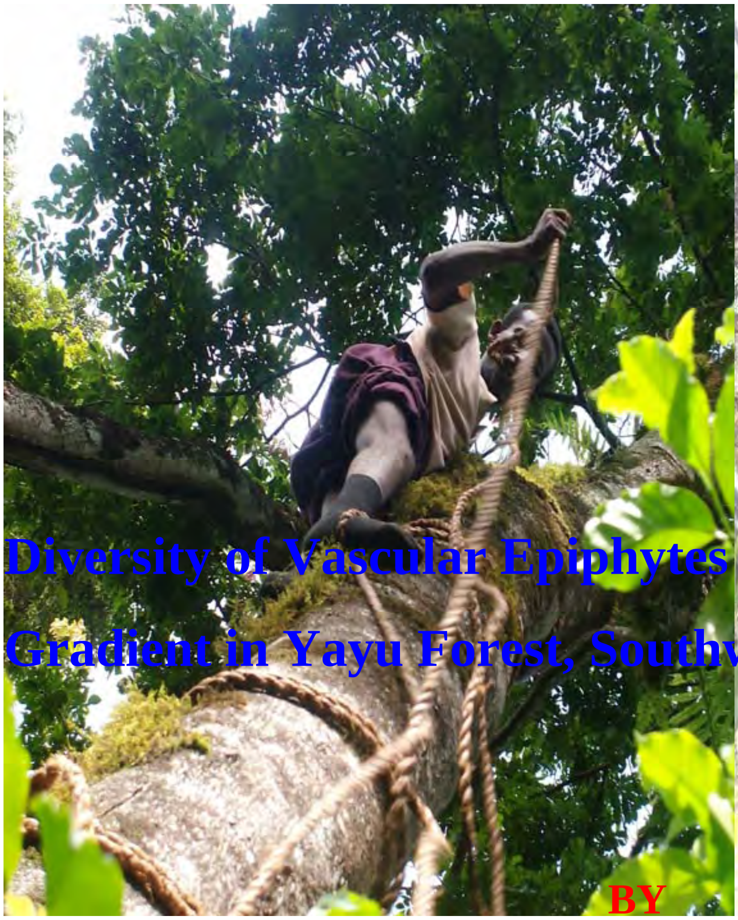
ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF BIOLOGY



Diversity of Vascular Epiphytes along Disturbance Gradient in Yayu Forest, Southwest Oromia, Ethiopia

BY

ABUNA TAFA ETISA

JULY 2010

ADDIS BABA

Diversity of Vascular Epiphytes along Disturbance Gradient in Yayu Forest, Southwest Oromia, Ethiopia

By

Abuna Tafa Etisa

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 (Botanical Science Stream)

July 2010
Addis Ababa

TABLE OF CONTENTS

PAGE

LIST OF TABLES

PAGE

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ACRONYMS

AAU	Addis Ababa University
CAM	Crassulacean acid metabolism
CSA	Central Statistical Agency
DBH	Diameter at Breast Height
ECFF	Ethiopian Coffee Forest Forum
ETH	National Herbarium of Ethiopia
FAO	Food and Agriculture Organization Environmental Protection
GPS	Global Positioning System
IUPC	International Union of Pure and Applied Chemistry
IRTs	Isolated Remnant Trees
m a.s.l.	Meter above sea level
NMSA	National Meteorological Services Agency
SNNP	Southern Nations, Nationalities and Peoples’
SPSS	Statistical Package for the Social Sciences
URL	Uniform Resource Locator
UNEP	United Nations Environmental Program

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my advisors Prof. Sileshi Nemomissa and Dr. Tadesse Woldemariam for their unreserved advice in selecting this interesting research topic and providing me valuable information and reference materials as well as continuous assistance and constructive suggestions through out my study.

I am indebted to Ethiopian Coffee Forest Forum (ECFF); from the nature of the study, if not for their partial financial support this canopy work was very difficult and even may not be effective. I am thankful to the Department of Biology, AAU for all support in facilitating my research work. My thanks also extend to all members of National Herbarium (ETH), Science and Digital library of Addis Ababa University for their support during my whole study and research time. I would like to acknowledge Geba-Dogi Forest Coffee Conservation Project for their willingly support in data collection by delegating one of their resourceful person in forest information and also voluntary to lend me their car in case of any inconvenience during my field work. I also thank Yayu District Administrative and Police station for their genuine cooperation.

I take the opportunity to thank to my field assistants Obo Dase Ol'ana and Obo Teka Debela who helped me in field data collection from very troublesome wet and slippery trunks high up the crown. Special thanks go to my friends who donated their time to help me in specimen identification in National Herbarium and in computer manipulation.

My deepest affection is reserved for my family, my spouse Ade Bizuayehu Legesse, and my children: Liban, Hawi, Milki and Obsa Abuna who have tolerated my selfish tunnel vision during my study and research time and remained supportive throughout, particularly Hawi and my niece Sidise Guta Tafa were helping me in data organization and typing processes.

Finally, thanks to my almighty God who kindly care and determine in all my life achievement and destiny.

ABSTRACT

The change in species diversity and composition of vascular epiphytes along disturbance gradient was studied in Yayu forest of southwest Ethiopia. Systematic sampling method was employed in data collection with a line transect was laid out along disturbance gradient of the forest. Based on their increasing level of disturbance, the forest was divided into three management zones: natural forest (core zone), semi-forest coffee production system (buffer zone) and agricultural matrices (transition zone) respectively. A total of thirty-six species of vascular epiphytes were recorded from thirty-five host (phorophyte) species in the study area. Each forest zone harbored considerable number of epiphyte species, 31 species in core zone, 32 species in buffer zone and 24 species in transition zone. This indicates the existence of changes of species diversity along disturbance gradient of the forest due to anthropogenic disturbance. The species diversity of vascular epiphytes is also greatly influenced by the phorophyte biophysical factors, such as vertical gradient on individual host plants, host size, bark texture and elevation. Thus, vertical distribution of vascular epiphytes indicated that species diversity increases from phorophyte base to the canopy. 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. Rough bark texture of the phorophytes has high water retention capacity and is more convenient for vascular epiphyte species establishment than smooth ones. 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. Furthermore, host preference of vascular epiphytes was apparently exhibited by few species such as: Angraecopsis infundibulum, Polystachya cultriformis, Vittaria volkensii, Chlorophytum comosum and Coleochloa abyssinica.

Key words: *Disturbance Gradient, Diversity, Phorophyte, Species composition, Species turnover, Vascular Epiphyte, Yayu Forest.*

1. INTRODUCTION

Epiphytes are defined as plants rooting on the surface of tree trunks or branches without harming the host tree (Benzing, 2004). 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.

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). 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). Similarly, although many epiphytic species exist, most of them are accounted for by only a few higher taxa (876 genera in 84 angiosperm families) (Gravendeel *et al*., 2004). This indicates that out of those taxa that have evolved an epiphytic habit, only few have radiated into species-rich groups (Ku¨per, 2004).

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 still based on this type of data (Johansson, 1974). These methods were also best employed in collecting specimens for the current study of epiphyte diversity in Yayu forest.

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).

However, these are still not easily available for native researchers of developing countries. In Ethiopia, Tesfa Alemayehu (2006) in his study about diversity and ecology of vascular epiphytes in Harenna forest of Bale Zone indicated lack of information on these plant groups in Ethiopia. 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.

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).

Of course, epiphytes have important ecological values and contribution to forest biodiversity such as increasing species diversity, primary productivity, biomass, litter fall, water retention, and they provide substrate for nitrogen fixing bacteria (Munoz *et al*., 2003). Vascular epiphytes also provide essential habitat and food for canopy dwelling fauna, and vascular epiphytes are sensitive indicators of change in microclimate (Gentry and Dodson1987). In addition, epiphytes increase the surface area of phorophytes for interception of water and nutrients during precipitation events. Thus, epiphytes can expand both the nutrient storage and absorption capacity of tropical and subtropical forest ecosystems (Hsu *et al.*, 2002). However, many epiphyte species in tropical forests are continuously affected by forest disturbance.

Many components of disturbance that cause changes in forest ecosystem indirectly affect epiphytic diversity and distribution. As epiphytes depend on their host plants, usually trees, any conversion to vegetation without trees will obviously result in a complete loss of epiphytes in the affected area (Hietz, 1999). A change in canopy matrix due to selective logging will affect the air moisture levels within the shrub layer, therefore affecting a key factor determining an epiphyte's ability to occupy such a habitat (Benzing, 2004). Anthropogenic disturbances caused the forest of the study area to be categorized in to three management zones: undisturbed forest (core zone), partially disturbed forest (buffer zone) and cleared forest of agricultural matrix (transition zone). Epiphyte species diversity and composition change with changing habitat. Thus, vascular epiphytes are more diversified in primary forests than secondary and disturbed forests (Barthlott *et al*., 2001).

However, the larger remnant shade trees and their coffee trees also harbored large number of epiphyte species. This shows that when coffee is grown under shade and shade trees are old and not pruned, large trees may host a diverse epiphyte community (Hietz, 1999). In general, both coffee trees and shade trees are important hosts for epiphytic plant diversity (Hylander. and Nemomissa, 2009).

Thus, the role of isolated remnant shade trees together with understorey coffee trees and their dwellers, vascular epiphyte species in reforestation processes, should be understood by all stakeholders and get considerable attention in conservation programs. The larger remnant shade trees constitute keystone structures that offer refuge and enhance connectivity for forest organisms, and provide nuclei of regeneration (Hietz, 2005). To promote and accelerate restoration of structurally complex forest, also epiphytes should be considered for early reintroduction to restoration plantings, particularly given their functional significance (Cummings, 2006).

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 along disturbance gradient in Yayu forest, interesting.

2. OBJECTIVES

2.1 General objective

- To identify and document the species diversity of vascular epiphytes in three management zones of Yayu forest (core zone, buffer zone and transition zone).

2.2 Specific objectives

- To compare the species diversity and distribution of vascular epiphytes along disturbance gradients.
- To compare the diversity and distribution of vascular epiphytes on host plants' base, trunk and canopy in the three forest management zones of the study area.
- 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; and why they are selected and left in agricultural field.

❖ Research Questions

- What is the list of vascular epiphyte species existing in Yayu forest?
- Do the diversity and composition of species of vascular epiphytes differ in different forest zones (transition, buffer and core zones)?
- What factors are influencing the diversity and distribution of epiphytes?
- What measures should be employed to effect the forest conservation?

3. REVIEW OF LITERATURE

3.1 What is an epiphyte?

Many definitions of epiphytes have been formulated. 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.

Madison (1977) reported that epiphytism has several levels, and distinguished these as: hemi-epiphytes 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.

3.2 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.

3.3 Characteristic evolution of epiphytes

For understorey plants in primary forests, they either have to adapt to the dark environment or grow up to reach the light. 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 Yayu 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).

3.4 Ecology and distribution of epiphytes

3.4.1 Diversity and distribution of vascular epiphytes in Yayu 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, 23466 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. Ku¨per (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 biogeographical 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).

The abundance of epiphytic growth is an important feature in montane forests, the biomass amounting to 12 tons per hectare. The diversity and abundance of epiphytic growth is one of the features said to distinguish mature Neotropical forests from late-secondary stages (Bader, 1999). Generally speaking, vascular epiphyte diversity has been found to be higher in primary than in secondary or disturbed vegetation (Hickey, 1994).

3.4.2 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.

3.5 Factors affecting epiphytes diversity and distribution

A classic explanation for the floristic differences between two sites is their ecological dissimilarity. Even if the two sites were located within the distributional range of the species populations, differing ecological conditions at the sites can exclude a species at one of them (Gentry & Dodson, 1987). 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).

