epiphytes in Chilimo forest.

### **1.1.2 Specific objectives**

- To determine the species diversity of vascular epiphytes in Chilimo forest.
- To investigate relationship between number of epiphyte species and host size, bark texture and elevation.
- To describe the type of host tree species (phorophytes) left in agricultural matrix.

## **1.2 Research Questions**

- What factors are influencing the diversity of vascular epiphytes in Chilimo forest?
- What is the species diversity of vascular epiphytes existing in Chilimo forest?
- Does the species diversity of vascular epiphytes differ along the agricultural matrix?
- What measures should be employed to effect the forest conservation?

## **2. LITERATURE REVIEW**

### **2.1 What is an epiphyte?**

There are several definitions of epiphytes have been formulated. Heywood (1993) defined epiphyte as “a plant that grows on the surface of another, without deriving food from its host”. Raven et al. (1992) have defined epiphyte, as “a plant that grow on another plant, but is not parasitic on it”. An epiphyte is an organism that grows on the surface of a plant and derives its moisture and nutrients from the air, rain, water (in marine environments) or from debris accumulating around it. Epiphytes take part in nutrient cycles and add to both the diversity and biomass of the ecosystem in which they occur like any other organism. They are an important source of food for many species. Madison (1977) defined epiphytes as species, which normally germinate on the surface of another living plant and pass the entire life cycle without becoming connected to the ground. Similarly, Kress (1989) defined epiphytes as those plants that normally spend their entire life cycle perched on another plant and receive all mineral nutrients from non-terrestrial sources. Furthermore, Benzing (1987) defined epiphytes as plants that spend much or all of their lives attached to other plants. Qualifying forms range from microbes to angiosperms; both aquatic and terrestrial vegetation provide mechanical support.

Vascular epiphyte in particular is epiphyte with a dedicated transport system for water and nutrients and occurs in tropical conditions (Elias, 2008). Epiphytes are not restricted to living objects in general and some are also not restricted to specific plant forms. This was reported as epiphytes can also grow on different non-living objects. Gravendeel et al., (2004), for example has published that the designation ‘epiphyte’ is reserved for rain-fed ‘atmospheric’ vascular plants, germinating on their host (which can be either trees or rocks) to which they are anchored by a few roots only. Epiphytes are not connected to the soil, and consequently must get nutrients from other sources, such as fog, dew, rain and mist or from nutrients being released from the ground rooted plants by decomposition or leaching, and dinitrogen fixation. Epiphytes can have a significant effect on the microenvironment of their host, and of ecosystems where they are abundant, as they hold water in the canopy and decrease water input to the soil some non-vascular epiphytes such as

lichens and mosses are well known for their ability to take up water rapidly. The epiphytes create a significantly cooler and moister environment in the host plant canopy, potentially greatly reducing water loss by the host through transpiration.

Madison (1977) reported that epiphytism has several levels, and distinguished these as: hemiepiphytes that differ from true epiphytes, because they are epiphytic only part of their lives. They either germinate in the ground, growing up like vines and losing their connection with the soil once they settle in the canopy (secondary hemi-epiphytes), or they start as epiphytes, sending out aerial roots towards the soil (primary hemi-epiphytes). Casual epiphytes in which some individuals in a population function as true epiphytes, while others grow terrestrially. These are distinguished from accidental epiphytes, species without special adaptations to epiphytic life that can occasionally be found growing in soil-pockets on trees or on rotting stumps. Semi-epiphytic climbers are vines that are rooted in the soil, but which climb with adventitious roots that also function in uptake of water and nutrients. Biedinger and Fischer (1996) however, considered only two types of epiphytism. Plants that live exclusively on a tree are called holoepiphytes, whereas hemiepiphytes are plants for a certain period during their lifecycle are connected to the ground. The current study followed the classification method of Biedinger and Fischer (the 2nd type). Through this report, the term epiphyte will be used to denote vascular epiphytes in particular.

## **2.2 Holoepiphytes (True epiphytes)**

Holoepiphytes (true epiphytes) are plants that never root in the soil. They complete their entire life cycle anchored to the host plants, and receive mineral nutrients and water from non-terrestrial resources. Neider et al. (2001) have defined holoepiphytes as non-parasitic plants that use other plants usually trees as a growing sites all through their life cycle. The true epiphytes, however, can live only in the canopy from the moment of seed dispersal typically by wind or birds (Benzing, cited in Reynolds, 2003).

### **2.3 Hemiepiphytes (Half epiphytes)**

Hemiepiphytes (half epiphytes) are plants that are strictly epiphytic for one stage of their life cycle, but become rooted in the soil during other stages. Hemi epiphytic plants are characterized as structural parasites and rely on other plants (phorophytes) to grow vertically (Luttge, 1997). The same author has published that the hemiepiphytes have a soil connection for only a portion of their life cycle and represent a growth form between epiphytic and terrestrial plants. The hemiepiphytes are of two types: primary and secondary hemiepiphytes. The primary hemiepiphytes, which begin life as an epiphyte and later become rooted in soil. The secondary hemiepiphytes begin life rooted in the soil and later assumes an epiphytes life. The secondary hemiepiphytes use other objects as a support in their quest for light and after establishing on the phorophyte, their old shoot and roots senesce and new aerial root grow towards the soil.

### **2.4 Humus epiphytes**

Many humus epiphytes are opportunistic epiphytes. They may grow at ground level or on cliffs but will also grow in pocket of humus trapped in the boles and trunks of trees. They were also called as accidental or edaphic epiphytes. They are normal terrestrial plants but their Diasporas accidentally land on the phorophytes by dispersal agents and the plants make establishment.

### **2.5 Distinguishing features of epiphyte**

Plants considered to represent a specific ecological category usually share key qualities that set them apart from other vegetation. Occurrence on the same general type of substratum and, more importantly, utilization of comparable resource bases by similar mechanisms require considerable, often conspicuous, convergence (Benzing, 1987). This author on the other hand reported that vascular epiphytes share few qualities beyond occurrence in tree crowns that identify them as a single ecological type, primarily because their phylogenetic origins and life styles in forest canopies are diverse.

Epiphytes are extreme specialists adapted to climatically and ecologically harsh conditions in the canopy (Biedinger and Fischer, 1996). Therefore, the distinguishing and remarkable feature of the epiphytic plant is their ability, in many cases their requirement, to grow in the canopy of the forest,

rather than from the forest floor (Reynolds, 2003). Epiphytes have evolved to take advantage of resources not widely available to other plants.

## **2.6 Characteristic evolution of epiphytes**

Epiphytes have found a clever way of escaping the dark circumstances of the forest understorey, without having to invest in expensive structures to rise towards the sun. This is, at least, one scenario of how epiphytism evolved (Bader, 1999). An advantage at high positions may also be the enhanced dispersability of wind borne seeds. This might have been a selection pressure favoring epiphytism especially in wind-dispersed species: 84% of all epiphyte species are dispersed by wind. The remaining 16% have fleshy fruits and are dispersed by animals. Seeds are generally rather small (<1 mm long) (Madison, 1977). Thus, fleshy, small seeded fruits and climbing habit would favor life in canopies. For theridophytes reproducing by spore formation, their wind dispersability is obvious. However, as many fruiting or seed producing epiphytes in Chilimo Forest were flowering at the study time, the dispersal agents could not be identified. Also response to the resulting elevated moisture demands requires uptake by long- lived roots from more or less continuous supplies in tree fissures (Benzing, 1987). Out of those taxa that have evolved to an epiphytic habit, only few have radiated into species rich groups (Gravendeel et al., 2004). Family orchidaceae, for example contains by far the most epiphytic species of all plant species (ca. 13951 in 440 genera) (Bader, 1999). This shows 70% of all orchid species are epiphytes (Gentry and Dodson, 1987) and 60% of all epiphyte species are members of the Orchidaceae (Kress, 1986).

## **2.7 Ecology and distribution of epiphytes**

### **2.7.1 Diversity and distribution of vascular epiphytes in Chilimo Forest**

Vascular epiphytes are the life forms most restricted to and typical of humid tropical forests (Hietz, 1999). This shows that comprising about 30,000 species or 10% of the earth's total vascular flora, most vascular epiphytes are limited to tropical and subtropical forests, where they may be the most diverse life form in very humid formations (Madison, 1977; Benzing, 1987). According to Bader (1999), in addition to tropics, vascular epiphytes are also found distributed in southern hemisphere temperate forests. Diversity and abundance of vascular epiphytes is greatest in the Neotropics, where, according to an estimation of Madison (1977), 15,510 species have been recorded as epiphytes, compared to 12,560 in all of the Paleotropics (Sugden & Robins 1979). Bader (1999) has suggested that the exact number of epiphyte-species in the world is still unknown, and changes with every new publication on the subject. He also has reported that the epiphytic lifestyle has developed in no less than 84 families of vascular plants, 23,466 species in 879 genera have been recorded, most of which are angiosperms (20,863 species in 784 genera). Recently Zotz and Hietz (2001) published that the number of species of vascular epiphytes that occurs mainly in tropics alone reaches up to 25,000.

Various evidences have indicated with slight differences that the contribution of vascular epiphytes to biodiversity hotspot countries is much larger. According to Gentry & Dodson (1987), in the most diverse tropical forests, epiphytes account for up to 35% of the total vascular plant flora and nearly half of the individual plants. Bader (1999) has also reported that in a mega-diverse tropical country such as Ecuador, epiphytes contribute up to 27% to the total flora, and on a local scale they may even outnumber all other life forms. Kuiper (2004) has published that epiphytes contribute up to 30% to the number of vascular plant species in certain global biodiversity hotspots.

However, studies explicitly addressing biogeographically aspects of epiphytes are scarce, and often based on data from only a very few study sites or restricted to a narrowly defined region (Kreft et al., 2004). In addition, Biedinger and Fischer (1996) reported that physiology, ecology and

vegetation of epiphytes have only been analyzed for particular plant groups and certain regions or countries. This under-exploration of vascular epiphytes is probably because of the inaccessibility of the epiphytic habitat and—in contrast to woody plants—a lack of standardized sampling methods (Kreft et al., 2004).

### **2.7.2 Distribution of vascular epiphytes on Phorophyte**

The diversity of epiphytes in old growth forest is in part a result of the variety of sites available on single trees and in the whole forest canopy (Hietz, 1999). Some species are adapted to the most humid and shady stem bases, others to exposed twigs and others require thick or rotten branches resulting in a partitioning of the available space and a more or less pronounced zonation within the tree (Hietz and Hietz-Seifert, 1995). Vertical distribution of vascular epiphytes revealed that species diversity was very abundant in the canopy zone than at base and trunk of the host trees (Mojiol et al., 2009). This is because of the presence of branches in the canopy layer that may result in accumulation of dusts, which encourages epiphyte plants to grow (Sillette, 1999).

Thus, vertical distribution of epiphytic biomass can reveal microhabitats at various locations on the phorophytes. Epiphytes that prefer the upper portions of their host tree canopies may have higher light requirements than those in the lower parts of the canopies, or they may be more tolerant of lower humidity, and/or greater degree of drought stress (Hsu et al., 2002). The lower tree trunk has been reported to contain the lowest epiphyte diversity. Even though, some epiphytes prefer this lower tree trunk. Most epiphyte studies do not specify the species richness for this zone (Mehltreter et al., 2005).

On the other hand, less-structured secondary vegetation may not offer all of the micro-sites like in old growth forest. The diverse disturbances in space and time, the more homogeneous size of trees in the plantation than in the old growth, and the lack of any understorey that permitted much light to reach the ground thus are unsuitable for some epiphyte species (Hietz, 1999).

Like most shrubs in montane tropical forests, wild coffee hosts a variety of mosses, liverworts, and a few vascular epiphytes (Hylander and Nemomissa, 2009). Different authors reported that phorophytes offer only site of epiphyte attachment without being harmed. However, farmers

considered epiphytes as weeds to reduce their coffee yield and so are removing from their coffee stands. Sporn et al. (2007) responded, as it is not the case for decline of the yield.