3.5.1 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). Johannsson (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).

3.5.2 Climate conditions

There is good evidence that even slight changes in temperature, rainfall, and CO2 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 lifeforms (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).

3.5.3 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).

3.5.4 Dispersal syndromes

Bader (1999) reported that apart from the growing conditions the supply of propagules is an important factor determining the distribution of epiphytes. Obviously epiphytes do not have a seed bank in the soil, so in regrowing forests the first epiphytes must arrive from the surrounding vegetation. As the diaspores 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.

Remnant forest fragments, even single trees, can be an important reservoir for epiphyte diversity and a source for seeds in regrowing forest (Bader, 1999).

3.5.5 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.

3.6 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 stomatal 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 velamen 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, velamen 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).

3.7 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 Hiremath (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).

3.8 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 transition zone of Yayu 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. The degree to which epiphytes are negatively affected depends on the severity and type of disturbance, the size of the remnant trees, or the age of the secondary forest and on the period since the disturbance (Hietz *et al.*, 2006).

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 (Laurance, 2007). However, when analyzing the role of homegardens 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^2 homegarden plot would reduce epiphytic diversity by 41%, on average.

3.9 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.

4. MATERIALS AND METHODS

4.1 Description of the study site

4.1.1 Location

The present study was conducted in Yayu Forest, located in Illubabor Zone, Southwest Oromia National Regional State, at about 550 km west of Addis Ababa. It is situated at $8^{0}20'$-$8^{0}22'$ N and $35^{0}46'$-$35^{0}51'$E and covers parts of the Yayu Forest along Gaba and Saki rivers and agricultural matrix adjacent to the forest area around Yayu Town (Figure 1).

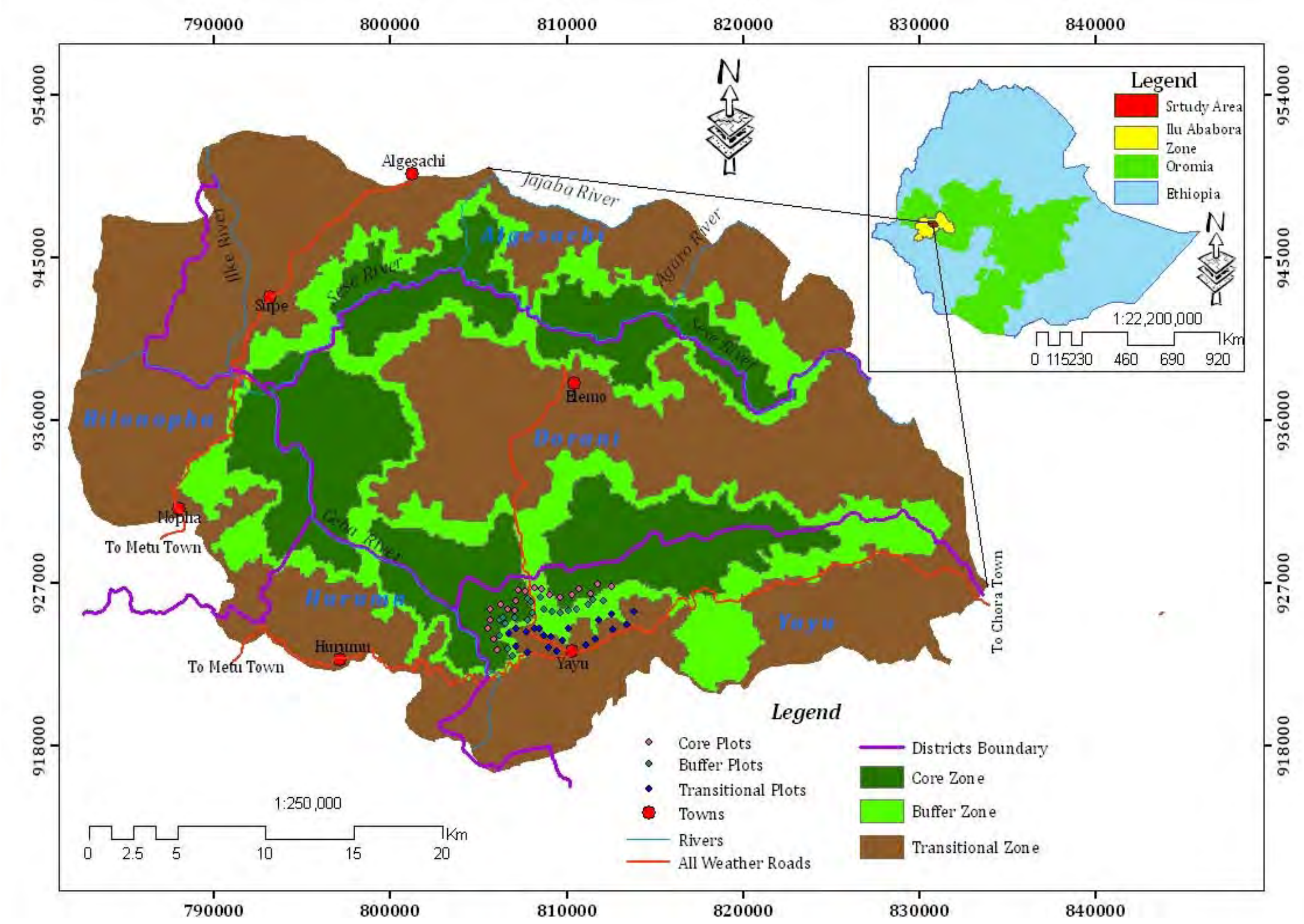


Figure 1: Map of the study area.

- **Core zone**-is undisturbed natural forest; **Buffer zone**-is partially disturbed forest; **Transition zone**-is completely cleared forest for agricultural purpose.

The study area is characterized by a rolling topography, and is highly dissected by small streams and gorges, and major rivers such as Geba, Dogi and Saki (Plate 1). The forest landscape in the study area falls between 1200 m - 2000 m a.s.l (Tadesse Woldemariam, 2003). However, all the study plots fall within the altitudinal ranges of 1300 and 1700 m.

Plate 1: Partial photograph of Yayu forest

4.1.2 Population

According to this 2007 census, the population size of Illubabor Zone is 1,278,183. Yayu Wereda shares this by population size of 52,829 (4.13 %) of which males account 26,720 (50.57%) and females 26,109 (49.42%). The majority of the people, 45,276 (85.7 %) are living in rural areas. The capital of the Zone called Metu, is located at 40 km in the southwest direction from the town of the study area, Yayu.

4.1.3 Vegetation

Yayu forest is categorized under Afromontane rainforest, which has a very high plant species diversity and abundance of the coffee trees compared to other similar forest areas in Ethiopia (Tadesse Woldemariam, 2003). Both coffee and other plant groups in the study area were considered equally important phorophytes in the study of vascular epiphytes. The same author has also reported that Yayu Forest consists of 220 species of vascular plants. The author classified the forest into three management zones, a core zone, a buffer zone and transition zone. Thus, the study was concerned with the diversity of vascular epiphyte species along this disturbance gradient.

i. Core zone

Core zone is undisturbed natural forest zone that only meant for the conservation of wild coffee population and other associated plant species. No human intervention should be allowed in this part except for research, monitoring and educational and public visits. It is a strictly protected zone.

ii. Buffer zone

This is semi-forest coffee production system in which traditional coffee production has been practiced. In this system, small-sized understorey trees and shrubs, which are competing with coffee plants, are cleared to enhance the productivity of the coffee. However, larger shade trees were left uncut to protect the coffee trees from direct sunlight. It is also forbidden to cut these shade trees.

iii. Transition zone

This zone is also known as agricultural matrix (Hylander and Nemomissa, 2009). All activities of traditional production systems like crop production, animal husbandry and garden coffee production are practiced here. It is a highly disturbed area with forest cleared for agricultural practice. However, few large sized shade trees, hosting many epiphyte species are still left uncut in the garden and agricultural field.

4.1.4 Climate

The rainfall and temperature data of 12 years (1983-2008) that had been recorded at Yayu meteorological station was taken from Ethiopian National Meteorological Agency (NMA). However, as the record of temperature and rainfall data was interrupted for certain years in between for unknown reason, the present report is based on summarized data of the area.

The study area is warm and humid. The mean annual temperature is about 20.7^{O}C, ranging from mean minimum of 12.1^{O}C to mean maximum of 30.9^{O}C. There is only slight difference in temperature through out the year, with hottest months in February to April and coldest months during July to September (Figure 2). On the other hand, the mean annual rainfall in Yayu Forest is about 1679 mm, with high variations of annual rainfall from year to year, ranging from about 1366.9 mm in 1984 to 2071.2 mm in 1988. The rainfall pattern is unimodal, with low rainfall in January and February. It gradually increases to the peak period between May and October, and then fall down in November and December (Figure 2).

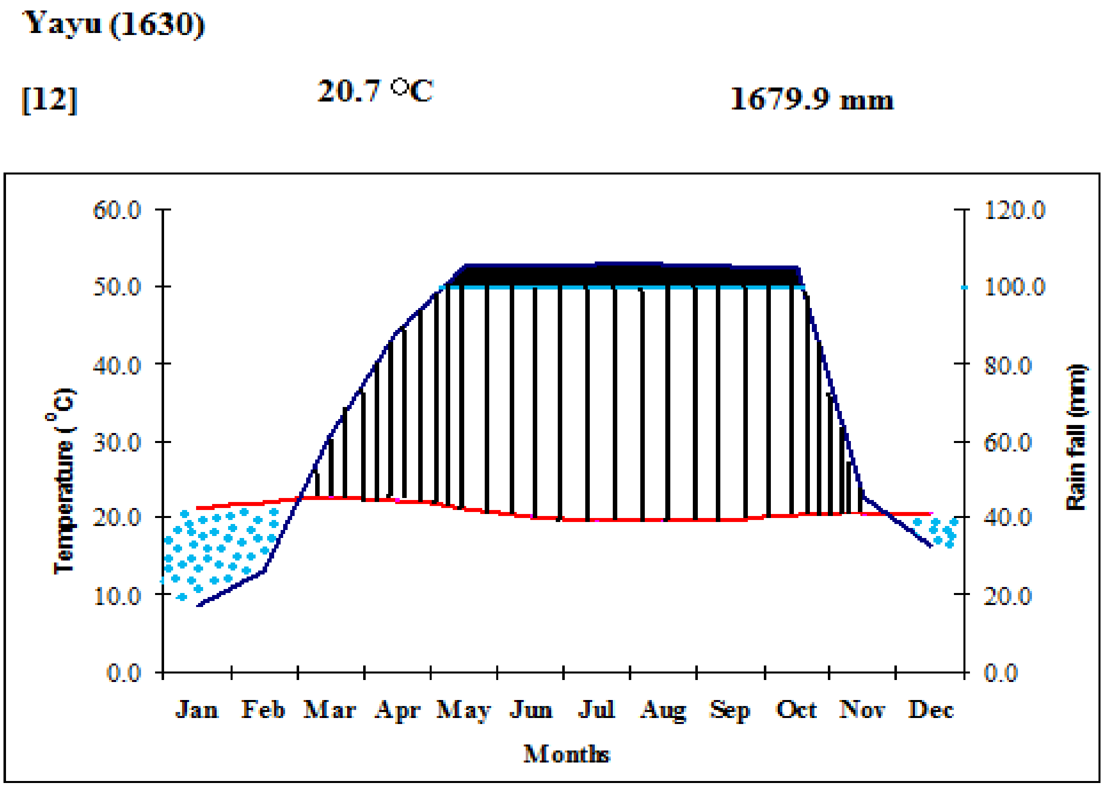


Figure 2: Climatic diagram of Yayu Wereda.

Source: National Meteorological Agency (NMA)

4.2 Methods of data collection

4.2.1 Sampling design

The map of aerial photograph of the study area prepared in 1986 was obtained from the National Map Agency of Ethiopia; GPS, Compass and Binocular were obtained from Addis Ababa University. An unsupervised classification of the study area into core, buffer and transition zones was performed using information obtained from Tadesse Woldemariam (2003), to create the image map of the area. Random sampling points were placed on the map. The physical variables such as latitude and longitude of each sample point were estimated from the map using calibrated plastic ruler and GPS. These are pre-processed activities aimed at making the fieldwork and further analysis more suitable and easier.

Systematic sampling method was employed in data collection. A line transect was laid out along disturbance gradient. The starting point of the first transect was randomly selected on the forest edge between the core and buffer zones. Other transects were then, laid out at a right angle but in opposite direction from the point of this forest edge into the forest interior, semi-forest and agricultural field. According to Belinchon (2007), a distance of 100 m into forest interior is the optimal distance of disturbance gradient. However, the present quadrats were laid at about 200 m from the forest edge into core and buffer forest zones while the distance of sample plots into transition zone was determined by the presence of host shade trees. Three quadrats were placed along each transect with every one quadrat laid in one particular habitat. The distance between two neighboring transects was about 500 m. The size of each quadrat was 20 m x 20 m = 400 m^2. In general, 20 transect lines with 60 quadrats were laid along disturbance gradient. A total of 20 quadrats were laid in each forest zone.

4.3 Vegetation sampling

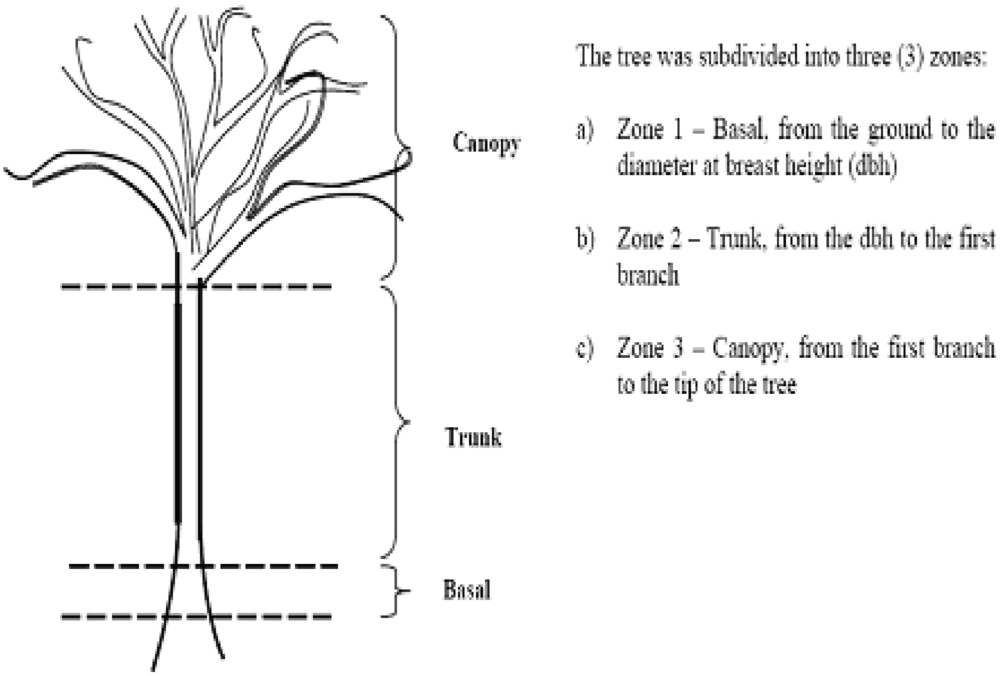
In order to observe the general patterns of vegetation and forest zonation of the study area, a reconnaissance survey was made from May 16 to 18, 2009. The actual data collection was conducted from May 19, 2009 to June 29, 2009. The main activities performed during the fieldwork were: **(1)** measuring the diameter at breast height (DBH) of phorophytes **(2)** counting and sampling species of vascular epiphytes and **(3)** bark texture and elevation a.s.l were recorded. Photographs have been taken for each sample plots with both digital and manual cameras. All tree species with DBH ≥ 2.0 cm were considered appropriate host for sampling epiphytes in this study. Because, phorophytes with dbh less than 2.0 cm have smaller surface area and thus hold either very few number or no vascular epiphyte species. 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. 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 (Plate 1) 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.

Plate 2: A local guide climbing to pick up sighted epiphytes

Specimens of unknown epiphyte and phorophyte species were given a code or nickname. Their identification was completed at the National Herbarium (ETH), Addis Ababa University through referring to the existing publications of Floras of Ethiopia and Eritrea, comparing with

Herbarium collections and consulting specialists. The last destiny of the identified specimens was to be labeled and placed in the National Herbarium in order to serve as references.

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 (Figure 3). For host coffee trees the corresponding zonations are estimated as: 0-30 cm, the bare stem above 30 cm to the point of many branches radiation and the leafy part above bare section respectively.



The tree was subdivided into three (3) zones:

a) Zone 1 – Basal, from the ground to the diameter at breast height (dbh)

b) Zone 2 – Trunk, from the dbh to the first branch

c) Zone 3 – Canopy, from the first branch to the tip of the tree

Figure 3: Schematic representation of vertical partion of phorophytes

Source: Kelly *et al.,* (2003), modified by Mojiol *et al.,* (2009)

The vegetation structure of the study area revealed that the three management zones of the forest subjected to this study was started by core zone from down the river valley and extended up to relatively middle elevation, followed by narrower buffer zone asiding the core zone, and agricultural matrix extending from buffer zone to higher altitude of plateau areas. It is clear from the context that the forest disturbance is increasing from much protected intact forest through semi-forest coffee production system to agricultural matrix.

4.4 Data analysis

In the present study, a comparative analysis of the species diversity and composition of vascular epiphytes was carried out in three forest management zones, on vertical stratum of host plants, with host dbh, with bark characteristics and along elevetional gradient. An exploratory data analysis has been employed to investigate how vegetation varies from place to place or within a certain area. Thus, Beta **(β)** diversity of vascular epiphyte species along disturbance gradient was compared for three management zones of the Yayu Forest. Beta diversity is habitat diversity that designates the degree of change in species composition between different areas and the rapidity of change of those habitats (Kent and Coker, 1992).

The species diversity and distribution of vascular epiphytes along altitudinal gradient and vertical stratification of microclimate on phorophyte sections/zones, and on different bark textures of the host plants were compared from number of species registered in the area. Species richness is a biologically appropriate measure of alpha **(α)** diversity and is usually expressed as number of species per sample unit (Whittaker, 1972).

Pearson’s product-moment correlation analysis was applied to measure the linear relationship between the size of host plants (dbh) and the number of vascular epiphyte species. The correlation analysis was done with SPSS, version 14.0 statistical packages. Before analysis was done, the data was checked for outlying observations and there was none.

5. RESULT AND DISCUSSION

5.1 Diversity and distribution of vascular epiphyte species in Yayu Forest

The study dealt with species diversity and distribution of vascular epiphytes in the three management zones of Yayu Forest (core, buffer and transition zones). The species were recorded from phorophytes with a DBH $\geq$ 2.0 cm and rooted inside 400 m^2 plot in each forest habitat type. A total of 260 host plants from 60 sample plots in the three forest zones were subjected to data collection and all of them harbored epiphytes, with the greater phorophyte proportion found in core zone (Table 1). The phorophyte plants were identified to contain 35 species, 28 genera and 17 families (Appendix 1). Moraceae is the largest host family represented by 10 species (28.6 %). These are: *Ficus mucuso, Ficus lutea, Ficus ovata, Trilepisium madagascariense, Ficus vasta, Ficus vallis-choudae, Ficus exasperata, Antiaris toxicaria, Morus mesozygia and Ficus thonningii.*

There were changes in species diversity and composition of phorophytes along disturbance gradient through forest zones. Accordingly, the species diversity of phorophytes showed a trend of decreasing from core zone to buffer zone to transition zone (25, 23 and 12 respectively) (Table 1). Furthermore, the changes in species composition of phorophytes were revealed in transition zone that with highly reduced phorophyte species for example, consisting: *Spathodea campanulata, Acacia abyssinica, Vernonia amygdalina and Ficus thonningii* which were not recorded as host plants from the rest of forest zones. These all were caused by continuing clearance of forest plants for timber production and agricultural practices.

Table 1: List of phorophytes recorded from three management zones of Yayu forest

No	Phorophyte species	Family	Forest zones		
			C	B	T
1	*Rothmannia urcelliformis (Hiern) Robyns.*	Rubiaceae	+	-	-
2	*Coffea arabica* L.	Rubiaceae	+	+	+
3	*Vangueria volkensii* K.Schum.	Rubiaceae	+	-	-
4	*Trichilia dregeana* Sond.	Meliaceae	+	+	+
5	*Ekebergia capensis* Sparrm.	Meliaceae	+	-	-
6	*Ficus mucuso* Ficalho.	Moraceae	+	-	-
7	*Ficus lutea*Vahl	Moraceae	+	+	-
8	*Ficus ovata* Vahl	Moraceae	+	+	+
9	*Trilepisium madagascariense DC.*	Moraceae	+	+	+
10	*Ficus vasta* Forssk.	Moraceae	+	+	-
11	*Ficus vallis-choudae* Del.	Moraceae	+	+	-
12	*Ficus exasperata* Vahl	Moraceae	-	+	-
13	*Antiaris toxicaria* Lesch.	Moraceae	+	-	-
14	*Morus mesozygia* Stampf.	Moraceae	-	+	-
15	*Ficus thonningii* Blume	Moraceae	-	-	+
16	*Cordia africana* Lam.	Boraginaceae	+	+	+
17	*Ehretia cymosa* Thonn.	Boraginaceae	+	+	-
18	*Albizia grandibracteata Taub.*	Fabaceae	+	+	-
19	*Albizia schimperiana* Oliv.	Fabaceae	+	+	+
20	*Millettia ferruginea* (Hochst.) Bak.	Fabaceae	+	-	-
21	*Acacia abyssinica* Hochst.ex Benth.	Fabaceae	-	-	+
22	*Croton macrostachyus* Del.	Euphorbiaceae	+	-	-
23	*Sapium ellipticum* (Krauss) Pax.	Euphorbiaceae	+	+	+
24	*Blighia unijugata* Bak.	Sapindaceae	+	+	-
25	*Veronia amygdalina* Del.	Asteraceae	-	-	+
26	*Polyscias fulva* (Hiern) Harms.	Araliaceae	+	-	-
27	*Mimosops kummel* A.DC.	Sapotaceae	+	+	-
28	*Flacourtia indica* (Brum.f.) Merr.	Flacourtiaceae	-	+	-
29	*Spathodea campanulata* P.Beauv.	Bignoniaceae	-	-	+
30	*Stereospermum kunthianum* Cham.	Bignoniaceae	-	+	-
31	*Bersama abyssinica* Fresen.	Melianthaceae	-	+	-
32	*Olea welwitschii* (Knobl.)Gilg & Schellenb.	Oleaceae	+	+	+
33	*Prunus africana* (Hook.f.) Kalkam.	Rosaceae	+	+	-
34	*Nuxia congesta* R. Bres. Fresen.	Loganiaceae	-	+	-
35	*Celtis africana* Burm.f.	Ulmaceae	+	+	-
Total			25	23	12

According to Tadesse Woldemariam (2003), Yayu Forest is composed of about 220 vascular plant species. Floristically, it is Afromontane rain forest that can be expressed by its constituent tree species such as *Celtis africana*, *Olea welwitschii*, *Blighia unijugata* and *Albizia grandibracteata* occupying areas above 1500 m (Friis, 1992). In addition, the forest is also composed of some additional species from lowland forest vegetation: *Morus mesozygia*, *Trilepisium madagascariense*, *Ficus exasperata*, *Trichilia dregeana* occupying areas below 1500m (Tadesse Woldemariam, 2003).