## **2.8 Factors affecting epiphytes diversity and distribution**

Benzing (1987) has suggested that epiphyte life history has been influenced by many selective forces, including substratum distribution and stability, and Chemical peculiarities of substrata. According to Bader (1999), the main limiting factors for epiphytes, light, water and nutrients, play an important role. Moisture supply, more than any other feature, determines where a particular type of epiphyte will survive (Benzing, 1987).

### **2.8.1 Host Morphology**

Interestingly, host tree species had a strong effect on the composition of the epiphyte community, a fact related to differences in bark chemistry of the hosts (Hietz, 1999). Johansson (1974) reported that the structural characteristics of trees such as bark structure, presence or absence of like latex, resins, or inclination of branches influence the epiphyte settlement. Variations in the amount of available phorophyte branches and their size, and roughness may further influence the amount and species of epiphytes that grow in a given part of the forest (Kernan & Fowler 1995). On the contrary, a naked bark surface must complicate water and mineral balance just as do thin soils and rock faces (Benzing, 1987).

Species diversity of epiphytes increased with the diameter of host trees. Larger trunks have more surface area to be colonized by epiphytes over longer periods of time (Zotz, 1997; Mehltreter et al., 2005; Wolf, et al., 2009). In addition, older trees might house more epiphyte species because they have had a longer period to intercept greater numbers of dispersing epiphyte propagules and accumulate them (Burns and Dawson, 2005).

### **2.8.2 Climate conditions**

There is good evidence that even slight changes in temperature, rainfall, and CO<sub>2</sub> levels could have had strong impacts on canopy structure (e.g. canopy density, leaf area index) and canopy humidity (Cowling et al., 2001). As epiphytes dwell in the canopy acting as interface to the abiotic world, they are directly exposed to changing climatic conditions and thus much more sensitive

than other life forms (Kreft et al., 2004). In tropical montane cloud forests the cool and always moist climate favors a higher diversity and biomass of epiphytes than is found in hot tropical lowland forest. However, even in (semi-) deserts epiphytes can be abundant, and even in moist montane forests many epiphytes show xeromorphic adaptations such as developing water-storing succulent tissue, which is a nearly universal trait in vascular epiphytes (Madison, 1977).

### **2.8.3 Disturbance**

Disturbance affecting microclimate and forest structure would be reflected in the distribution of epiphytes within the forest: densities of epiphytes to be lower, species growing on thicker branches and in the more humid part of the canopy to be more strongly affected (Hietz et al., 2006).

### **2.8.4 Dispersal syndromes**

Remnant forest fragments, even single trees, can be an important reservoir for epiphyte diversity and a source for seeds in regrowing forest (Bader, 1999). Obviously epiphytes do not have a seed bank in the soil, so in regrowing forests the first epiphytes must arrive from the surrounding vegetation. Bader (1999) reported that apart from the growing conditions the supply of propagules is an important factor determining the distribution of epiphytes. As the Diasporas of epiphytes have to be transported in and between tree crowns and falling to the soil, most have very mobile seeds (Madison, 1977); a fact that may allow them to travel more easily between fragments than plants with heavy seeds.

### **2.8.5 Elevation**

Height above the ground and altitude above sea level are parameters always found to be important for epiphyte occurrence (Hietz & Hietz-Seifert 1995). Average number of vascular epiphytes on a single phorophyte decreases with increasing altitude (Biedinger and Fischer, 1996). In tropical rain forests, the vertical stratification within the canopy of epiphytes is correlated with gradients in humidity and the moisture availability of microhabitats (Zotz and Hietz, 2001) that affects epiphyte distribution on individual phorophytes.

## **2.9 Characteristic adaptation of vascular epiphytes**

Survival to epiphyte is often predicated on extensive storage capacity, economical water use, and ability to rebound rapidly from drought-imposed stress all, which may need morphological adaptation (Benzing 1987). Thus, constant adjustment to rapidly changing moisture supply must be accomplished via appropriate stomata and photosynthetic response. A big proportion (over 50%) of epiphyte species is said to have Crassulacean acid metabolism (CAM) photosynthesis, allowing the stomata to stay closed during the day, thus reducing water-loss (Bader, 1999). According to Benzing & pridgeon (1983), water balance is also aided by special absorptive tissues that prolong contact with transitory fluids via mini-impoundment (e.g., the vela men of orchid roots). The possibility to take up water directly from rain or mist through aerial roots or leaf-trichome is an adaptation for survival in xeric habitats (Bader, 1999). Thus, epiphytic ecology, relating to the vegetative part of the plants was illustrated by well-known features characteristic of epiphytes like succulence, vela men radicum or small body size (Biedinger and Fischer, 1996).

According to Bader (1999), another prerequisite to live epiphytically is the ability to attach to the phorophyte. Thus in over 99% of vascular epiphyte genera, species have part of their roots arising from the stem rather than the primary root. Usually these adventitious roots are used for adhesion to the bark of the phorophyte. They also allow for clonal reproduction by fragmentation of the plant. Like other stress-tolerant plants, epiphytes grow slowly, a characteristic, which moderates resource requirements but heightens vulnerability to habitat patchiness, disturbance, and other phenomena that oblige heightened fecundity (Benzing, 1987).

## **2.10 The role of vascular epiphyte in forest biodiversity**

Epiphytes are responsible for much of the biotic diversity that makes humid tropical forests, the most complex of all the world's terrestrial ecosystems (Gentry and Dodson, 1987). This is because epiphytes are important components of tropical forests, contributing directly (about 10 % of vascular plant species are epiphytes) to their biodiversity (Benzing 1990) and indirectly providing habitats and resources for many arboreal arthropods, frogs, salamanders and a variety of macro- and micro-flora (Benzing, 1996). Epiphytes are also playing important roles in ecosystem processes such as water, and nutrient cycling and storage (Benzing, 1995). They are a vulnerable

group and consequently represent a good indicator group of biodiversity that can be monitored to assess the effects of forest disturbance (Hietz, 1999). Thus, these characteristics make vascular epiphytes potential indicators of habitat quality.

Ewel and Hire math (2005) suggested that ‘diversity breeds diversity.’ Structural complexity associated with coffee cultivation below shade trees for example, is favorable to general forest biodiversity, as compared to either sun coffee or isolated trees without a coffee tree layer (Hylander and Nemomissa, 2009). Rich epiphytic vegetation is important for bird abundance and diversity in coffee shade system, because epiphytic vegetation increases the abundance of invertebrate food resources and provides nesting material and nest sites.

Although epiphytes often play a significant role in the functioning of forest ecosystems, their ecological importance has often been overlooked (Burns and Dawson, 2005). Research results about the ecology, diversity, and significance of epiphytes in the rainforests have been published recently (Bittner and Trejos, 1997). Thus, their floristic composition and contribution to total forest flora is known for only a very few forests. That is, though documenting the epiphyte flora of epiphyte-rich tropical forests will enhance our knowledge of these communities (Ingram et al., 1996), they are comparatively poorly studied, probably due to their hardly accessible habitat (Kuper et al., 2004).

### **2.11 The effect of forest disturbance on epiphyte distribution**

For many species of plants and animals, the loss of their habitat represents the greatest threat to their survival (UNEP, 1995). Species loss and the erosion of genetic diversity are highest in the tropics (Myers, 1988). This is a result of high deforestation rates in many tropical countries (FAO, 1993) and the fact that tropical forests harbor more species of plants and animals than any other area of the world (UNEP, 1995).

As epiphytes depend on their host plants, usually trees, any conversion to forest vegetation will obviously result in a complete loss of epiphytes in the affected area (Hietz, 1999). This shows that disturbance is lethal to epiphytes particularly when supporting bark fragments exfoliate, inhabited twigs fall, infested trees collapse, and (less common but broader in extent) natural disasters ravage

whole communities (Benzing, 1987). Wherever disturbance increases forest openness, the locations close to the soil will become sunnier and drier, affecting especially epiphytes requiring high atmospheric humidity (Hietz, 1999) this is true in Chilimo Forest. Logging for example affects epiphytes by reducing the available habitat and by altering the microclimate in the forest (Barthlott et al., 2001). When large trees are removed, epiphytes that require either large branches as substrate or those with a long life cycle will be affected by changing their population structure (Padmawathe et al., 2004). In addition, the colonization and establishment of vascular epiphytes is a very slow process, hence a small disturbance in the epiphytic succession would affect the seral stages and ultimately their growth (Zotz, 1995). These factors make epiphytes sensitive to changes in the environment.

In general, many of the world's tropical forests have been converted to agriculture-dominated landscapes (Hylander and Nemomissa, 2009). Little is known about the capacity of these landscapes to harbor native forest biodiversity (Laurence, 2007). However, when analyzing the role of home gardens as forest species repositories, most of the epiphyte species were found at least once on both coffee and shade trees (Hylander and Nemomissa, 2009). Thus, both coffee trees and shade trees are important hosts for epiphytic plant diversity. These authors have suggested that removing again coffee trees from any single 200 m<sup>2</sup> home garden plot would reduce epiphytic diversity by 41%, on average.

## **2.12 Epiphyte Conservation**

Floristic recovery of a montane forest where the primary rain forest has been greatly reduced this century by various human activities is not known if and on what timescale a forest like the primary mossy forest will develop again (Bader, 1999). Furthermore, since lowland forests offer a wide range of habitats for different epiphyte groups and are constantly under threat, due to their easy accessibility, immediate attention is necessary to protect these special habitats (Padmawathe et al., 2004). The above authors have suggested that varying approaches have to be adopted for conservation of different epiphytes under conditions of selective logging. In case of orchids, for example, remnant larger trees within logged forests continue to ensure their survival. Thus retaining larger trees in logged forests would help in conserving orchids at least (Barthlott et al.,

2001). Furthermore, single remnant trees have been shown to be potential nuclei for the reforestation of abandoned pastures or fields, as they attract birds from the forest that deposit seeds of forest plants and lead to an intense regrowth beneath the spared trees and host epiphytes long after the forest had been cleared (Hietz, 1999). However, Hietz (1999) has suggested that severe disturbance and destruction will not stop soon. It is therefore necessary to study not only diversity in pristine environments but also the impact of alternative uses and management practices on biodiversity to conserve as much as possible where disturbance and deforestation cannot be prevented and, where possible, to improve the conservation value of areas already degraded\

## **3 MATERIALS AND METHODS**

### **3.1 Description of the study area**

#### **3.1.1 Location**

The Chilimo Forest (collectively known as Chilimo Gaji Forest) is a dry Afro-montane forest, located in Dendi Woreda, West Showa zone, Oromia Regional State. It is situated 78 km west of Addis Ababa, 7 km north of the small town of Ghinchi and close to the main road running to Ambo ( Addis Ababa-Naqamte road). Dendi woreda is one of the twenty two woreda's of West Showa Zone. The forest is located approximately between latitude  $9^{\circ}00'N$  and  $10^{\circ}08'N$  and longitudes  $38^{\circ}05'E$  and  $38^{\circ}15'E$  and it cover is estimated to 5,000 ha, with elevations ranging from 2000 to 3288 m a.s.l (Melaku, 2003).The woreda has a total area of 79,939 ha and the population of the woreda is 212,937 out of these, male 108,598 and 104,339 (Dendi woreda FED Report, 2017). The forest represents the remnants of the dry Afro-montane forests in the central plateau of Ethiopia. The main species in the canopy layers are Junipers procera, Podocarpus falcatus, Prunus africana, Olea europaea subspecies cuspidata, Hagenia abyssinica, Apodytes dimidiata, Ficus spp., Erythrina brucei, and Croton macrosytachus (Melaku, 2003). Local communities use this forest as a grazing land for their cattle. The people living in the forest are farmers working with both crops and livestock. There is also a palace/house of former emperor Haile Selassie. The forest is maintained in a sustainable manner by the community and is actually a succes story in community sustained forest management. Thus, the study was concerned with the diversity of vascular epiphytes species in Chilimo forest.