On the other hand, **36** species of vascular epiphyte plants were recorded from sampled areas of Yayu Forest. The epiphytes are categorized under 21 genera and 8 families (Table 2). Although their proportion and indeed their presence vary in total richness according to the type of forest formation (forest zones), the species richness of vascular epiphyte families in Yayu Forest were recorded with their decreasing order as Orchidaceae represented by 20 species (55.6%), Polypodiaceae with 5 species (13.9 %), Aspleniaceae and Piperaceae each with 3 species (8.33 % each), Oleandraceae by 2 species (5.6 %) while the rest and scarce families Vittariaceae, Antheriaceae and Cyperaceae each was represented by a single species (2.8 % each) (Figure 4). The result indicated that Orchidaceae contributed more species followed by Polypodiaceae.

Table 2: List of vascular epiphytes recorded from three management zones of Yayu forest

No	Epiphyte species	Family	Forest zones		
			C	B	T
1	*Aerangis brachycarpa* (A.Rich.) Th.Dur. & Schinz.	Orchidaceae	+	+	+
2	*Angraecopsis holochila* Summerh.	Orchidaceae	+	-	-
3	*Angraecopsis infundibulum* Lindl.	Orchidaceae	+	-	-
4	*Angraecopsis trifurea* (Rchb.f.) Schltr.	Orchidaceae	+	+	+
5	*Bolusiella iridifolia* (Rolfe) Schltr.	Orchidaceae	+	-	+
6	*Bulbophyllum lupulinum* Lindl.	Orchidaceae	+	+	-
7	*Calyptrochilum christyanum* (Rchb.f) Summerh.	Orchidaceae	+	+	+
8	*Cyrtorchis arcuata* (Lindl.) Schltr.	Orchidaceae	+	+	+
9	*Cyrtorchis erythraeae* (Rolfe) Schltr.	Orchidaceae	+	+	+
10	*Diaphananthe fragrantissima* (Rchb.f.) Schltr.	Orchidaceae	+	+	-
11	*Diaphananthe tenuicalcar* Summerh.	Orchidaceae	+	+	+
12	*Microcoelia globulosa* (Hochst.) L.Jonsson.	Orchidaceae	+	+	+
13	*Polystachya bennettiana* Rchb.f.	Orchidaceae	+	+	+
14	*Polystachya cultriformis* (Thou.) Sprengel.	Orchidaceae	-	+	-
15	*Polystachya eurychila* Summerh.	Orchidaceae	+	+	+
16	*Polystachya fusiformis* (Thou.) Lindl.	Orchidaceae	-	+	+
17	*Polystachya lindblomii* Schltr.	Orchidaceae	+	+	-
18	*Polystachya steudneri* Rchb.f.	Orchidaceae	+	+	+
19	*Polystachya tessellata* Lindl.	Orchidaceae	+	+	+
20	*Tridactyle bicaudata* (Lindl.) Schltr.	Orchidaceae	+	+	-
21	*Drynaria volkensii* Hieron.	Polypodiaceae	+	+	+
22	*Lepisourus excavatus* (Willd.) Ching.	Polypodiaceae	+	+	+
23	*Loxogramme abyssinica* (Baker.) M.G.Price.	Polypodiaceae	+	+	+
24	*Peleopeltis macrocarpa* (Bory ex Willd.) Kaulf.	Polypodiaceae	+	+	+
25	*Pyrrosia schimperiana* (Mett.ex Kuhn.) Alston.	Polypodiaceae	+	+	+
26	*Asplenium aethiopicum* (Burm.f.) Bech.	Aspleniaceae	+	+	+
27	*Asplenium sandersonii* Hook	Aspleniaceae	+	+	-
28	*Asplenium theciferum* (Kunth.) Mett.	Aspleniaceae	-	+	+
29	*Peperomia abyssinica* Miq.	Piperaceae	+	+	-
30	*Peperomia molleri* C.Dc.	Piperaceae	+	+	+
31	*Peperomia tetraphylla* (G.Forst.) Hook&Arn	Piperaceae	+	+	+
32	*Arthropteris monocarpa* (Cordem.) C.Chr.	Oleandraceae	+	+	+
33	*Arthropteris orientalis* (Gmel.) Posth.	Oleandraceae	+	+	+
34	*Vittaria volkensii* Hieron	Vittariaceae	-	+	-
35	*Chlorophytum comosum* (Thunb.) Jaeq.	Anthericaceae	+	-	-
36	*Coleochloa abyssinica* (Hochst.ex.A.Rich) Gilly	Cyperaceae	-	+	-
Total			31	32	24

C = core zone**, B =** buffer zone**, T =** transition zone

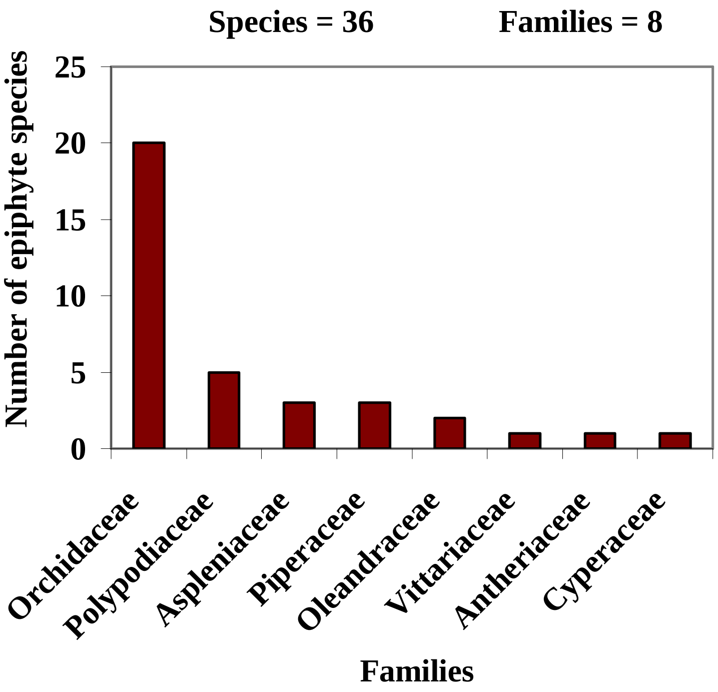


Figure 4: Vascular epiphyte richnessof some plant famiies in Yayu forest

The number of species of vascular epiphytes registered in each forest habitat was 31 species in core zone, 32 in buffer zone and 24 in transition zone (Table 2). Thus, the buffer and core zones were relatively more specious forests with a slight difference between them, while the transition zone was poorer in number of epiphyte species. The study indicated that the number of epiphyte species in the core zone was found to be slightly less than that of the buffer zone. Furthermore, they have considerable differences in species composition. This may be caused by increased openness of the forest that favors the growth of sun-loving epiphyte species and that larger host trees in buffer zone were almost left uncut during preparation for coffee production. This indicates that disturbance affecting the existence of phorophytes or change in the micro climatic conditions of the forest still remained to be the cause of differences in species diversity and composition among the three forest zones.

UNEP (1995) reported that for many species of plants and animals, the loss of their habitat represents the greatest threat to their survival. This negative effect is probably more severe for epiphytes, which cannot draw water from the ground soil like terrestrial pants. Therefore, the reduction in epiphyte species diversity of secondary forests as compared to mature forests is ascribed to differences in the physical characteristics among forest habitats, such as lower diversity and density of phorophyte structures and micro climatic (Barthlott *et al.,* 2001; Kromer & Grastein, 2003). Thus, vascular epiphyte diversity has been found to be higher in primary than in secondary or disturbed vegetation (Hickey, 1994; Barthlott *et al.,* 2001). This is to mean that 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).

The transition zone in Yayu Forest is for example, where the highly reduced diversity and density of phorophytes (Table 1) caused by changes in microclimate condition of the area and thus resulted in reduction of number of vascular epiphyte species. It was found that there were about 12 epiphyte species existing in either core zone or buffer zone or in both but did not appear on isolated remnant trees in agricultural matrix (Table 2). These are: *Peperomia abyssinica, Angraecopsis holochila, Angraecopsis infundibulum, Bulbophyllum lupulinum, Diaphananthe fragrantissima, Polystachya cultriformis, Vittaria volkensii, Chlorophytum comosum, Coleochloa abyssinica, Tridactyle bicaudata, Asplenium sandersonii and Polystachya lindblomii.* The absence of these species may be attributed to the reduction of phorophyte species that resulted in reduction of epiphytes' niche availability as well as change in microclimatic condition and due to distance of isolated remnant shade trees from the main forest that may cause dispersal limitation.

In general, the result of the study indicates that the vascular epiphytes, components of the plant community comprise 16.36% (36/220) of all the reported vascular plants species in the Yayu 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, Yasunı´, Ecuador; Hietz (2005) reported 122 species of vascular epiphytes in the nine coffee plantations and four forests in Mexico. Bittner– Javier and Trejos-Zelaya (1997) reported 52 vascular epiphyte species in a montane rain forest in Costa Rica. Mehltreter *et al.* (2005) reported 55 species on all hosts from a cloud forest of Veracruz, Mexico. 78 species were reported from Cameroonian semi-deciduous rain forest (Zapfack, *et al.*, 1996). Tesfa Alemayehu (2006) reported 55 vascular epiphyte species from Harenna 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 Harenna Forest only 40% (22 in numbers) were holoepiphytes. Accordingly, Harenna Forest holds less holoepiphyte species than Yayu Forest, which consists of 36 true epiphyte species.

The relatively lower diversity of vascular epiphytes in Yayu 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. Many authors reported the distribution pattern of vascular epiphytes species in wet and lowland or seasonal forests. K¨oster *et al.* (2005) for example, suggested that montane rain forests of the Neotropics are generally considered to harbor the maximum of the world's vascular epiphyte diversity whereas in contrast lowland rainforests are very poor in epiphytes. Furthermore, Werner (2009) reported that in tropical montane cloud forests, moisture tends to be plentiful throughout the year, and epiphytic vascular plants attain high diversity; however, distinctly seasonal montane forests have relatively low epiphyte diversity. This shows that the less number of vascular epiphyte species in warm climatic conditions may be due to the less humidity caused by evapotranspiration.

Others have reported the effect of forest disturbance on epiphyte diversity and distribution. In the establishment of vascular epiphytes, a small disturbance would affect the seral stages of succession and ultimately their growth (Zotz, 1995). Therefore, disturbance is reductive in niche availability to epiphytes particularly when supporting bark fragments exfoliate, inhabited twigs fall, infested trees collapse, and natural disasters ravage whole communities (Benzing, 1987). Similarly, logging affects epiphytes by reducing the available habitat and by altering the microclimate in the forest (Barthlott *et al.*, 2001**).** This shows that when large trees are removed, epiphytes that either requires large branches as substrate or those with a long life cycle will be affected by changing population structure (Padmawathe *et al.,* 2004). Similar result was recorded in transition zone of Yayu Forest.

The relatively larger number of vascular epiphyte species recorded from Yayu Afromontane forest during the study was the group of monocot angiosperms, which in turn dominated by orchids (20 species). Furthermore, the larger epiphytic angiosperm genera of the area were *Polystachya* with 7 species followed by *Angraecopsis* and *Peperomia* each with 3 species (Table 2). Sebsebe Demissew *et al.,* (2004) suggested that among three orchid genera that are represented by more than ten species in Ethiopia, *Polystachya* is predominantly an epiphytic genus with 12 species while the two others, *Habenaria* and *Eulophia* are terrestrial and not the aim of this paper to deal with. Therefore, of the 12 species of *Polystachya*, Yayu Forest hosted more than half, 7 species: *Polystachya bennettiana, P. cultriformis, P. eurychila, P. fusiformis, P. lindblomii, P. steudneri and P. tessellata.* Marin (2006) reported from the forest in Costarica that among vascular epiphytes, the monocots greatly contribute to the diversity of the group with orchids being overly dominant.

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.

The families of pteridophytes constitute the second large group of epiphytes next to orchids in the Yayu Forest and dominated by Polypodiaceae with *Asplenium* was the largest genus (with 3 species) of pteridophytes in the area. The less diversification of pteridophytes than orchids may be attributed to the existence of relatively less moisture in the disturbed zones of the study area. However, different authors have reported the dominance of pteridophytes in some tropical forests. Mojiol *et al*. (2009) in his study at Kawang Forest Reserve, Malaysia revealed that vascular epiphyte communities were dominated by the division of Pteridophyta especially the two families of ferns: Aspleniaceae and Polypodiaceae. Furthermore, Hooper and Haufler (2006) have explained that the species of *Pleopeltis* (Polypodiaceae) are common epiphytes in the wet Neotropics, especially at midelevations in the mountains of Central America and southern Mexico. Also Tesfa Alemayehu (2006) from Harenna forest of Bale, Ethiopia has reported that the most species rich family is Aspleniaceae (ferns) followed by Orchidaceae. This may be accounted to the presence of available microclimatic condition for growth of pteridophytes in the study areas.

5.1.1 Comparison of the species diversity and composition of vascular epiphytes in three forest zones

Among 36 vascular epiphyte species in the study area, 21 species (58.3%) were found distributed throughout all the three forest zones while nine species (25%), each were recorded from two different forest habitats (core and buffer or core and transition or buffer and transition zones) and out of the remaining six species (16.7%), three of them: *Angraecopsis holochila*, *Angraecopsis infundibulum* and *Chlorophytum comosum* were recorded only from the core zone, whereas *Polystachya cultriformis, Vittaria volkensii* and *Coleochloa abyssinica* were recorded only from the buffer zone (Table 2).

This shows that even though the three forest zones have large number of epiphyte species in common 21 (58.3 %), others 15 species (41.7 %) come and go along the disturbance gradient of the forest. However, there was no epiphyte species found restricted to the transition zone only. That means each of the species recorded from agricultural matrix appeared at least once in one of the other habitat types. This indicates that the epiphytes in this zone may be the remnant species of the forest prior to disturbance or still there may be dispersal and establishment of epiphytic diaspores every time from neighboring natural forest to the transition zone. Furthermore, the decreased in species diversity of epiphytes in transition zone may follow the highly decreased density of the forest in the area.

Hietz (1999) reported that as epiphytes depend on their host plants, usually trees, any logging of the trees without selection would obviously result in a complete loss of epiphytes in the affected area. The difference in response to human disturbance also indicates that there are different limiting factors to the growth and distribution of vascular epiphyte species. May be dispersal limitation and mortality are the two potential limiting factors for epiphytes (Fayle *et al.,* 2009). Drought is the main source of mortality for some species than others. Because some are better at withstanding hot dry conditions, whereas some others thrive (flourish) in the cooler, damper understorey (Fayle *et al.,* 2009).

Obviously, core zone is supposed to have more species than other forest zones. However, the result of this study revealed that the number of epiphyte species in moderately disturbed buffer zone is slightly larger than that of undisturbed intact forest; which is not common trend to most findings about number of epiphyte species across forest disturbance gradient (Figure 5). On the other hand, the habitats also showed differences in species composition. Thus, four vascular epiphyte species that found in core zone for example, were not appeared in buffer zone whereas five other species which were not recorded in core zone but were registered from buffer zone (Table 2). This may be caused by light availability created from disturbance, which may foster a larger number of sun-loving epiphytes (Nkongmeneck, 2002). Gillespie (2002) also reported that epiphyte diversity is greater in open disturbed areas than in intact forests.

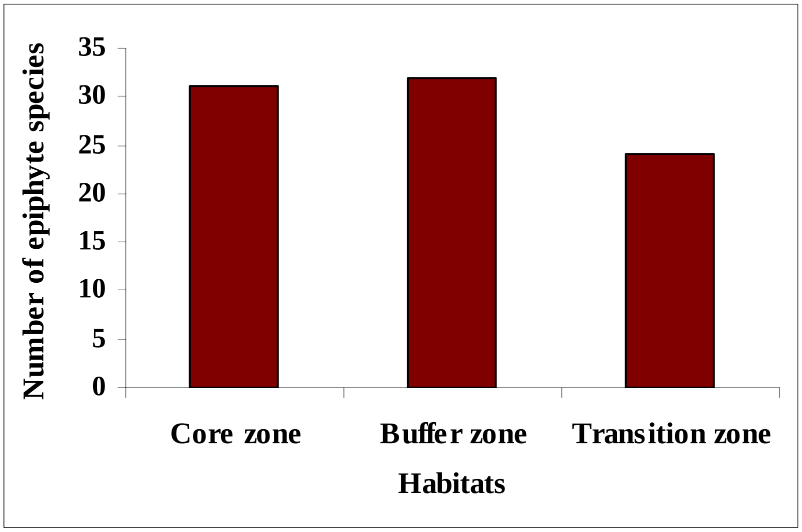


Figure 5: Comparison of distribution of vascular epiphyte species in the three forest habitats

Furthermore, when coffee is grown under shade and shade trees are old and not pruned, the number of epiphytes per tree and the total number of epiphytes per plot were about as high as in natural forests (Hietz, 1999). The coffee trees together with some larger isolated remnant shade trees observed in Yayu Forest, for example *Albizia schimperiana* harbored considerable number of vascular epiphyte species. This may be caused by that larger trees are likely, on average, to be older, allowing more time to capture epiphytic seeds and spores and may host a diverse epiphyte community (Hietz, 1999; Cummings *et al.*, 2006). This helps to recognize the importance of coffee trees and isolated remnant trees in conservation processes of forest in general and epiphyte in particular.

Although disturbance causes to open the closed forests that may allow the sun-loving epiphytes to be fostered, they are imperiled through the intense destruction of tree felling (Nkongmeneck 2002). This may be the case that resulted in declined number of epiphyte species in Yayu Forest, from 32 species in buffer zone to 24 species in transition zone. Furthermore, Werner (2009) suggested that numerous drought-intolerant, hygrophilous taxa decrease in number or vanish after isolation of remnant trees. This implies that intensive devastation of larger trees in Yayu Forest resulted not only in the reduction of phorophytes density and distribution but also change of species diversity and composition of vascular epiphytes inhabiting them.

5.1.2 Vertical distribution of vascular epiphytes across disturbance gradient

Vertical distribution of vascular epiphytes per phorophyte is not the same from basal parts to the top most branches across disturbance gradient of the forest. To examine these differences in the vertical stratification and horizontal distribution of epiphyte, the lists of vascular epiphyte species recorded from three zones of phorophytes in three forest habitats are given in Table 4, as well as the Schematic representation of vertical partition of host plants is depicted in Fig.3.

The total numbers of vascular epiphyte species recorded from each management zone of Yayu Forest were 31, 32 and 24 species from core, buffer and transition zones respectively. Furthermore, the total numbers of vascular epiphyte species vertically distributed from canopy to trunk to basal sections of phorophytes in each habitat were indicated that in core zone, 31, 25 and 7; in buffer zone, 31, 22 and 7; and in transition zone 24, 14 and 4 respectively (Table 4).

Table 3: Vertical distribution of vascular epiphytes across disturbance gradient of the forest

No	Epiphyte species	Core Zone			Buffer Zone			Transition zone		
		B	T	C	B	T	C	B	T	C
1	*Aerangis brachycarpa* (A.Rich) Th.Dur.& Schinz.	-	+	+	+	+	+	-	+	+
2	*Angraecopsis holochila* Summerh.	+	-	+	-	-	-	-	-	-
3	*Angraecopsis infundibulum* Lindl.	-	+	+	-	-	-	-	-	-
4	*Angraecopsis trifurea* (Rchb.f.) Schltr.	-	+	+	-	-	+	-	-	+
5	*Bolusiella iridifolia* (Rolfe) Schltr.	-	+	+	-	-	-	-	+	+
6	*Bulbophyllum lupulinum* Lindl.	-	+	+	-	-	+	-	-	-
7	*Calyptrochilum christyanum* (Rchb.f) Summerh.	-	+	+	-	+	+	-	-	+
8	*Cyrtorchis arcuata* (Lindl.) Schltr.	-	+	+	-	+	+	-	-	+
9	*Cyrtorchis erythraeae* (Rolfe) Schltr.	-	+	+	-	+	+	-	-	+
10	*Diaphananthe fragrantissima* (Rchb.f.) Schltr.	-	-	+	-	+	+	-	-	-
11	*Diaphananthe tenuicalcar* Summerh.	-	-	+	-	+	+	-	+	+
12	*Microcoelia globulosa* (Hochst.) L.Jonsson.	-	-	+	-	+	+	-	+	+
13	*Polystachya bennettiana* Rchb.f.	-	+	+	-	+	+	-	+	+
14	*Polystachya cultriformis* (Thou.) Sprengel.	-	-	-	-	+	+	-	-	-
15	*Polystachya eurychila* Summerh.	-	+	+	-	-	+	-	-	+
16	*Polystachya fusiformis* (Thou.) Lindl.	-	-	-	-	-	+	-	-	+
17	*Polystachya lindblomii* Schltr.	-	+	+	-	+	+	-	-	-
18	*Polystachya steudneri* Rchb.f.	-	+	+	-	-	+	-	+	+

Table 3: Continued...

19	*Polystachya tessellata* Lindl.	-	+	+	-	+	+	-	-	+
20	*Tridactyle bicaudata* (Lindl.) Schltr.	-	+	+	-	-	+	-	-	-
21	*Drynaria volkensii* Hieron.	-	+	+	-	+	+	+	+	+
22	*Lepisourus excavatus* (Willd.) Ching.	-	+	+	-	+	+	+	+	+
23	*Loxogramme abyssinica* (Baker.) M.G.Price.	+	+	+	-	+	+	-	-	+
24	*Peleopeltis macrocarpa* (Bory ex Willd.) Kaulf.	-	+	+	-	+	+	-	+	+
25	*Pyrrosia schimperiana* (Mett.ex Kuhn.) Alston.	-	+	+	-	+	+	-	+	+
26	*Asplenium aethiopicum* (Burm.f.) Bech.	+	+	+	+	+	+	-	+	+
27	*Asplenium sandersonii* Hook	+	+	+	+	+	+	-	-	-
28	*Asplenium theciferum* (Kunth.) Mett.	-	-	-	-	-	+	-	+	+
29	*Peperomia abyssinica* Miq.	-	-	+	-	-	+	-	-	-
30	*Peperomia molleri* C.Dc.	+	+	+	-	+	+	-	-	+
31	*Peperomia tetraphylla* (G.Forst.) Hook&Arn	+	+	+	+	+	+	+	+	+
32	*Arthropteris monocarpa* (Cordem.) C.Chr.	+	+	+	+	+	+	+	+	+
33	*Arthropteris orientalis* (Gmel.) Posth.	-	+	+	+	+	+	-	-	+
34	*Vittaria volkensii* Hieron	-	-	-	+	-	-	-	-	-
35	*Chlorophytum comosum* (Thunb.) Jaeq.	-	-	+	-	-	-	-	-	-
36	*Coleochloa abyssinica* (Hochst.ex.A.Rich) Gilly	-	-	-	-	-	+	-	-	-
Total		7	25	31	7	22	31	4	14	24

Section B = Basal (ground to diameter at breast height (dbh), **T** = Trunk (dbh to the first branch) and **C** = Canopy (first branch to the tip of the tree).