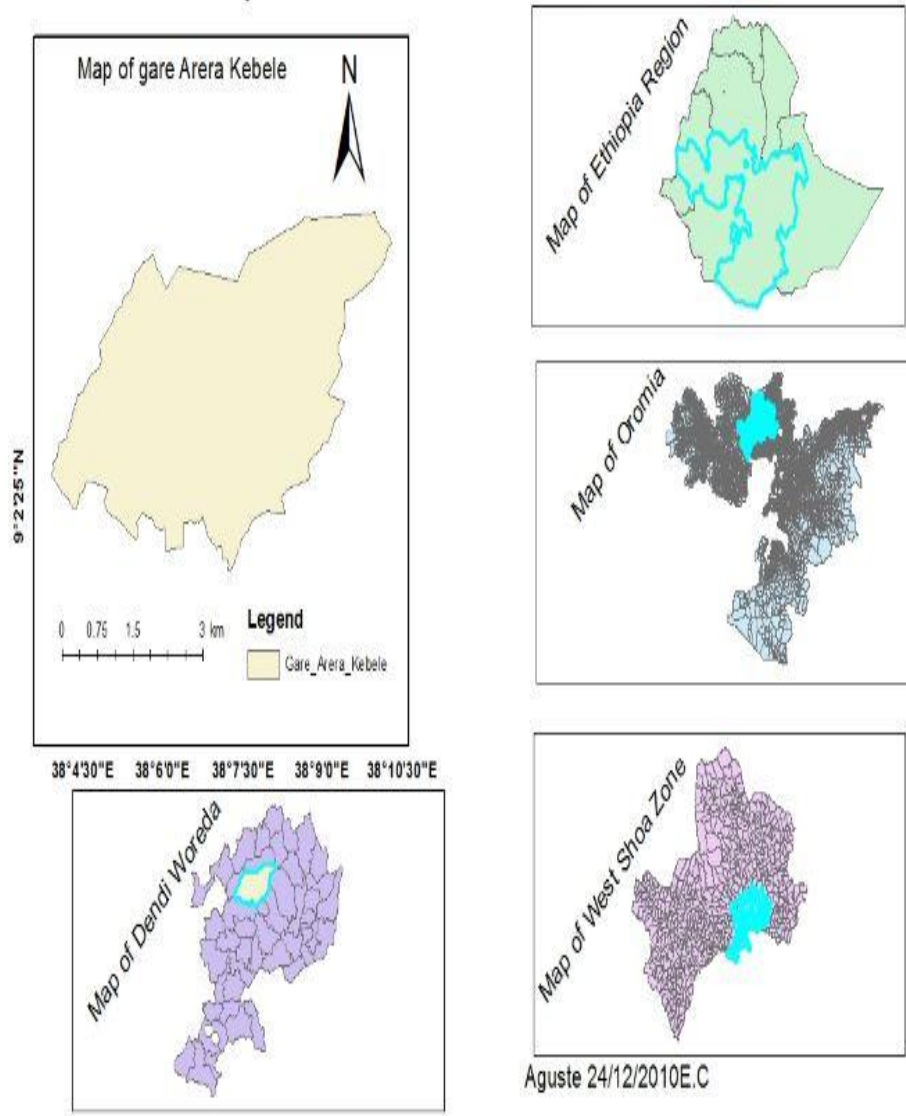


Figure: 2 Map of the study area



**Plate 1:** Partial photograph of Chilimo forest by the author June, 2019

### **3.1.2 Population**

According to 2007 population and housing census of Ethiopia the total population of Dendi woreda were 209,554 among which 106,050 were male and the rest were female. There were 20,215 households, of which 16,092 were male-headed households while the remaining 4,123 were female-headed. The average family size per household varies between 3 and 5 persons. The economically active work force over 15 and below 65 years of age is estimated to be 49%.

### **3.1.3 Vegetation**

The Chilimo forest is a dry Afro-Montane forest in the West Shoa zone in Dendi Woreda, with an estimated forest cover of about 5,000 ha. The forest is composed of mixed broad leaved coniferous forest. The dominant species in the forest include *Juniperus procera*, *Podocarpus falcatus*, *Prunus africana*, *Olea europaea*, and *Hagenia abyssinica* (Melaku, 2003). The people living in the forest are farmers working with both crops and livestock. There is also a palace/house of former emperor Haile Selassie. The forest is maintained in a sustainable manner by the community and is actually a success story in community sustained forest management. Thus, the study was concerned with the diversity of vascular epiphytes species in Chilimo forest.

### **3.1.4 Climate**

It is important to realize that temperature and altitude are the two important factors which are strongly correlated to reflect the climatic condition of the study area. Dendi woreda has a tropical climate that is modified by altitude and the mean maximum temperature is 23.3<sup>0</sup>c while the minimum temperature is 9.6<sup>0</sup>c (Holeta research center, 2014). The diverse topographic features of the area represent a diverse climatic condition. The woreda encompasses Dega and Woina Dega agro-ecological zones. From an agricultural point of view it is actually unimodal, because farmers can only grow one rain fed crop per year. The agricultural season is closely associated with the rain fall pattern. The annual rainfall of the study area is 1409.2mm. The local names for the seasons are:

**Arfaasaa (March to May):** a little rain falls during this season. If the rains look promising, some Arfaasaa (Belg) crops like maize and sorghum may be planted. However, as these rains are very rare in the study area, farmers mostly use this season to prepare their land for the coming summer.

**Ganna (June to August)** is the rainy season. Almost all variety of crops is sown from the beginning up to the end of this period. The season represents one of the main cropping season of the woreda.

**Birraa (September to November):** It is a season when farmers end their ploughing farm land and take a rest. At the same time at the end of the season it is also a time of harvesting some wheat crops at waina Dega agro-ecological zone.

**Bona (December to February):** It is relatively dry season when crops are harvested, threshed and stored. This season is the pick season for the destruction of forest for the purpose of firewood, charcoal for household energy and selling to the immediate urban consumers.

The Chilimo-Gaji Forest Area and the surrounding kebeles are made up of two major agro ecologies, namely: (i) Dega and (ii) the Woina Dega. The type and range of crops grown in these two agro-ecological zones are different and in most cases the agronomic practices are not the same. Because of cold temperature in the Dega zone the range of crops grown and potential tree species are fewer compared to the Woina Dega agro ecological zone. The other constraint as related to Chilimo-Gaji forest is the case of steep slopes susceptible to soil erosion and water runoff. There are often cases where the whole crop field freshly cultivated and sown and crops get washed down leaving bare land reduce crops yield. One of the key constraints of the agricultural land use of the zone is the traditional practice of fallowing croplands letting land use efficiency of only 50% only. This is to say only half of the agricultural land is not in use every growing season to maintain land productivity and they keep on with poverty ridden situation. This practice resulted in more dependence on the immediate forest product illegally or legally to compensate the yield reduction during fallow period.

Household fuel wood shortage for cooking and space heating in the Dega Zone is also acute as deforestation in the nearby area is nearly complete during the transitional period of 1991. This creates the need to enter into the Chilimo-Gaji forest for gathering firewood and making charcoal.

Families living in the Dega zone have very little or no surplus produce for sale to generate cash income. Firewood and timber from the forest have therefore tended to bridge this shortfall, along with sale of sheep, equines, donkeys and horses.

### 3.1.5 Land use

The natural vegetation in the study area is under heavy pressure due to the rapid population growth. The indigenous tree of the study area is removed mainly to expand agricultural farm lands, fuel woods and for the construction of houses, fences around their residence, charcoal production for market. In addition plantation forest is another vegetation of the study area in which eucalyptus tree is main vegetation type of the area. Most people plant these trees around their residence and near their farm lands. Currently, it is a fashion to see eucalyptus trees everywhere in the woreda especially around sloppy area, near streams, swampy areas and even on very agriculturally productive land. Even though it is not experienced in the village of study area, due to proximity of the village dwellers to Chilimo-Gaji forest, it is highly expanding in the woreda where the former natural forest was dominated the land and now replaced by this exotic tree species. According to the Dendi woreda agricultural office, the total area of the woreda is 79,939.29hek. and is categorized as the following land utilization.

**Table 1: woreda land use classification**

No.	Land use	Area in hek.	In %
1	Agricultural land	54057hek	67.65
2	Grazing land	14,912.36hek	18.65
3	Natural forest and shrubs land	7925.93hek	9.91
4	Swamp and marshy land	804hek	1.01
5	Land occupied by lakes	820hek	1.03
6	Urban land	821hek	1.04
7	Others land used for different purposes	599hek	0.75
<b>Total</b>		<b>79,939.29hek</b>	<b>100%</b>

**Source:** ARDO of Dendi woreda, (2014).

## **3.2 Methods of data collection**

### **3.2.1 Sampling Design**

Systematic sampling method was employed in data collection. A reconnaissance survey was selected as a sample based on accessibility and the presence of epiphytes. The size of each quadrat was  $20 \times 20 \text{m} = 400 \text{m}^2$  quadrants were laid out systematically based on vegetation type in the study site. A total of thirty four quadrats were laid in each forest zone. All vascular epiphytes were recorded on all host trees with diameter at breast height (dbh)  $\geq 10 \text{cm}$  found in all plots. The number of vascular epiphytes on each phorophytes was counted. Each host tree was divided in to three vertical zones namely: Basal (from ground to dbh), Trunk (from dbh to first branch) and Canopy (from first branch to the tip of the tree).

### **3.2.2 Vegetation Sampling**

In order to observe the general patterns of vegetation and forest zonation of the study area, a reconnaissance survey was made from May 24 to 30, 2011. The actual data collection was conducted from June 1, 2011 to June 30, 2011. Data collected were qualitative; presence/absence of all vascular epiphytes occurring on host plants rooted inside the plots was recorded. Sample specimens of both vascular epiphyte species and phorophyte plant species were collected and pressed there in the field. The main activities performed during fieldwork were: measuring the diameter at breast height (DBH) of phorophytes, counting and sampling species of vascular epiphytes and bark texture and elevation, the abundance, and the exact location on the phorophytes were determined. All tree species with DBH  $\geq 10 \text{ cm}$  were considered appropriate host for sampling epiphytes in this study. Because, phorophytes with dbh less than 10 cm have smaller surface area and thus hold either very few number or no vascular epiphyte species.



**Plate 2:** A local guide climbing to pick up sighted epiphytes by author June, 2019

Sampling of epiphyte species was done through the following means: (1) collecting from fallen old branches (2) using binoculars for well developed epiphytes occurring high up in the canopies and (3) with the help of indigenous climber which was the most important method used for observations and/or specimen collection. The fallen phorophyte branches were sampled only when it was confirmed that they have come from mother trees found in the quadrat. This was determined by observing and associating with the scar on the mother trees.

Photographs have been taken for each sample plots with both digital and manual cameras. The vertical distribution of vascular epiphytes on the phorophytes was studied following Mojiol et al., (2009) zonation. Accordingly, host trees were partitioned into three zones: (1) Basal, from the ground to the diameter at breast height (dbh), (2) Trunk, from the dbh to the first branch and (3) Canopy, from the first branch to the tip of the tree.

### **3.2.3 Data analysis**

The voucher specimens of both phorophytes and epiphytes with their reproductive parts were collected and pressed in triplicates. Only, small parts of the phorophytes plants with their leaves and reproductive organs were used in order to fit with the size of the pressing material. However, the whole plant was used in the case of epiphytes. Then, Epiphytes were collected following standard herbarium techniques(the specimen was properly; pressed, dried and identified at the National Herbarium of Ethiopia, Department of Plant Biology and Biodiversity Management, Addis Ababa University using the Flora of Ethiopia and Eritrea, and comparison with herbarium specimens housed at ETH).

The last destiny of the identified specimens was to be labeled and placed in the national Herbarium in order to serve as references. The relationship between the numbers of epiphyte species and the size of host plants (dbh) were analyzed by using a computer software program known as SPSS, version 20. Host specificity of the epiphytes is also analyzed by using qualitative data recorded during field collection. The control of textures (i.e., host size and bark textures) phorophytes on the diversity of epiphyte species per tree was compared and described qualitatively. Species richness is a biologically appropriate measure of alpha ( $\alpha$ ) diversity and is usually expressed as number of species per sample unit (Whittaker, 1972). Before analysis was done, the data was checked for outlying observations and there was none.

## **4 RESULTS AND DISCUSSION**

### **4.1 RESULTS**

#### **4.1.1 Species Diversity of Vascular Epiphytes**

A total of 18 species of vascular epiphytes belonging to 7 families have been recorded from the seventeen host (phorophyte) species in the study sites (Figure 2). The species were recorded from phorophytes with a dbh  $\geq$  10cm and rooted inside 400m<sup>2</sup> plot in each forest habitat type. Almost all of the identified species was holoeiphytes. Orchidaceae, Polypodiaceae and Aspleniaceae are dominant from the families of vascular epiphytes in the study area. Orchidaceae was the most dominant family with six species (33%) while Polypodiaceae was the second dominant family with four species (22%). The third species rich family was Aspleniaceae with three species (16.6%). The fourth species rich family was Piperaceae with two species (11%). The remaining 3 families (Asteraceae, Amaranthaceae and Oleandraceae) each contained only one species.

The difference in species diversity of vascular epiphytes recorded by above author and the high diversity of Orchidaceae in the study area may be related to its characteristics high stress tolerance and its adaptive traits. Reported that, Adaptation of orchids to temporary water stress and their ability to grow in drier and more-sun exposed areas of the upper canopy irrespective of the forest types make them inappropriate indicators of disturbances. Increasing altitudes, decrease diversity of epiphyte due to moisture and go from lower altitude to higher altitude sparsely of forest increases. The main reason for decrease in number of epiphytes towards higher altitudes could be attributed to the low density of the forest trees, which resulted in the availability of suitable host trees (phorophyte) on which the epiphytes grew. As a result of this condition of the forest at higher altitudes, the species richness and abundance of associated epiphytes was limited.

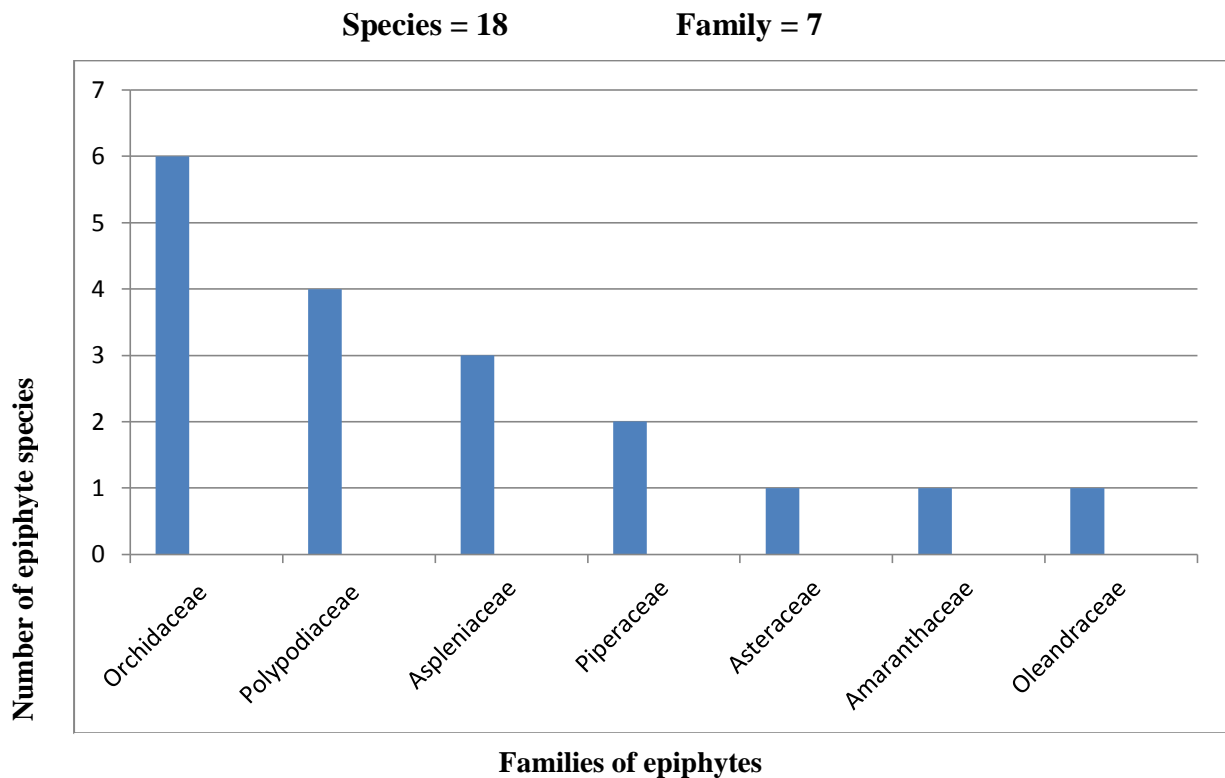
**Table 2: List of phorophyte species recorded from Chilimo Forest.**

No.	Phorophyte species	Family	Vernacular Name
1	<i>Ekebergia capensis</i> Sparrm.	Meliaceae	Sombo
2	<i>Ficus mucoso</i> Ficalho.	Moraceae	Harbu (small fruit)
3	<i>Ficus vallis-choudae</i> Del.	Moraceae	Harbu (big fruit)
4	<i>Antiaris toxicaria</i> Lesch.	Moraceae	Dangi
5	<i>Ficus thonningii</i> Blume.	Moraceae	Dambi
6	<i>Cordia africana</i> Lam.	Boraginaceae	Wadesa
7	<i>Albizia grandibracteata</i> Taub.	Fabaceae	Alale
8	<i>Albizia schimperiana</i> Oliv.	Fabaceae	Bobessa
9	<i>Millettia ferruginea</i> (Hochst.) Bak.	Fabaceae	Sotallo
10	<i>Acacia abyssinica</i> Hochst.ex Benth.	Fabaceae	Sondi
11	<i>Croton macrostachyus</i> Del.	Euphorbiaceae	Bakanisa
12	<i>Vernonia amygdalina</i> Del.	Asteraceae	Dhebicha
13	<i>Spathodea campanulata</i> P.Beauv.	Bignoniaceae	Muka dire-D
14	<i>Bersama abyssinica</i> Fresen.	Meliantaceae	Lolchisa
15	<i>Olea welwitschii</i> (Knobl.)Gilg & Schellenb.	Oleaceae	Baha
16	<i>Prunus africanum</i> (Hook.f.) Kalkam.	Rosaceae	Homi
17	<i>Nuxia congesta</i> R. Bres. Fresen.	Loganiaceae	Qayisa

About 18 species of vascular epiphyte plants were recorded from sampled area of Chilimo forest. The epiphytes categorized under 7 families (Table 3). Although their proportion and indeed their presence vary in total richness according to the class or zone of phorophytes, the species richness of vascular epiphyte families in Chilimo Forest were recorded with their decreasing order as Orchidaceae represented by 6 species (33%), Polypodiaceae with 4 species (22%), Aspleniaceae with 3 species (16.6%) and Piperaceae with 2 species (11%), while the rest and scarce families (Asteraceae, Amaranthaceae and Oleandraceae) each was represented by a single species ( 5.56 % each) (Figure 2). The result indicated that Orchidaceae contributed more species followed by Polypodiaceae.

**Table 3: List of vascular epiphytes in Chilimo forests.**

No.	Epiphyte species	Family	Phorophyte Zone		
			Basal	Trunk	Canopy
1	<i>Achyranthus aspera</i> L.	<i>Amaranthaceae</i>	-	+	-
2	<i>Adenostema mauritianum</i> DC.	<i>Asteraceae</i>	+	+	+
3	<i>Aerangis brachycarpa</i> (A.Rich.)Th.Dur.&Schinz	<i>Orchidaceae</i>	-	+	+
4	<i>Aerangis thomsonii</i> (Rolfe) Schltr	<i>Orchidaceae</i>	-	+	+
5	<i>Arthropteris monocarpa</i> (Cordem.) C.Chr.	<i>Oleandraceae</i>	-	+	+
6	<i>Asplenium aethiopicum</i> (Burm.f.) Bech.	<i>Aspleniaceae</i>	+	+	+
7	<i>Asplenium sandersonii</i> Hook.	<i>Aspleniaceae</i>	+	+	+
8	<i>Asplenium theciferum</i> (HBK.)Mett.	<i>Aspleniaceae</i>	-	-	-
9	<i>Cyrtorchis arcuata</i> (Lindl.) Schltr.	<i>Orchidaceae</i>	-	+	+
10	<i>Cyrtorchis erythraeae</i> (Rolfe) Schltr	<i>Orchidaceae</i>	-	+	+
11	<i>Diaphananthe tenuicalcar</i> Summerh.	<i>Orchidaceae</i>	-	-	+
12	<i>Drynaria volkensis</i> Hieron.	<i>Polypodiaceae</i>	+	+	+
13	<i>Lepisorus excavatus</i> (Willd.) Ching	<i>Polypodiaceae</i>	-	+	+
14	<i>Lepisorus schraderi</i> (Mett.) Ching	<i>Polypodiaceae</i>	-	+	+
15	<i>Loxogramme abyssinica</i> (Baker) M.G.Price	<i>Polypodiaceae</i>	+	+	+
16	<i>Microcoelia globulosa</i> (Hochst.) L.Jonsson	<i>Orchidaceae</i>	-	-	+
17	<i>Peperomia abyssinica</i> Miq.	<i>Piperaceae</i>	+	+	+
18	<i>Peperomia tetraphylla</i> (Forster) Hook.& Arn.	<i>Piperaceae</i>	+	+	+
Total			7	10	12



**Figure 2:** Vascular epiphyte richness of some plant families in Chilimo Forest.

The number of species of vascular epiphytes registered in each phorophyte zones habitat was 7 species in basal, 10 in trunk and 12 in canopy (Table 3). Thus, the canopy and trunk of phorophyte zones were relatively more specious forests with a slight difference between them, while the basal phorophyte zone was poorer in number of epiphyte species. The study indicated that the number of epiphyte species in the trunk zone was found to be slightly less than that of the canopy zone. The data collected from phorophytes with different sizes and corresponding number of epiphyte species were analysis by using statistical package for the social sciences (SPSS). Similar results have been reported by different authors that, there is positive relationship between phorophytes and number of epiphyte species (number of epiphyte species increase with increasing sizes of phorophytes). According to Hietz-Seifert U. et al, the number of epiphytic species per tree was strongly correlated with tree size. The tree size relates to several factors that contribute to epiphyte establishment and larger trees are likely, on average, to be older, allowing more time to capture

spores. A significant positive relationship was found from the association between trunk size and epiphyte. The dynamics of vascular epiphyte assemblages is expected to differ from that of terrestrial plants in a number of ways, mostly because it is governed or influenced by the dynamics of the supporting trees (Zotz et al., 2005).