Thus, the distribution of vascular epiphyte species along vertical gradient of microclimate condition on phorophytes sections showed the same pattern in all forest zones 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.Vertical distribution of the number of species in core zone and buffer were almost similar with slight difference on phorophyte trunks. However, vertical distribution of epiphytes sharply declined from 31, 25 and 7 species on canopy, trunk and basal sections respectively in core zone to 24, 14 and 4 in transition zone. This may be caused by highly reduced number of phorophyte species in transition zone (Table 1) that may cause change of microclimatic condition to more unfavorable dry environment and exposure to extremely open and unstable agricultural habitat.

Furthermore, not only the species richness but also species composition of vascular epiphytes were different for vertical sections of phorophytes in all the three forest zones. Even for similar number of epiphyte species on corresponding phorophyte sections in both core and buffer zones, for example, the species compositions were still different. Core zone inhabiting species: *Chlorophytum comosum, Bolusiella iridifolia, Angraecopsis holochila, and Angraecopsis infundibulum* on canopy*, Tridactyle bicaudata, Polystachya eurychila, Polystachya steudneri, Angraecopsis infundibulum, Angraecopsis trifurea, Bolusiella iridifolia, and Bulbophyllum lupulinum* on trunk and *Peperomia molleri, Loxogramme abyssinica, and Angraecopsis holochila* on basal section of phorophytes did not appear on corresponding host plant sections in buffer zone while buffer zone dwelling species: *Polystachya cultriformis, Polystachya fusiformis, Asplenium theciferum, and Coleochloa abyssinica* on canopy, *Polystachya cultriformis, Diaphananthe fragrantissima, Diaphananthe tenuicalcar and Microcoelia globulosa* on trunk and *Aerangis brachycarpa, Arthropteris orientalis* and *Vittaria volkensii* on basal section of phorophytes in turn did not appear on the same host parts in core zone (Table 4). These all might have resulted from change in microclimatic condition caused by anthropogenic disturbance, which in turn can be expressed by light and moisture availability for epiphyte growth. On the other hand, some epiphyte species such as *Peperomia tetraphylla and Arthropteris monocarpa* were found adapted to be distributed on all vertical sections of phorophytes in all the three zones of Yayu Forest.

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**).**

5.1.2.1 Vertical distribution of epiphytes on coffee trees

Though the proportion of diversity of vascular epiphyte species along disturbance gradient with respect to coffee tree hosts in Yayu Forest is not the same as that of other host plants, still more epiphyte species were registered in semi-forest coffee production system than in core or transition zones. Accordingly, the total numbers of species recorded from coffee host plants in core, buffer and transition zones were 7, 14 and 12 respectively (Appendix 3). The buffer zone is known for its denser host coffee plantation than core or transition zone. On the other hand, natural coffee trees in undisturbed core forest have been mostly grown in dark and shady areas where light is not available for sun-loving epiphytes. These imply that the understorey coffee hosts in shaded core zone became less available for growth of epiphytes than other forest zones, whereas buffer zone is more specious than others and followed by more open transition zone.

Table 4: Vertical distribution of epiphytes on coffee host plants along forest disturbance

	Number of epiphytes on coffee host sections			
Habitats		Basal	Trunk	Canopy
	Core	0	4	4
	Buffer	2	9	13
	Transition	1	9	11

The comparison of vertical distribution of epiphytes on coffee trees along disturbance gradient indicated that species diversity decreases when moving from canopy to basal section of host coffee in buffer and transition zones while the number of species remained the same on both canopy and trunk and even not recorded from basal section in core zone of the forest (Table 5).

Like most shrubs in montane tropical forests, wild coffee hosts a few vascular epiphytes; a function maintained or even increased in the homegardens, where the coffee trees below a tree generally harbored more species than the shade tree itself (Hylander and Nemomissa, 2009). Tree density strongly affects microclimate, and with coffee plantations presumably being drier and sunnier than closed forests, epiphytes favoring exposed microsites are better suited to grow in coffee plantations than shade-adapted species from the lower strata of the forest (Hietz, 2005). Thus, shade coffee plantations can harbor a high diversity of epiphytes and, with the loss of natural forests, have become important refuges for canopy dependent organisms. Hylander and Nemomissa (2009) have stressed the importance of shade-coffee plants for the conservation of epiphytes in that removing coffee trees from any single 200 m^2 home garden plot would reduce epiphytic diversity by 41% on average.

The farmers argued the existence of epiphytes on their coffee trees for they assumed it causes the decline of their coffee yield. However, Sporn *et al.*, (2007) reported, as it is not the case, even for cacao in which the flowers develop directly from the stem and thus might be overgrown by epiphytes.

5.1.3 Host specificity of vascular epiphytes

Most vascular epiphyte species in Yayu Forest were not host specific. Thirty-one species (86.1 %) of the epiphyte in the study area were recorded from two or more phorophyte species. However, five epiphyte species (13.9 %) each were recorded from a single phorophyte species. These are: *Angraecopsis infundibulum, Polystachya cultriformis, Vittaria volkensii, Chlorophytum comosum,* and *Coleochloa abyssinica* (Appenix 4). On the other hand there were no phorophyte species holding only a single epiphyte species, all were supporting at least 2 epiphyte species. It is only one phorophyte species, *Stereospermum kunthianum,* which hosted the least number (2 species) of epiphyte of a single genus (*Polystachya*), *Polystachya bennettiana* and *Polystachya tessellata* (Table 6).

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 24 to 26 vascular epiphyte species are *Albizia schimperiana* and *Sapium ellipticum* each harboring 26 species, *Ficus ovata* holds 25 species and *Albizia grandibracteata* 24 species (Table 6). On the other hand among vascular epiphyte species found distributed on large number of phorophyte species (23-25 species), *Polystachya bennettiana*, *Drynaria volkensii*, *Lepisourus excavatus* and *Pyrrosia schimperiana* each was recorded from 25 host plants**;** *Peperomia tetraphylla* from 24 and *Cyrtorchis erythraeae* from 23 host species (Appendix 4).

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

No	**Phorophyte species**	**Number of epiphyte species**
1	*Stereospermum kunthianum* Cham.	2
2	*Ficus exasperata* Vahl.	3
3	*Ficus mucuso* Ficalho.	3
4	*Vangueria volkensii* K.Schum.	3
5	*Bersama abyssinica* Fresen.	4
6	*Nuxia congesta* R. Bres. Fresen.	4
7	*Vernonia amygdalina* Del.	4
8	*Ficus thonningii* Blume.	5
9	*Spathodea campanulata* P.Beauv.	5
10	*Croton macrostachyus* Del.	6
11	*Polyscias fulva* (Hiern) Harms.	7
12	*Mimosops kummel* A.Dc.	8
13	*Morus mesozygia* Stampf.	8
14	*Prunus africanum* (Hook.f.) Kalkam.	8
15	*Millettia ferruginea* (Hochst.) Bak.	9
16	*Ekebergia capensis* Sparrm.	10
17	*Rothmannia urcelliformis* (Hiern) Robyns.	10
18	*Celtis africana* Burm.f.	12
19	*Ficus lutea*Vahl.	13
20	*Ficus vasta* Forssk.	13
21	*Ehretia cymosa* Thonn.	14
22	*Flacourtia indica* (Brum.f.) Merr.	14

Table 5: Continued…

23	*Antiaris toxicaria* Lesch.	16
24	*Coffea arabica* L.	18
25	*Acacia abyssinica* Hochst. Ex Benth	19
26	*Blighia unijugata* Bak.	19
27	*Cordia africana* Lam.	20
28	*Ficus vallis-choudae* Del.	20
29	*Olea welwitschii* (Knobl.)Gilg&Schellenb.	21
30	*Trichilia dregeana* Sond.	21
31	*Trilepiosium madagascariense* DC.	22
32	*Albizia grandibracteata* Taub.	24
33	*Ficus ovata* Vahl.	25
34	*Albizia schimperiana* Oliv.	26
35	*Sapium ellipticum* (Krauss) pax.	26

The study indicated that five vascular epiphyte species are apparently host specific. However, all the five 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 can not be found every where.

Tesfa Alemayehu (2006) in his study at Harenna Forest of Bale Zone, also reported that 90.9 % of vascular holoepiphyte species were not host specific. According to Tesfa, only two species (9.1 %) were recorded from specific host trees, even from these two species only *Aerangis brachycarpa* was recorded from a single phorophyte while the other species *Liparis diestelii* was from two different phorophyte species. On the contrary, the species *Aerangis brachycarpa* in Yayu Forest was recorded from 13 different phorophyte species. This indicates that either the species is not host specific or there may be factors determining host specificity of some epiphytes in particular forest. This needs further study.

The controversy of host specificity of vascular epiphyte is yet continuing. In some reports, epiphyte species showed marked preferences for host tree (phorophyte) species, whereas in other studies little or no host specificity was seen. Munoz *et al.* (2003) reported that epiphyte species had significant preferences for one or two host tree species. According to this author some epiphytic ferns or angiosperms showed significant preferences for some host tree species, while at the same time rejecting others. The most preferred host trees may have particularly favorable qualities (e.g. trunk and bark characteristics). On the other hand Liu and Xu (2005) and Trapnell and Hamrick (2006) suggested that there was no significant positive relationship between epiphyte species and hosts, although a small number of epiphyte species only occurred on individual trees. Generally, epiphytes occur on a number of different phorophytes, but with variable frequency (Benzing, 1990).

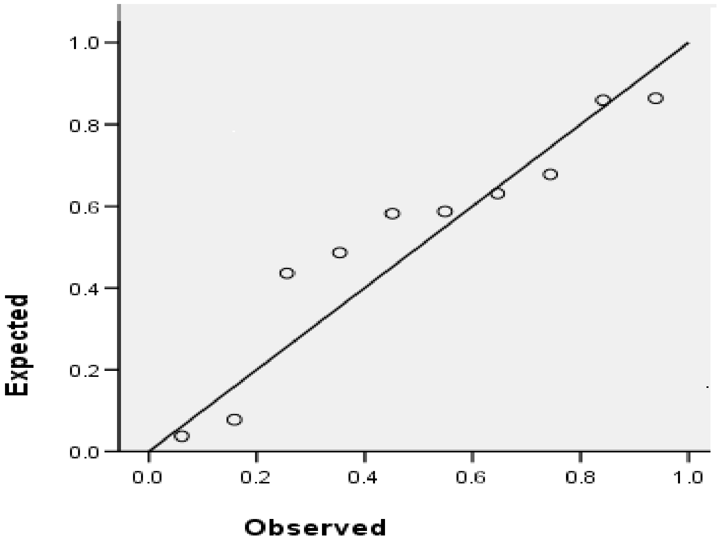
Different authors reported various factors affecting the occurrence of vascular epiphyte species on their host plants. Accordingly, Laube (2006) reported that each potential host tree species offers a different set of architectural traits: branch angles, diameters, chemical and morphological bark characteristics, 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).