In general, the result of the study indicates that the vascular epiphytes, components of the plant community comprise 18 of all the reported vascular plants species in the Chilimo Forest. This is a very low number or proportion of vascular epiphyte species when compared to that reported from different tropical forests. Many reports from various montane forests revealed the existence of higher number of vascular epiphyte species. Ingram et al. (1996) reported 256 vascular epiphyte species from a Neotropical cloud forest; Montverde, Costa Rica; Kreft et al. (2004) also identified 256 vascular epiphyte species in Western Amazonia, Yasuni', Ecuador; Hietz (2005) reported 122 species of vascular epiphytes in the nine coffee plantations and four forests in Mexico. Tesfa Alemayehu (2006) reported 55 vascular epiphyte species from Harena Afromontane Forest, Bale, Ethiopia. However, many of these and other reports of the vascular epiphytes recorded from different tropical forests did not identify the habit of those vascular epiphytes (whether they are true epiphytes or other forms). This may make the comparison to some extent incomplete. Only Tesfa Alemayehu (2006) reported that among 55 epiphyte species of Harena Forest only 40% (22 in numbers) were holoeiphytes. Abuna Tafa (2010) reported 36 vascular epiphyte species from Yayu Coffee Forest, West Oromia, and Ethiopia. The relatively lower diversity of vascular epiphytes in Chilimo Forest, when compared with some other tropical forests, may be due to forest disturbance caused by human activities and their domestic animals and also can be attributed to the seasonality and warm climatic conditions of the area. The deforestation practices being performed by local people were the logging activities for agriculture, fuel and timber production and the major forest disturbance practice observed in the area. The relatively larger number of vascular epiphyte species recorded from Chilimo dry Afromontane forest during the study was the group of monocot angiosperms, which in turn dominated by orchids (6 species).

The relatively high diversity of orchids in the study area may be related to its characteristic high stress tolerance and its adaptive traits. Adaptation of orchids to temporary water stress (Walter, 1971) and their ability to grow in drier and more sun-exposed areas of the upper canopy (Smith,

1986) irrespective of the forest types makes them inappropriate indicators of disturbances. Sebsebe Demissew et al., (2004) has also reported that the orchids of Ethiopia are generally poorly collected, particularly forest of south-west Ethiopia are under-explored and the orchids of previously Gamu Gofa and Illubabor regions are very poorly represented in Herbaria.

#### **4.1.2 Vertical distributions of vascular epiphytes on phorophytes**

The vertical distribution patterns of vascular epiphytes, from the basal part to the top of most crowns of the phorophytes, showed variation. Differences in the pattern of vertical distribution of vascular epiphyte are found on different zones of their host plant species. Species distribution of vascular epiphytes per phorophyte is not the same from basal parts to the top most branches. The number of epiphytic species increased from the tree base to the middle branches and then declined towards the top branch region while richness of vascular epiphyte species increased in the order of base-trunk-canopy regions in Chilimo forest (Table-3). Three species of vascular epiphytes namely *Asplenium sandersonii* Hook, *Drynaria Volkensii*, and *Peperomia abyssinica* are distributed throughout its host zone (Table 3). *Cyrtorchis arcuata*, *Lepisorus excavates*, *Loxogramme abyssinica*, *Lepisorus schrader* and *Peperomia tetraphylla* was observed from two host zones. Ten species namely *Achyranthus aspera*, *Adenostema mauritianum*, *Aerangis brachycarpa*, *Aerangis thomsonii*, *Arthropteris monocarpa*, *Asplenium aethiopicum*, *Asplenium theciferum*, *Cyrtorchis erythraeae*, *Diaphananthe tenuicalcar* Summerh, and *Microcoelia globulosa* found to grow one phorophyte zones. This difference may be depends up on different factors like surface area and exposition to different environmental disturbance. According to Abuna Tafa some vascular epiphytes are not restricted only base or trunk and canopy, so this is similar with my founding.

Most of the epiphytes species are found on canopy of tree and large stems. Vascular epiphytes (*Asplenium aethiopicum*, *Adenostema mauritianum* *Diaphananthe tenuicalcar* Summerh, and *Microcoelia globulosa*) were only growing in the canopy region. These due to crown species may be regarded as better adapted to drier conditions and high irradiance as vascular epiphytes that inhabit the upper canopy are suggested to prefer low moisture and high light requirements. Three vascular epiphytes namely *Aerangis thomsonii*, *Arthropteris monocarpa* and *Asplenium theciferum* were restricted only in the basal region.

Generally, from above, the most of epiphytic species abundantly distributed over the middle zone and canopy of their host plants. In a similar manner Pos E.T. et al in their study of vascular epiphytic plant ecology of Brazil Nation forest stated that, the least number of epiphytic plant species was recorded from the basal area. The reason for the least number of epiphytes from the basal area of the host plant may be branches in the canopy that prevent sunlight and also easily disturbed by animals.

**Table 4: List of Vertical distributions of vascular epiphytes on host Zones.**

No.	Epiphyte species	Family	Phorophyte Zone		
			Basal	Trunk	Canopy
1	<i>Achyranthus aspera</i> L.	<i>Amaranthaceae</i>	-	+	-
2	<i>Adenostema mauritianum</i> DC.	<i>Asteraceae</i>	-	-	+
3	<i>Aerangis brachycarpa</i> (A.Rich.)Th.Dur.&Schinz	<i>Orchidaceae</i>	-	+	-
4	<i>Aerangis thomsonii</i> (Rolfe) Schltr	<i>Orchidaceae</i>	+	-	-
5	<i>Arthropteris monocarpa</i> (Cordem.) C.Chr.	<i>Oleandraceae</i>	+	-	-
6	<i>Asplenium aethiopicum</i> (Burm.f.) Bech.	<i>Aspleniaceae</i>	-	-	+
7	<i>Asplenium sandersonii</i> Hook.	<i>Aspleniaceae</i>	+	+	+
8	<i>Asplenium theciferum</i> (HBK.)Mett.	<i>Aspleniaceae</i>	+	-	-
9	<i>Cyrtorchis arcuata</i> (Lindl.) Schltr.	<i>Orchidaceae</i>	-	+	+
10	<i>Cyrtorchis erythraeae</i> (Rolfe) Schltr	<i>Orchidaceae</i>	-	+	-
11	<i>Diaphananthe tenuicalcar</i> Summerh.	<i>Orchidaceae</i>	-	-	+
12	<i>Drynaria volkensis</i> Hieron.	<i>Polypodiaceae</i>	+	+	+
13	<i>Lepisorus excavatus</i> (Willd.) Ching	<i>Polypodiaceae</i>	-	+	+
14	<i>Lepisorus schraderi</i> (Mett.) Ching	<i>Polypodiaceae</i>	+	-	+
15	<i>Loxogramme abyssinica</i> (Baker) M.G.Price	<i>Polypodiaceae</i>	-	+	+
16	<i>Microcoelia globulosa</i> (Hochst.) L.Jonsson	<i>Orchidaceae</i>	-	-	+
17	<i>Peperomia abyssinica</i> Miq.	<i>Piperaceae</i>	+	+	+
18	<i>Peperomia tetraphylla</i> (Forster) Hook. & Arn.	<i>Piperaceae</i>	-	+	+
Total			7	10	12

Base = ground to diameter at breast height (DBH), trunk = DBH to the first branch, and Canopy = first branch to the tip of the tree.

Diameter at breast height (DBH) of phorophytes and diversity of vascular epiphytes: The data collected from phorophytes with different sizes and corresponding number of epiphyte species. Thus, the distribution of vascular epiphyte species along vertical gradient of microclimate condition on phorophytes sections showed that a large concentration of epiphytes occurred at canopy and decreasing through the basal section of the phorophytes. That is, tree canopy is a more specious section while basal part of phorophyte is lower in epiphyte species richness. This indicates that more epiphyte species in the study area may be sun-loving or dry tolerant whereas the shade tolerant or moisture loving species are less in number. Similar results have been reported by different authors that, there is positive relationship between phorophytes and number of epiphyte species (number of epiphyte species increase with increasing sizes of phorophytes). According to Hietz-Seifert U. et al, the number of epiphytic species per tree was strongly correlated with tree size. The tree size relates to several factors that contribute to epiphyte establishment and larger trees are likely, on average, to be older, allowing more time to capture spores. A significant positive relationship was found from the association between trunk size and epiphyte. In the study area, the vertical distribution of epiphytes sharply declined from 12, 10 and 7 species on canopy, trunk and basal sections respectively.

The vertical distribution of epiphytic biomass can reveal microhabitats at various locations on the phorophytes (Hsu et al., 2002). It is mostly determined by light and water availability (Steege & Cornelissen, 1989). Going from the top of the canopy down to the forest floor, several climatological factors change. Generally, air humidity and vapor pressure increases while wind speed, average temperature and amount of light decrease (Parker, 1995). Epiphytes that prefer the upper portions of their host tree canopies may have higher light requirements than those in the lower parts of the canopies, or they may be more tolerant of lower humidity and/or greater degree of drought stress (Hsu et al., 2002). Mesophytes (moisture-loving) epiphytes are confined to the basal portion of phorophytes. However, this lower tree trunk has been reported to contain the lowest epiphyte diversity (Mehltreter et al., 2005). Most epiphyte studies do not specify the species

richness for this host zone. Phorophyte characteristics, such as tree size, age and crown architecture, also contribute to habitat heterogeneity and create vertical stratification, which promotes epiphyte diversity (Bennet, 1986).

### **4.1.3 Host specificity of vascular epiphytes**

Most vascular epiphytic species in Chilimo Forest were not host specific. Most of vascular epiphyte is registered from two or more host tree species. Sixteen species (88.89%) of the epiphyte in the study area were recorded from two or more phorophyte species but, two epiphyte species (*Aerangis brachycarpa* and *Peperomia tetraphylla*) which is 11.11 % were recorded from a single phorophyte species. This is an agree with Tesfa Alemayehu, in his study at Hareenna Forest of Bale, Ethiopia and Abuna Tafa, in his study at Yayu forest of southwest Oromia, Ethiopia reported that (90.9 % and 86.1%), respectively were not host specific. According to Tesfa and Abuna, only two species (9.1 %) and five species (13.9%) were recorded from specific host trees respectively. According to Benzing D.H., epiphytes occur on a number of different phorophytes, but with variable frequency.

Although, all phorophytes are not equally suitable for distribution of vascular epiphytes. In most phorophytes species are important to vascular epiphytes but others are less host contain vascular epiphytes. This may base on bark characteristics (rough), branch inclination and large size of host trees. This due to larger trees are essential determining of epiphyte diversity than small trees, because large trees are high water holding capacity, accumulation of nutrient and germination of seed. In general, some phorophytes harbored large number of epiphyte species, while many epiphyte species in turn are found distributed on large number of host plants. Some of the most specious phorophytes hosting 12 to 16 vascular epiphyte species are *Cordia africana* Lam. harboring 12 species; *Olea welwitschii* holds 14 species and *Acacia abyssinica* 16 species (Table 5)

**Table 5: Number of vascular epiphyte species existing on each sampled phorophyte.**

No.	Phorophyte species	Number of epiphyte species
1	<i>Ekebergia capensis</i> Sparrm.	6
2	<i>Ficus mucoso</i> Ficalho.	2
3	<i>Ficus vallis-choudae</i> Del.	10
4	<i>Antiaris toxicaria</i> Lesch.	5
5	<i>Ficus thonningii</i> Blume.	3
6	<i>Cordia africana</i> Lam.	12
7	<i>Albizia grandibracteata</i> Taub.	8
8	<i>Albizia schimperiana</i> Oliv.	2
9	<i>Millettia ferruginea</i> (Hochst.) Bak.	4
10	<i>Acacia abyssinica</i> Hochst.ex Benth.	16
11	<i>Croton macrostachyus</i> Del.	3
12	<i>Vernonia amygdalina</i> Del.	4
13	<i>Spathodea campanulata</i> P.Beauv.	2
14	<i>Bersama abyssinica</i> Fresen.	3
15	<i>Olea welwitschii</i> (Knobl.)Gilg & Schellenb.	14
16	<i>Prunus africanum</i> (Hook.f.) Kalkam.	6
17	<i>Nuxia congesta</i> R. Bres. Fresen.	3

The study indicated that two vascular epiphyte species are apparently host specific. However, all the two host specific species also appeared only in a single plot. The host specificity reported by the result may not be attributed to a single factor. Thus, they may not be host specific; instead, it could be due to the characteristic of phorophyte species, the epiphyte species may be newly emerged to the site, they may be the member of those species disappearing by the effect of disturbance on their habitat or there may be rare species that cannot be found everywhere.

Different authors reported various factors affecting the occurrence of vascular epiphyte species on their host plants. Accordingly, Laube (2006) reported that each potential host tree species offers a different set of architectural traits: branch angles, diameters, chemical and morphological bark characteristics, and a microclimatic regime which suggests that there could be rather unique epiphyte assemblages on each host tree species. The occurrence of different epiphyte species on different tree fern for example, is related with the tree fern morphology and the age of the tree fern trunk (Bittner and Trejos, 1997). The result that no orchids are growing on tree ferns is possibly due to chemical substances found in the trunk of tree ferns. Often trees with a rough bark are, for example, preferred hosts (Hietz, 1999) rough barks help the establishment and germination of epiphytes seed. Older parts of the trunks also have more possibilities for colonization from epiphytes (Bergstrom and Carter, 2008). Thus, it was suggested that true host specificity of epiphytes is rare, but host species can affect epiphytes at least to the extent that some trees have suitable substrates and are densely colonized, whereas others are less suitable with only sparse epiphyte growth on them (Hietz,2005).

#### **4.1.4 Bark texture of phorophytes and vascular epiphytes**

Bark texture of host plants were analysis by based on observation. The bark texture of phorophyte was classified into two types, these are rough and smooth. Most of the recorded phorophyte species (80%) possessed rough bark texture while 20% of them were smooth barked (Table 6). Among species of vascular epiphytes recorded from sampled areas of the study, almost all species 17(94.44%) were registered from rough barked phorophytes. According to Munoz A.A. et al, smoother texture of host bark could explain the lower epiphytic cover compared with rough

textures of other tree species in the forest. The more textured the bark, the more substrate recesses available to catch seeds and accumulate nutrients. Such pockets and fissures harbor humus and retain moisture. Rough bark may characterize the colonization of epiphyte species in a host trees. Age-related changes in bark structure and humus accumulation in the canopy create further diversification of the arboreal habitat. In general; almost all smooth barks were not comfortable to diversity of vascular epiphytes. Bark substrate characteristics also are of primary importance to seedling recruitment. These include bark texture, whether the bark is stable or exfoliating, its water-holding capacity, porosity, and bark chemistry (pH, growth inhibiting exudates, and/or leachates. Phorophyte characteristics such as bark texture, branch inclination (Increased inclination is associated with reduced water, light, and nutrient accumulation), stand age, cardinal orientation and presence or absence of like latex, resins have factors that influence diversity of vascular epiphytes in the study area. The favorable bark characteristics, such as high water content and high water retention capacity are essential for more diverse and more abundant of epiphytes on host species. Bark thickness and water retention capacity is strongly correlated. Different report revealed that the nature of bark texture of phorophytes in general, determines the number of epiphytes that germinate and grow on the host plants. Bark roughness may further influence the amount and species of epiphytes that grow in a given part of the forest.

**Table 6: List of vascular epiphyte species existing at different bark textures of phorophytes.**

No	Epiphyte species	Bark texture of host species	
		Rough	Smooth
1	<i>Achyranthus aspera L.</i>	+	-
2	<i>Adenostema mauritianum DC.</i>	+	+
3	<i>Aerangis brachycarpa (A.Rich.)Th.Dur. &amp; Schinz</i>	+	-
4	<i>Aerangis thomsonii (Rolfe) Schltr</i>	+	+
5	<i>Arthropteris monocarpa (Cordem.) C.Chr.</i>	+	+
6	<i>Asplenium aethiopicum (Burm.f.) Bech.</i>	+	+
7	<i>Asplenium sandersonii Hook.</i>	+	+

8	<i>Asplenium theciferum</i> (HBK.)Mett.	+	+
9	<i>Cyrtorchis arcuata</i> (Lindl.) Schltr.	+	+
10	<i>Cyrtorchis erythraeae</i> (Rolfe) Schltr	+	+
11	<i>Diaphananthe tenuicalcar</i> Summerh.	+	-
12	<i>Drynaria volkensii</i> Hieron.	+	-
13	<i>Lepisorus excavatus</i> (Willd.) Ching	+	+
14	<i>Lepisorus schraderi</i> (Mett.) Ching	-	+
15	<i>Loxogramme abyssinica</i> (Baker) M.G.Price	+	+
16	<i>Microcoelia globulosa</i> (Hochst.) L.Jonsson	+	-
17	<i>Peperomia abyssinica</i> Miq.	+	+
18	<i>Peperomia tetraphylla</i> (Forster) Hook.& Arn.	+	+
Total		17	13

Effects of phorophytes on the composition of the epiphyte community were also related to differences in bark chemistry of the hosts (Hietz, 1999). According to Johansson (1974), the structural characteristics of trees such as bark texture, presence or absence of like latex, resins, or inclination of branches have influence on epiphyte settlement. Epiphytes are more diverse and more abundant on host species with supposedly favorable bark characteristics, such as high water content and high water retention capacity. Bark thickness and water retention capacity are strongly correlated (Mheltreter et al., 2005). According to Hietz P., trees with a rough bark are preferred hosts. Older host plants also have more possibilities for colonization from epiphytes. Laube S. and Zotz G. reported that, each potential host tree species offers a different set of architectural traits: branch angles, diameters, chemical and morphological bark characteristics, and a microclimatic regime which suggests that there could be rather unique epiphyte assemblages on each host tree species.

#### 4.1.5 Altitudinal distribution of vascular epiphyte

Height above sea level is another factor that strongly influences the occurrence of epiphytes. The sampled plots in the study area were laid between 2000 m-3288 m altitudinal ranges. High diversity of vascular epiphytes found around height of 2300 m-2750 m a.s.l. (medium elevation). Above 2750 m, there is a slight oscillation of distribution with general decreasing pattern of number of epiphyte along altitudinal gradient (higher number of species in lower altitude and lower number in higher altitude). However, the numbers of vascular epiphyte species existing at the extreme lowest and highest altitudes were equivalent, both with the least number of epiphytes. This shows that there may be optimum altitudinal range for epiphytic distribution. Some species were found distributed throughout the altitudinal gradient where as some were restricted to the lowest altitudinal range and higher altitudinal range of the sampled area. Some species such as *Asplenium sandersonii* Hook, *Drynaria volkensii*, *Peperomia abyssinica* Miq and *Arthropteris monocarpa* were found distributed throughout the altitudinal gradient. Some others, *Aerangis thomsonii*, *Cyrtorchis arcuata*, *Lepisorus schraderi* and *Cyrtorchis erythraeae* were restricted to the lowest altitudinal range of the sampled area. The third groups *Asplenium theciferum*, *Adenostema mauritianum*, *Loxogramme abyssinica* and *Peperomia tetraphylla* were found to be at higher altitude.

The result shows that altitude may be one of the important environmental factors that govern species distribution. The number of epiphyte species varied considerably between forest types and a typical decrease of species richness with altitude was observed in the area of 'Reserva Biologica Sanfrancisco' in southern Ecuador (Bussmann, 2001). It is because the forests change in structure and tree species composition at increasing altitude, providing different quantities and qualities of substrate to epiphytes. Based on climatic parallels with latitude, species richness was thought to decrease with increasing elevation (Stevens, 1992). The likelihood of the elevation ranges of many species is higher at mid-elevations than for the lower and higher elevations Cardelús et al. (2006).

Generally based on the above result, altitude is one of the important environmental factors that govern species distribution. Height above the ground and altitude above sea level are parameters always found to be important for epiphyte occurrence. Also another finding by Biedinger N. et al,

Average number of vascular epiphytes on a single phorophyte decreases with increasing altitude. Not only this, but the study by show that, in tropical rain forests, the vertical stratification with in canopy of epiphytes is correlated with gradients in humidity and the moisture availability of microhabitats that affects epiphyte distribution on individual phorophytes. Altitude is one of the environmental factors that measure diversity of vascular epiphytes species richness was thought to decrease with increasing elevation.

#### **4.1.6 Phorophyte species retained in agricultural matrix**

This is to document the importance of scattered isolated remnant trees in agricultural matrices for the survival of vascular epiphytes after forest clearance. Six phorophyte species belonging to six families were found existing in agricultural matrices (Table 7). Among those phorophytes inhabiting agricultural matrix, *Acacia abyssinica* and *Nuxia congesta* were the most frequently appearing shade trees together with their abundant and they harbor larger number of vascular epiphyte species. Under shade trees showed that they have been supporting large number of vascular epiphyte species. Owners of the farm land from where the host shade trees were sampled informally interviewed for the reason why they selectively allowed the remnant shade trees in their farm field and garden to remain uncut. They responded that the important characteristics that isolated remnant trees in agriculture field used both for increase soil fertility and also have some other domestic values (for shade that used as house especially during eating meal and tired). The most popular phorophyte species found in agricultural matrices are *Acacia abyssinica* (Sondi by local name).

**Table 7: Lists of phorophyte species in Agricultural matrices.**

<b>No.</b>	<b>Phorophyte species</b>	<b>Families</b>	<b>Local Name</b>
1	<i>Acacia abyssinica Hochst.ex Benth.</i>	<i>Fabaceae</i>	<i>Sondi</i>
2	<i>Olea welwitschii (Knobl.)Gilg&amp;Schellenb.</i>	<i>Oleaceae</i>	<i>Baha</i>
3	<i>Vernonia amygdalina Del.</i>	<i>Asteraceae</i>	<i>Dhebicha</i>
4	<i>Cordia africana Lam.</i>	<i>Boraginaceae</i>	<i>Wadesa</i>
5	<i>Croton macrostachyus Del.</i>	<i>Euphorbiaceae</i>	<i>Bakanisa</i>
6	<i>Nuxia congesta R. Bres. Fresen.</i>	<i>Loganiaceae</i>	<i>Qayisa</i>

Establishment of epiphyte communities will enhance energy capture, moisture capture and retention, and biotic community diversity in restoration plantings, continuing the process of returning agricultural pasture to a complex forest (Cummings et al., 2006). Thus, isolated trees constitute the smallest possible forest fragment (Williams-Linera et al., 1995) exposed to multiple (maximum)physical edge effects. This phorophytes is ecologically, socially, economically and culturally very important for the inhabitants residing nearby who are mostly dependent on forest product to make their living. Loss of such a forest and the various threatened species would have great implications for the environment, biodiversity and socio-economic setup of the communities.

## 4.2 DISCUSSION

The result shows that altitude may be one of the important environmental factors that govern species distribution. The number of epiphyte species varied considerably between forest types and a typical decrease of species richness with altitude was observed in the area of 'Reserva Biologica Sanfrancisco' in southern Ecuador (Bussmann, 2001). It is because the forests change in structure and tree species composition at increasing altitude, providing different quantities and qualities of substrate to epiphytes. Based on climatic parallels with latitude, species richness was thought to decrease with increasing elevation (Stevens, 1992). The likelihood of the elevation ranges of many species is higher at mid-elevations than for the lower and higher elevations Cardelús et al. (2006).

Vascular epiphytes as a study group are particularly appropriate for rapid baseline surveys because they are relatively small (allowing for high species richness fairly small plots), physiognomically distinctive (making them easy to survey), have high species numbers (allowing for quantitative analyses) and are comparatively easy to identify. The high diversity of vascular epiphytes is one of the most striking characteristics of tropical rain forests and humid montane forests. These organisms are of major significance for a great number of reasons: 1) they contribute substantially to ecosystem diversity, production and nutrient cycles; 2) they provide appreciable nutrient and energy sources to associated organisms such as pollinating birds, bats and mutualistic ants; 3) they act as global indicators for climate change; 4) they are of major horticultural and, hence, of economic value; and 5) they create an arena for observational and experimental studies on a wide range of biological questions including diversity patterns, systematics, plant interactions, ecophysiology and mechanisms of evolutionary change.