5.2 Characteristic structures of phorophyte as a function of diversity of vascular epiphytes

5.2.2 Diameter at breast height (DBH)

The analysis of data collected from phorophytes with different sizes and corresponding number of epiphyte species yielded that Pearson's correlation coefficient is highly significant at less than 1 percent level (r^2 adjusted = 0.69, $p<0.01$). This indicates that DBH and number of epiphyte species are significantly and positively associated. Similarly, a scatter plot showed that there is a linear relationship between number of epiphyte species and host sizes (Fig.6). A 10 cm increase in DBH increases on average the number of epiphyte species by 1.34. The mean vascular epiphyte species count per phorophyte is 23.1 with standard deviation of 4.8 (N = 10) (Appendix 5).



$\mathbf{y} = -0.157 + 1.34\mathbf{x}$ $\mathbf{r}^2 = 0.69$

Where, **y** = No. of epiphytes spp. (expected), **x** = DBH (observed)

Figure 6: Relationship between DBH of phorophytes and number of vascular epiphyte species.

Various authors reported the relationship of phrophytes' DBH and number of epiphyte species and yet all agreed that increase in number of epiphyte species coincides with increasing sizes of phorophytes. Cummings *et al.,* (2006) suggested that tree size relates to several factors that contribute to epiphyte establishment and growth. Larger trees are likely, on average, to be older, allowing more time to capture spores. Furthermore, larger trees in terms of available surface area, likely capture more water than small trees, an essential determinant of epiphyte distribution. Liu & Xu (2005) also reported that a significant positive relationship was found from the association between trunk size and epiphyte. Major epiphytes, especially larger epiphyte species occurred on middle and large stems. Mehltreter *et al.,* (2005) in his study similarly reported that for angiosperm trees, dbh was positively correlated with the number of epiphyte species or epiphyte richness. This is not surprising because large trees offer more surface than small trees and older hosts have been available for a longer time than younger hosts have for epiphyte colonization.

5.2.3 Bark texture of host plants

Qualitative analysis of bark texture was made based on observation (rough / smooth). In this study, the bark texture of phorophyte was classified into two types, rough and smooth. Most of the recorded phorophyte species (80%) possessed rough bark texture while 20% of them were smooth barked (Table 7). Among species of vascular epiphytes recorded from sampled areas of the three management zones of the forest, almost all species 35 (97.2%) were registered from rough barked phorophytes. Of these rough bark dwellers, 27 species of epiphytes were also found to be distributed on smooth barked host plants. However, 8 species were restricted to only rough barked hosts (Table 7). On the other hand, only a single epiphyte species, *Polystachya cultriformis* was restricted to hosts with smooth bark while all the rest epiphyte species on smooth bark were also found to reside on rough barked phorophytes. *Polystachya cultriformis* however, appeared only in one sample plot and on one host plant only. Therefore, it may not be true restriction to a particular bark texture.

The result shows that phorophytes with rough bark held more number of epiphyte species. However, all smooth barks were not necessarily bare as such and therefore support considerable number of species. Different reports 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. A naked bark surface must complicate water and mineral balance just as do thin soils and rock faces (Benzing, 1987). Thus, smoother texture of host bark could explain the lower epiphytic cover compared with rough textures of other tree species in the forest (Munoz, 2003). Rough bark texture of the phorophytes is more convenient for vascular epiphyte species establishment than smooth ones. Age-related changes in bark structure and humus accumulation in the canopy create further diversification of the arboreal habitat (Nadkarni, 2000).

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

No.	**Epiphyte species**	**Bark texture of host species**	
		Smooth	**Rough**
1	*Aerangis brachycarpa* (A.Rich) Th.Dur. & Schinz.	+	+
2	*Angraecopsis holochila* Summerh.	+	+
3	*Angraecopsis infundibulum* Lindl.	-	+
4	*Angraecopsis trifurea* (Rchb.f.) Schltr.	-	+
5	*Bolusiella iridifolia* (Rolfe) Schltr.	-	+
6	*Bulbophyllum lupulinum* Lindl.	+	+
7	*Calyptrochilum christyanum* (Rchb.f) Summerh.	+	+
8	*Cyrtorchis arcuata* (Lindl.) Schltr.	+	+
9	*Cyrtorchis erythraeae* (Rolfe) Schltr.	+	+
10	*Diaphananthe fragrantissima* (Rchb.f.) Schltr.	+	+
11	*Diaphananthe tenuicalcar* Summerh.	+	+
12	*Microcoelia globulosa* (Hochst.) L.Jonsson.	-	+

Table 6: Continued…

13	*Polystachya bennettiana* Rchb.f.	+	+
14	*Polystachya cultriformis* (Thou.) Sprengel.	+	-
15	*Polystachya eurychila* Summerh.	+	+
16	*Polystachya fusiformis* (Thou.) Lindl.	-	+
17	*Polystachya lindblomii* Schltr.	+	+
18	*Polystachya steudneri* Rchb.f.	+	+
19	*Polystachya tessellata* Lindl.	+	+
20	*Tridactyle bicaudata* (Lindl.) Schltr.	+	+
21	*Drynaria volkensii* Hieron.	+	+
22	*Lepisourus excavatus* (Willd.) Ching.	+	+
23	*Loxogramme abyssinica* (Baker.) M.G.Price.	+	+
24	*Peleopeltis macrocarpa* (Bory ex Willd.) Kaulf.	+	+
25	*Pyrrosia schimperiana* (Mett.ex Kuhn.) Alston.	+	+
26	*Asplenium aethiopicum* (Burm.f.) Bech.	+	+
27	*Asplenium sandersonii* Hook	+	+
28	*Asplenium theciferum* (Kunth.) Mett.	+	+
29	*Peperomia abyssinica* Miq.	+	+
30	*Peperomia molleri* C.Dc.	+	+
31	*Peperomia tetraphylla* (G.Forst.) Hook&Arn	+	+
32	*Arthropteris monocarpa* (Cordem.) C.Chr.	+	+
33	*Arthropteris orientalis* (Gmel.) Posth.	+	+
34	*Vittaria volkensii* Hieron	-	+
35	*Chlorophytum comosum* (Thunb.) Jaeq.	-	+
36	*Coleochloa abyssinica* (Hochst.ex.A.Rich) Gilly		+
Total		28	35

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 Johannsson (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).

5.3 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 1300 m-1700 m altitudinal ranges. A concentration of vascular epiphytes occurred around height of 1351 m-1500 m a.s.l., after which slight oscillations of distribution up the increasing altitude were shown with general decreasing pattern of number of epiphyte species along altitudinal gradient (higher number of species in lower altitude and lower number in higher altitude) (Fig. 7). 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 such as *Polystachya eurychila*, *Polystachya steudneri*, *Drynaria volkensii* and *Arthropteris monocarpa* were found distributed throughout the altitudinal gradient. Some others, *Angraecopsis infundibulum* and *Polystachya cultriformis* were restricted to the lowest altitudinal range of the sampled area. The third groups *Asplenium theciferum*, *Polystachya fusiformis*, *Angraecopsis holochila* and *Vittaria volkensii* were found to be at higher altitude (Appendix 6).

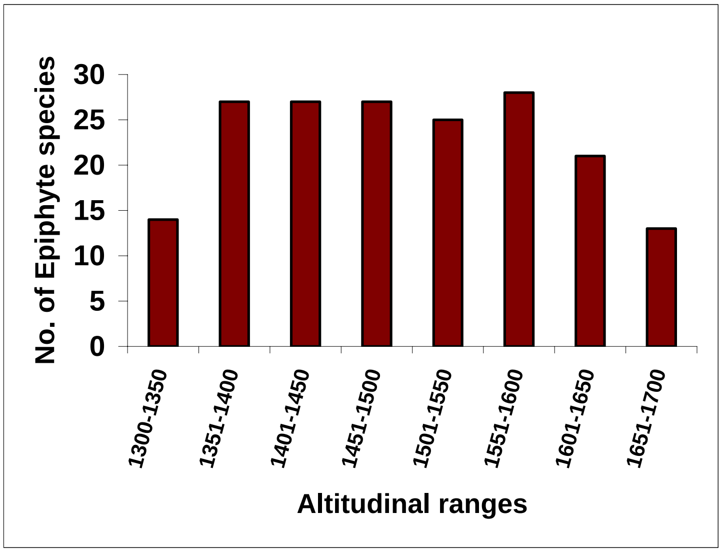


Figure 7: Altitudinal distribution of vascular epiphyte species.

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 Biologioca 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 elevational ranges of many species is higher at mid-elevations than for the lower and higher elevations Cardelús *et al.* (2006).

5.4 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. twelve phorophyte species belonging to nine families were found existing in transition zone of the forest (Table 8). Among those phorophytes inhabiting agricultural matrix, *Albizia schimperiana* and *Acacia abyssinica* were the most frequently appearing shade trees together with their abundant understorey coffee trees and they harbor larger number of vascular epiphyte species. On the other hand, though each coffee tree has hosted a few vascular epiphytes, the collective effect of cluster of host coffee trees 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 coffee shade trees in transition zone should have are: absence of alelopathic effect on undergrowth coffee plants, presence of smaller leaves that can allow the passage of light, rain water and air through, for example such as *Albizia schimperiana and Acacia abyssinica.* Trees with broad leaves should be taller enough to allow the passage of light and air at least on the sides, and some shrubs such as *Vernonia amygdalina* increase soil fertility and also have some other domestic values. Farmers believe that the leaf of *Vernonia amygdalina* for example, will increase soil fertility and then their crop yield when cut and distributed over ploughed farmland.

Table 7: Lists of phorophyte species in transition zone

No	**Phorophyte species**	**Families**
1	*Coffea arabica* L.	Rubiaceae
2	*Trichilia dregeana* Sond.	Meliaceae
3	*Ficus ovata* Vahl	Moraceae
4	*Trilepisium madagascariense DC.*	Moraceae
5	*Ficus thonningii* Blume	Moraceae
6	*Cordia africana* Lam.	Boraginaceae
7	*Albizia schimperiana* Oliv.	Fabaceae
8	*Acacia abyssinica* Hochst.ex Benth.	Fabaceae
9	*Sapium ellipticum* (Krauss) Pax.	Euphorbiaceae
10	*Vernonia amygdalina* Del.	Asteraceae
11	*Spathodea campanulata* P.Beauv.	Bignoniaceae
12	*Olea welwitschii* (Knobl.)Gilg&Schellenb.	Oleaceae

Wolf (2005) suggested that disturbance is measured as the proportion of coppice trees and had a negative effect on epiphyte biomass and species richness per ground surface area. Nevertheless, epiphytes show resilience to disturbance if forests are selectively logged to spare big trees. Such trees constitute keystone structures that offer refuge and enhance connectivity for forest organisms, and provide nuclei of regeneration (Hietz, 2005). They may also serve as nearby epiphyte seed sources for the re-growing trees. Anthropogenic disturbances also force a shift to more drought tolerant epiphyte species (Wolf, 2005). 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.

6. CONCLUSIONS AND RECOMMENDATION

6.1 Conclusion

The method of collecting data to study epiphyte remains a challenge, particularly to those developing, tropical countries. This has impeded the initiatives of making inventory to epiphyte diversity in our forests.

Yayu Forest is a type of Afromontane rain forest. It is one of the most important forests that have been apparently left intact in the southwest Ethiopia. It harbors many animals and plant life. Vascular epiphytes and wild coffee are among the large constituent flora of the forest. However, high forest disturbance were observed in the study area, which caused the change in species diversity and composition of vascular epiphytes along disturbance gradient. This shows that epiphytes are good indicators of disturbance and climatic change. In general, species diversity of vascular epiphytes in Yayu Forest is low; when compared with other tropical forests.