The diversity of vascular epiphyte was influenced by phorophyte and diversity increases from base to canopy. Increasing altitudes, decrease diversity of epiphyte due to moisture and go from lower altitude to higher altitude sparsely of forest increases. The main reason for decrease in number of epiphytes towards higher altitudes could be attributed to the low density of the forest trees, which resulted in the availability of suitable host trees (phorophyte) on which the epiphytes grew. As a result of this condition of the forest at higher altitudes, the species richness and abundance of

associated epiphytes was limited. Epiphytes are extremely important element of the flora (they represent about 10% of all plant species globally) are responsible for much of the biotic diversity that makes humid tropical forests the most complex of all worlds terrestrial ecosystems (Madison 1977; Benzing 1987). There is growing recognition that vascular epiphytes are increasingly threatened. The main causes for epiphyte extirpation and population reduction are over collecting of horticultural valuable species for commercial purposes and habitat loss due to deforestation and land use changes. Because epiphytes, especially orchids, may occupy very narrow ranges and often occur in regions of rapid development, many tropical plant species listed as “endangered” by conservationists are epiphytes.

The above results indicate that diameter size, bark texture of host tree, horizontal stems and branches had the greatest influence on diversity of epiphyte species in the study area. A very high accumulation of humus and thus, the ability to hold water for long time, creates a suitable condition for seedling attachment and growth of vascular epiphytes. Establishment of epiphyte communities will enhance energy capture, moisture capture and retention, and biotic community diversity in restoration plantings, continuing the process of returning agricultural pasture to a complex forest (Cummings et al., 2006). About 18 species of vascular epiphyte plants were recorded from sampled area of Chilimo forest. The epiphytes categorized under 7 families (Table 3). The result indicated that Orchidaceae contributed more species followed by Polypodiaceae.

The number of vascular epiphyte species recorded from Chilimo Forest is very low compared to the number reported from different tropical forests. Barthlott et al. (2001) reported 178 and 81 epiphytic species from primary and secondary rainforests, respectively from Venezuela. Bussmann et al. (2000) reported 223 species from Estacion Cientifica Forest, San Francisco. This could be related to the forest disturbances caused by human activities. The deforestation activities performed by local people (for agriculture, fuel, and timber) and logging activities were some of the disturbances observed in Chilimo Forest. The disturbance activities mentioned above resulted in the removal of forest trees on which the epiphytes could have been hosted, thus resulting in the decrease of epiphytic species diversity.

## **5 CONCLUSIONS AND RECOMMENDATION**

### **5.1 Conclusion**

This study was envisioned to investigate diversity and distribution of vascular epiphytes in Chilimo forests and within this study, total of 18 vascular epiphyte species was recorded which belong to 7 families were collected and identified. Orchidaceae is the most dominant and species rich family this may related to its characteristics high stress tolerance and its adaptive traits.

When compared with other tropical forest, species diversity of vascular epiphytes in the study area is low. This may relate to environmental factors like forest disturbance, bark texture of host, altitude and DBH that measure the diversity of vascular epiphytes. The result of this study demonstrated that epiphyte life tied to host plants that provide them mechanical support. The number of species is relatively higher on large tree and it decline as the height and size of host decrease. The distribution of epiphyte has shown an increasing trend from the stem to crown of phorophyte but decreasing from lower altitudes to higher altitude. Tree bark texture also influence the number of epiphyte species, in that rough texture support more epiphytes than smooth ones. The host size has an effect on number of epiphyte species; the large size of phorophytes, the more number of epiphyte species on it.

Forests are primary sources of diverse resources to local people whereas epiphytes are inconspicuous, rarely noticed, and less interest attracting components of the forest. Vascular epiphytes are one of the most important components of forest ecosystems; they are home to many arthropods and birds. Reduction of epiphytic species due to human activities may have indirect effects in agro ecosystems through its influence on pollination and other ecosystem services. Therefore, all the local community whose direct impact of disturbance may face should made awareness and practice sustainable use of natural resource and conservation management. Not only the local community but the woreda should equally worry about the disturbances of the natural resource.

## 5.2 Recommendation

This finding will have a significant motivational role for researchers in Ethiopia, who always have been restricted to study about diversity of vascular epiphytes. It suggests that floristic expression of vascular epiphytes in tropical forests is considerable; even in the forests strongly influenced by human interference. Vascular epiphytes are the main components of forest eco system, but are understudied. They provide substrate dwelling animals, indicator for conservation initials, nutrient and water cycle, and maintenance of moisture of the environment. They are also very sensitive to disturbances compared to other vegetation communities. Though this vegetation community plays an important role in many aspects of forest ecology, few studies is were carried out on them past decades. The lack of attention may be related to the lack of immediate and tangible products compared to woody trees. The increasing human interference is becoming a big challenge to Chilimo Forest in general and vascular epiphytes in particular. Therefore, I recommended that:

- Since epiphytes are vulnerable to any disturbances causing deforestation; they are good indicators of changes in forest structure. Therefore, any reforestation or in situ conservation should consider the establishment of vascular epiphytes in newly growing forest.
- The woreda should design awareness creation programmes so that the local people in the area should bring about attitudinal change about protection and conservation of the forest properly.
- The Local human community is highly dependent on the forest for fuel, charcoal and timber production. During my field study I observed the struggle of some local people to cut timber trees and to clear natural forest for the preparation of new farmland. Thus all communities and stakeholders in Dendi Woreda should be take responsibility.
- Any conservation measure to conserve the forest community should primarily consider the epiphyte community, as they are very sensitive to disturbances.
- The current study is the first attempt to study vascular epiphyte in Chilimo forest. Therefore, ecologists, biologists and research centers existing in the country should pay attention to study the epiphyte community, which are one of the components of the forest.

## 6 REFERENCES

- Abuna Tafa (2010). Diversity of Vascular Epiphytes along Disturbance Gradient in Yayu Forest, Southwest Oromia, Ethiopia. M.Sc. Thesis, Addis Ababa University, Addis Ababa.
- Bader, M. (1999). A study on the distribution of vascular epiphytes in a secondary cloud forest, Central cordillera, Colombia. MSc. thesis, Wageningen University, Colombia.
- Barthlott, W., Schdmit-Neuerburg, V., Nieder, J. and Engwald, S. (2001). Diversity and abundance of vascular epiphytes: A comparison of secondary vegetation and primary montane rainforest in the Venezuelan Andes. *Plant Ecol.* **152**: 145–156.
- Bennet, B.C. (1986). Patchiness, diversity, and abundance relationships of vascular epiphytes. *Selbyana* **9**: 70–75.
- Bennet, B.C. (1992). Uses of epiphytes Lianas and Parasites by the Shuae people of Amazonian Ecuador. *Selbayana* **13**:99-144.
- Benzing, D. H. (1987). Vascular epiphytism: taxonomic participation and adaptive diversity. *Ann. Miss. Botan. Gard.* **74 (2)**: 183-204.
- Benzing, D.H. (1990). Vascular Epiphytes: General Biology and Related Biota. Cambridge University Press, Cambridge.
- Benzing, D.H. (1998). Vulnerabilities of tropical forests to climate change. The significance of resident epiphytes. *Clim. Change* **39**: 519–540.
- Benzing, D.H. (2004). Vascular epiphytes. In: Forest Canopies, pp. 175–211 (Lowman, M.D. and Rinker, H.B., eds). Springer Verlag, Berlin.
- Bergstrom, J. B. and Carter, R. (2008). Host-tree selection by an epiphytic orchid, *Epidendrum Magnoliae*, in an Inland Hardwood Hammock in Georgia. *Southeas. Natura.* **7 (4)**:571-580
- Biedinger, N. and Fischer, E. (1996). Epiphytic vegetation and ecology in central Africa forests. *Rwanda, Zaire. Ecotro.* **2**:121-142.
- Burns, C. K. and Dawson, J. (2005). Patterns in the diversity and distribution of epiphytes and Vines in a New Zealand forest. Victoria University, New Zealand. *Austral Ecol.* **30**: 883-891.

- Busmann, R.W., Werner, F. and Schaff, A. (2000). Epiphyte diversity in a tropical mountain ecosystem: the example of Estacion Cientifica San Francisco, Ecuador University at Bayreuth.
- Callaway, R.M., Reinhart, K.O., Tucker, S.C. and Pennings, S.C. (2001). Effects of epiphytic Lichen on host preference of the vascular epiphyte *Tillandsia usneoides*; *oikos* **94**:433- 44.
- Colwell, R. K. and Watkins, J. E. (2006). Vascular epiphyte distribution patterns: explaining the mid-elevation richness peak. *J. Ecol.* **94**: 144–156.
- Cowling, S. A., Maslin, M. A. and Sykes, M. T. (2001). Pale vegetation simulations of Lowland Amazonia and implications of Neotropical allopatry and speciation. *Quatern. Resear.* **55**: 140–149. Cardelús, L. C.,
- Coxson, D.S. and Nadkarni, N.M. (1995). Ecological roles of epiphytes in nutrient cycles of forest ecosystems. In: *Forest Canopies*, pp. 495–543 (Lowman, M.D. and Nadkarni, N.M., eds.). Academic Press, San Diego.
- Cummings, J., Martin, M., and Rogers, A. (2006). Quantifying the abundance of four large epiphytic fern species in remnant complex notophyll vine forest on the Atherton Tableland, North Queensland, Australia. *Cunninghamia*. **9** (4): 521–527.
- Elias, N. (2005). Road edge effect on forest canopy structure and epiphyte biodiversity in a tropical mountainous rainforest Nyungwe National Park, Rwanda. MSc. thesis, International Institute for Geo-Information Science and Earth Observation. Netherlands.
- Ewel, J. and Hiremath, J. (2005). Plant–plant interactions in tropical forests. Cambridge University Press.
- FAO (1993). Forest resources assessment *Tropical countries*. FAO forestry paper 112, FAO, Rome.
- Fattland, B. (1996). Vascular epiphytes of far North Queensland. Pp.1-6.
- Gentry, A. H., and Dodson, C. H. (1987). Diversity and biogeography of Neotropical vascular Epiphytes. *Ann. Miss. Botan. Gard.* **74** (2):205–233.
- Gravendeel, B., Smithson, A., Slik, F. J. W. and Schuiteman, A. (2004). Epiphytism and Pollinator specialization: drivers for orchid diversity? *Phil. Trans. R. Soc. Lond.* **359**: 1523-1535.
- Gradstein, S. R. and Nadkarni, N. M. (2009). A protocol for sampling vascular epiphyte richness

- and abundance. *J. Trop. Ecol.* **25**:107-121
- Heywood, V.H. (1993). Flowering plants of the world. Oxford University Press. New York.
- Hietz, P. (1999). Diversity and conservation of epiphyte in a changing environment URL: ©1999 IUPAC.
- Hsu, C., Horng, F. and Kuo, C. (2002). Epiphyte biomass and nutrient capital of a moist Subtropical forest in north-eastern Taiwan. *J. Trop. Ecol.* **18**:659–670.
- Hylander, K. and Nemomissa S. (2009). Home garden coffee as a repository of epiphyte Biodiversity in Ethiopia. *Front Ecol. Environ.* **7**:1890.
- Ingram, S. W., Ferrell-Ingram, K. and Nadkarni, N. M. (1996). Floristic composition of vascular epiphytes in a Neotropical cloud forest. Monteverde, Costa Rica. *Selbyana*. **17**: 88- 103.
- Johannsson, D. H. (1974). Ecology of vascular epiphytes in West African rain forest. Acra. Nigeria. *Phytogeogr. Suec.* **59**: 1-136
- Kernan, C. and Fower, N. (1995). Differential substrate use by epiphyte in Corcovado National Park, Costa Rica. *Journal of Ecology* **83**: 63-73.
- Kress, W.J. (1989). The systematic distribution of vascular epiphytes. In: Vascular Plants As Epiphytes: *Evolution and Ecophysiology*, pp. 234–261 (Lüttge, U., ed.). Ecological Studies 76, Springer-Verlag, Berlin, New York
- Kreft, H., Koster, N., Kuiper, Laman, T. (1995). Safety recommendations for climbing rainforest trees with 'single rope technique'. *Biotrop.* **27**:406-10.
- Laube, S. (2006). Long-term changes of vascular epiphyte assemblages in the tropical lowlands of Panama. Dissertation, University of Kaiserslautern, Germany. 1-77 pp.
- Lowman, M. D. (2001). Plants in the forest canopy: Some reflections on current research and future direction. *Pl. Ecol.* **153**: 39–50.
- Lüttge, U. (1997). Physiological study of tropical plants, Berlin, New York, Springer.
- Madison, M. (1977) vascular epiphytes: their systematic occurrence and salient features. *Selbyana* **2**: 1-13.
- Mehltreter, K., Flores, A. and Garcia, G. J. (2005). Host preferences of low-trunk vascular Epiphytes in a cloud forest of Veracruz, Mexico. *J. Trop. Ecol.* **21**:651–660.

- Melaku Bekele. (2003). Forest Property Right, the role of the state and institutional exigency: The Ethiopian experience. Doctoral Thesis, Swedish University of Science, Uppsala, Sweden.
- Mojiol, A. R., Jitnu, A. M. A., Adella, A., Ganang, G. M., Nasly, N. (2009). Vascular epiphytes diversity at Pusat Sejadi, Kawang forest reserve, Sabah, Malaysia. *J. Sust. develo.* **2(1)**:121-127.
- Munoz, A.A., Chacion, P., Perez, F., Barnet, E.S. and Armesto, J.J. (2003). Diversity and Host tree preference of vascular epiphytes and vines in Temperature Rain Forest in Southern Chile. *Australian Journal of Botany* **51(4)**: 381- 391.
- Myers, N. (1988). Biodiversity. National Academy press. Washington. 28-35 pp.
- Nadkarni, N. M. (1984). Epiphyte biomass and nutrient capital of a Neotropical Elfin forest. *Biotro*.**16**: 249–256.
- Nadkarni, N.M (2000). Colonization of stripped branch surfaces by epiphytes in a lower montane cloud forest. *Monteverde, Costa Rica. Biotro*.**32**:358-363.
- Nieder, J., and Michaloud, G. (2001). Epiphytes and their Contribution to Canopy Diversity. *Plant Ecology***153**: 51-63.
- Padmawathe, R., Qureshi, Q. and Rawat, G. S. (2004). Effects of selective logging on vascular epiphyte diversity in a moist lowland forest of Eastern Himalaya, India. *Biol.Conserv.* **119**: 81– 92.
- Raven, P. H, Evert, R.F .and Eichhom, S.E. (1992).Biology of Plants. Worth Publisher, New York.
- Reynolds, A. (2003). Epiphytes of the tropics. Miami University. Pre-course presentation of topic, Costa Rica. 1-6 pp.
- Schubert, S. T. (1990). Epiphytic bromeliads on Florida trees. Plant pathology circular.333 pp.
- Schnitzer, A. and Carson, H. (2000).Tree fall gap and maintenance of species diversity in a tropical forest.*Ecology***82**: 913- 919.
- Sebsebe Demissew, Cribb, P., and Rasmussen, F (2004).Field guide to Ethiopian orchid. 1300 pp.

- Sillette, S. C. (1999). Tree crown structure and vascular epiphytes distribution in Sequoia Sempervirens rainforest canopies. *Selbyana*.**20** (1): 76–9.
- Smith, Robert L. (1992). Elements of ecology (3<sup>rd</sup> Ed.)Harper Collins publisher inc.U.S.A.Pp 258-529.
- Sporn S. G, Bos M. M, and Gradstein S. R (2007). Is productivity of cacao impeded by epiphytes? An experimental approach.*Agr.Ecosyst.Environ*.**122**: 490-93.
- Stevens, G. C. (1992). The elevational gradient in altitudinal range: an extension Rapaport's latitudinal rule to altitude. *Amer.Natur*. **140**: 893-911.
- Sugden A. M. and. Robins J. R. (1979). Aspects of the ecology of vascular epiphytes in Colombian cloud forests, I. the distribution of epiphytic flora.*Biotro*.**11(3)**: 173-188.
- Ter Steege, H. and J. H. C. Cornelissen.(1989). Distribution and ecology of vascular epiphytes in lowland rainforest of Guyana.*Biotro*.**21(4)**: 331–339.
- Tesfa Alemayehu (2006). Diversity and Ecology of Vascular Epiphytes in Harenna Afromontane Forest, Bale, Ethiopia. M.Sc. Thesis, Addis Ababa University, Addis Ababa.
- UNEP (1995).Global Biodiversity Assessment. Cambridge University Press, Cambridge
- Walter (1971).Ecology of tropical and subtropical vegetation. In: Padmawathe, R., Qureshi, Q. and Rawat, G. S. (2004). Effects of selective logging on vascular epiphyte diversity in a moist lowland forest of Eastern Himalaya, India. *Biol. Conserv*. **119**: 81–92.
- Whittaker R. H (1972). Evaluation and measurement of species diversity. *Evol. Biol*.**21**:213 - 251.
- Williams-Linera, G., Sosa V. and Platas, T. (1995).The fate of epiphytic orchids after fragmentation of a Mexican cloud forest.*Selbyana*.**16** (1): 36-40. Wolf, J. H. D., W., Nieder, J. and Barthlott, W. (2004).Diversity and biogeography of vascular epiphytes in Western Amazonia. Yasuni', Ecuador. *J. Biogeogr*. **31**: 1463–1476
- Zoty. (1997). Substrate use of three epiphytic bromeliads.*Ecogr*.**20**: 264-70 pp.
- Zotz, G., Laube, S. and Schmidt, G. (2005).Long-term population dynamics of the epiphytic bromeliad. *Werauhia sanguinolenta*.*Ecogr*.**28**: 806-814.

## 7 APPENDICES

**Appendix 1:** List of phorophyte species recorded from Chilimo Forest.

No.	Phorophyte species	Family	Vernacular Name
1	<i>Ekebergia capensis</i> Sparrm.	Meliaceae	Sombo
2	<i>Ficus mucuso</i> Ficalho.	Moraceae	Harbu (small fruit)
3	<i>Ficus vallis-choudae</i> Del.	Moraceae	Harbu (big fruit)
4	<i>Antiaris toxicaria</i> Lesch.	Moraceae	Dangi
5	<i>Ficus thonningii</i> Blume.	Moraceae	Dambi
6	<i>Cordia africana</i> Lam.	Boraginaceae	Wadesa
7	<i>Albizia grandibracteata</i> Taub.	Fabaceae	Alale
8	<i>Albizia schimperiana</i> Oliv.	Fabaceae	Bobessa
9	<i>Millettia ferruginea</i> (Hochst.) Bak.	Fabaceae	Sotallo
10	<i>Acacia abyssinica</i> Hochst.ex Benth.	Fabaceae	Sondi
11	<i>Croton macrostachyus</i> Del.	Euphorbiaceae	Bakanisa
12	<i>Vernonia amygdalina</i> Del.	Asteraceae	Dhebicha
13	<i>Spathodea campanulata</i> P.Beauv.	Bignoniaceae	Muka dire-D
14	<i>Bersama abyssinica</i> Fresen.	Melanthaceae	Lolchisa
15	<i>Olea welwitschii</i> (Knobl.)Gilg & Schellenb.	Oleaceae	Baha
16	<i>Prunus africanum</i> (Hook.f.) Kalkam.	Rosaceae	Homi
17	<i>Nuxia congesta</i> R. Bres. Fresen.	Loganiaceae	Qayisa

**Appendix 2:** List of Vertical distributions of vascular epiphytes on host Zones.

No.	Epiphyte species	Family	Phorophyte Zone		
			Basal	Trunk	Canopy
1	<i>Achyranthus aspera</i> L.	<i>Amaranthaceae</i>	-	+	-
2	<i>Adenostema mauritianum</i> DC.	<i>Asteraceae</i>	-	-	+
3	<i>Aerangis brachycarpa</i> (A.Rich.)Th.Dur.&Schinz	<i>Orchidaceae</i>	-	+	-
4	<i>Aerangis thomsonii</i> (Rolfe) Schltr	<i>Orchidaceae</i>	+	-	-
5	<i>Arthropteris monocarpa</i> (Cordem.) C.Chr.	<i>Oleandraceae</i>	+	-	-
6	<i>Asplenium aethiopicum</i> (Burm.f.) Bech.	<i>Aspleniaceae</i>	-	-	+
7	<i>Asplenium sandersonii</i> Hook.	<i>Aspleniaceae</i>	+	+	+
8	<i>Asplenium theciferum</i> (HBK.)Mett.	<i>Aspleniaceae</i>	+	-	-
9	<i>Cyrtorchis arcuata</i> (Lindl.) Schltr.	<i>Orchidaceae</i>	-	+	+
10	<i>Cyrtorchis erythraeae</i> (Rolfe) Schltr	<i>Orchidaceae</i>	-	+	-
11	<i>Diaphananthe tenuicalcar</i> Summerh.	<i>Orchidaceae</i>	-	-	+
12	<i>Drynaria volkensis</i> Hieron.	<i>Polypodiaceae</i>	+	+	+
13	<i>Lepisorus excavatus</i> (Willd.) Ching	<i>Polypodiaceae</i>	-	+	+
14	<i>Lepisorus schraderi</i> (Mett.) Ching	<i>Polypodiaceae</i>	+	-	+
15	<i>Loxogramme abyssinica</i> (Baker) M.G.Price	<i>Polypodiaceae</i>	-	+	+
16	<i>Microcoelia globulosa</i> (Hochst.) L.Jonsson	<i>Orchidaceae</i>	-	-	+
17	<i>Peperomia abyssinica</i> Miq.	<i>Piperaceae</i>	+	+	+
18	<i>Peperomia tetraphylla</i> (Forster) Hook.& Arn.	<i>Piperaceae</i>	-	+	+
Total			7	10	12

**Appendix 3:** Number of vascular epiphyte species existing on each sampled phorophyte.

No.	Phorophyte species	Number of epiphyte species
1	<i>Ekebergia capensis</i> Sparrm.	6
2	<i>Ficus mucoso</i> Ficalho.	2
3	<i>Ficus vallis-choudae</i> Del.	10
4	<i>Antiaris toxicaria</i> Lesch.	5
5	<i>Ficus thonningii</i> Blume.	3
6	<i>Cordia africana</i> Lam.	12
7	<i>Albizia grandibracteata</i> Taub.	8
8	<i>Albizia schimperiana</i> Oliv.	2
9	<i>Millettia ferruginea</i> (Hochst.) Bak.	4
10	<i>Acacia abyssinica</i> Hochst.ex Benth.	16
11	<i>Croton macrostachyus</i> Del.	3
12	<i>Vernonia amygdalina</i> Del.	4
13	<i>Spathodea campanulata</i> P.Beauv.	2
14	<i>Bersama abyssinica</i> Fresen.	3
15	<i>Olea welwitschii</i> (Knobl.)Gilg & Schellenb.	14
16	<i>Prunus africanum</i> (Hook.f.) Kalkam.	6
17	<i>Nuxia congesta</i> R. Bres. Fresen.	3

## **DECLARATION**

I, the undersigned, declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been dully acknowledged.

Author: \_\_\_\_\_

Bayisa Abdisa

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

Thesis Advisors: \_\_\_\_\_

Prof. Sileshi Nemomissa

**Place:** Department of Zoological Science, Addis Ababa University.

Date: August, 2019