There are strong relationships between vascular epiphyte presence /absence and environmental variables. Some of the variables are: forest disturbance, vertical gradient of microclimate on single host plant, DBH and bark texture of phorophytes, and l elevation a.s.l. The change in species composition of vascular epiphyte is associated with the changes in these variables.

Yayu Forest was divided in to three management zones, based on their level of disturbances: core zone, buffer zone and transition zone respectively with their increasing level of disturbance. The result of this study demonstrated that as epiphyte life is tied to host plants that provide them mechanical support; their number of species is relatively higher in core zone and buffer zones than transition zone where only few remnants isolated trees together with coffee trees were supporting considerable but relatively less number of epiphyte species. The distribution of epiphyte species has shown an increasing trend from the stem base to upper crown of phorophyte but decreasing from lower to higher altitudes. The host size (DBH) has an effect on number of epiphyte species; the larger the size of phorophytes the more number of epiphyte species on it. Tree bark structure also influence the number of epiphyte species, in that rough textures support more epiphytes than smooth ones.

Though high epiphyte diversity is associated with natural closed forest, the present study showed that the most diverse epiphyte communities are not necessarily associated only with the most closed sites, as is generally believed. The complex interactions of many mechanisms appear to foster high epiphyte diversity even in semi-(open) forest habitat. Furthermore, it is believed that little disturbance increases species diversity. Human disturbance serves as a catalyst for promoting change (and perhaps a short term increase) in diversity by increasing habitat diversity (Nkongmeneck 2002).

The isolated remnant shade trees in agricultural matrix with its coffee trees play an important role as forest species repositories. This indicates that vascular epiphyte species found on both shade trees and their coffee trees were all recorded from forest interior. Thus, the tradition of growing coffee under old shade trees is probably an important reason for the relatively good conservation of many epiphytes.

6.2 Recommendation

This finding will have a significant motivational role for researchers in Ethiopia, who always have been restricted to floristic study of non-epiphytic flora. It suggests that floristic expression of vascular epiphytes in tropical forests is considerable; even in the forests strongly influenced by human interference. The result indicated the influence of anthropogenic disturbance on epiphyte communities and the necessity of forest conservation. Human disturbance appeared to prevent the succession of epiphyte community. The study also highlighted the potential diversity of vascular epiphytes in Yayu Forest that was unstudied before.

The increasing human interference is becoming a big challenge to Yayu Forest in general and vascular epiphytes in particular. Therefore, it is recommended that:

- Since epiphytes are vulnerable to any disturbances causing deforestation, they are good indicators of changes in forest structure. Therefore, any reafforestation or *in situ* conservation should consider the establishment of of vascular epiphytes in newly growing forest.

- The Local human community is highly dependent on the forest for coffee 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 coffee farmland. On the other hand, the organizations called ‘Geba-Dogi Forest Coffee Conservation Project’ and ‘Ethiopian Coffee Forest Forum (ECFF)’ together with governmental organizations such as Agricultural Offices, Police Stations and Judiciary Offices were working to teach and train local people about forest conservation and also protect the forest. Still, it needs highly integrated and participatory method of sustainable conservation. Thus all stakeholders should be equally worried in general and Government in particular.

- The Local people have indigenous knowledge of forest conservation. Larger isolated shade trees have been conserved together with their undergrowth coffee trees and other plant species in their garden and farm for decades. Thus, the diversity of coffee management systems, which include traditional polycultures with a range of shade trees, should be encouraged. Because old and large trees support more diverse epiphytes, preserving such trees is an important contribution to maintaining biodiversity in general and serves as refuges for vascular epiphyte species in particular. Thus, the knowledge should be encouraged and promoted to reforestation of disturbed areas.

- The study of epiphyte diversity and distribution is yet not undertaken for many Ethiopian forests; except some reports from the study of vascular epiphytes in Harenna forest of Bale Zone of Oromia Regional State and the study of Homegarden coffee as a repository of epiphyte biodiversity around Bonga Town, southwest Ethiopia. The present study may be part of our trial that attempted to study vascular epiphytes in Yayu Forest. Thus, investigation of these ecologically important parts of our forests should not be taken aside.

7. REFERENCES

Annaselvam, J. and Parthasarathy, N. (2001). Diversity and distribution of herbaceous vascular epiphytes in a tropical evergreen forest at Varagalaiar, Western Ghats, India. *Biodiv. and conserv.* **10**:317-329.

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. (2004). Diversity and biogeography of vascular epiphytes in Western Amazonia, Yasunı´, Ecuador. *J. Biogeogr.* **31**: 1463–1476.

Barthlott, W., Schmit-Neuerburg, V., Nieder, J., Engwald, S. (2001). Diversity and abundance of vascular epiphytes: a comparison of secondary vegetation and primary montane rainforestin the Venzuelan Andes. *Pl. Ecol.* **152:** 145-156.

Belinchon, R., Martinez, I. (2007). “Edge effects on epiphytic communities in a Mediterranean Quercus pyrenaica forest.” *J. veget.Sci.* **18**(1): 81-90.

Bennet, B.C. (1986). Patchiness, diversity, and abundance relationships of vascular epiphytes. *Selbyana* **9**: 70–75.

Benzing, D. H. (1987). Vascular epiphytism: taxonomic participation and adaptive diversity. *Ann. Miss. Botan. Gard.* **74**(2): 183-204.

__________(1990). *Vascular Epiphytes: General Biology and Related Biota*. Cambridge University Press. New York. NY. 354 pp.

__________(1995). *Vascular epiphytes*. 225–254 pp. In: Lowman, M. D. & Nadkarni, N. M. (eds.). *Forest canopies*. Academic Press, San Diego, CA.

__________(1996). *Epiphytes.* In: Richards, P.W. (ed.), *Tropical rain forests*, second ed. Cambridge University Press, London.

__________(2004). *Vascular epiphytes*.175-211 pp. In: 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.

Benzing and Pridgeon (1983). Foliar trichomes of pleurothallidinae (Orchidaceae). 173-180pp. In: Benzing, D. H. (1987). Vascular epiphytism: Taxonomic participation and adaptive diversity. *Ann.miss.botan.gard*. **74**(2): 183-204.

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.

Bittner, J. and Trejos, J. (1997). Analysis of the vascular epiphytes of tree ferns in a montane rainforestin Costa Rica. *Tior. Aplicsc.* **4** (2)-73.

Bussmann, W. R. (2001). Epiphyte diversity in a tropical Andean forest, Ecuador. *Ecotro.* **7:** 43-59.

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.

Cardelús, L. C., Colwell, R. K. and Watkins, J. E. (2006). Vascular epiphyte distribution patterns: explaining the mid-elevation richness peak. *J. Ecol.* **94:** 144–156.

Collins, M. (1990). The Last Rain forests. 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.

Cowling, S. A., Maslin, M. A. and Sykes, M. T. (2001). Paleovegetation simulations of lowland Amazonia and implications of Neotropical allopatry and speciation. *Quatern. Resear.* **55:** 140–149.

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 rainforestNyungwe 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, 1990: Tropical countries*. FAO forestry paper 112, FAO, Rome.

Fayle, M. T., Chung, Y. C., Dumbrell, A. J., Eggleton, P., and Foster, W. A. (2009). The Effect of rainforestcanopy architecture on the distribution of epiphytic ferns (Asplenium spp.) in Sabah, Malaysia. *Biotro.* **11**(11): 1–6.

Flores-Palacios, A., & J. G. García-Franco. (2003). Effect of isolation on the structure and nutrient budget of oak epiphyte communities. *Pl. Ecol.* **1736:** 259–269.

Friis, I. (1992). Forest and Forest Trees of Northeast Tropical Africa: Their natural habitats and distribution pattern in Ethiopia, Djibouti and Somalia. *Kew. Bull. Add. Ser*. **15**:1-396.

Gentry, A. H., and Dodson, C. H. (1987). Diversity and biogeography of Neotropical vascular epiphytes. *Ann. Miss. Botan. Gard.* **74**(2):205–233.

Gillespie, T. W. (2002). Species richness and cover of orchids and bromeliads on an active volcano. *Selbyana.* **22**(2): 192- 196.

Given, D. R. (1993). Principles and practice of plant conservation. Chapman & Hall, London.

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.

Hepcan, S. (2000). A methodological approach for designating management zones in Mount Spil National Park, Turkey. *Environ. Manag.* **26**: 329-338pp.

Hickey, J. E. (1994). A floristic comparison of vascular species in Tasmanian oldgrowth mixed forest with regeneration resulting from logging and wildfire. *Austral. J. Botan.* **42**: 383–404.

Hietz, P. (1999). Diversity and conservation of epiphyte in a changing environment *URL*: ©1999 *IUPAC*.

_______(2005). Conservation of vascular epiphyte diversity in Mexican coffee plantations. *Cons. Biol.* **19**: 391–399.

Hietz, P. and Hietz-Seifert, U. (1995^{a}). Structure and ecology of epiphytic communities of a cloud forest in central Veracrucz, Mexico. *J. Veget. Sci.* **6**: 719-728.

Hietz, P., Buchberger, G. & Winkler, M. (2006). Effect of forest disturbance on abundance and distribution of epiphytic bromeliads and orchids. Vienna, Austria. *Ecotro.* **12**: 103-112.

Hooper A. E. and Haufler. H. C. (2006). Genetic diversity and breeding system in a group of Neotropical epiphytic ferns (pleopeltis; polypodiaceae). *Amer. J. Bota.* **84**(12): 1664–1674.

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. *Selbvana.* **17**: 88- 103.

Johannsson, D. H. (1974). Ecology of vascular epiphytes in West African rain forest. Acra. Nigeria. *Phytogeogr.* Suec. **59**: 1-136.

Kreft, H., Ko¨ster, N., Ku¨per, W., Nieder, J. and Barthlott, W. (2004). Diversity and biogeography of vascular epiphytes in Western Amazonia. Yasunı´, Ecuador. *J. Biogeogr.* **31**: 1463–1476.

K¨oster, N., Kreft, H., K¨uper, W., Nieder J. & Barthlott W. (2005). Andes versus Amazon – patterns of vascular epiphyte diversity on different spatial scales. In: proceedings of 4th international canopy conference Germany.

Kress, W. J. (1986). The systematic distribution of vascular epiphytes: An update. *Selbyana*. **9:**2–22.

Kro¨mer, T. (2003) Diversita¨t und O¨ kologie der vaskula¨ren Epiphyten in prima¨ren und sekunda¨ren Bergwa¨ ldern oliviens, PhD dissertation. University of Go¨ttingen, Go¨ttingen. In: Kreft, H., Ko¨ster, N., Ku¨per, W., Nieder, J. and Barthlott, W. (2004**).** Diversity and biogeography of vascular epiphytes in Western Amazonia. Yasunı´, Ecuador. *J. Biogeogr.* **31**: 1463–1476.

Laman, T. (1995). Safety recommendations for climbing rainforesttrees 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.

Laurance, W. F. (2007). Have we overstated the tropical biodiversity crisis? *Trends Ecol. Evol*. **22**:65- 70.

Liu, W. J. and Xu, H. (2005).Species diversity and spatial distribution of epiphytes in a montane moist evergreen broad-leaved forest. In: proceedings of 4th international canopy conference. Leipzig, Germany.

Lowman, M. D. (2001). Plants in the forest canopy: Some reflections on current research and future direction. *Pl. Ecol.* **153**: 39–50.

Madison M. (1977). Vascular epiphytes: Their systematic occurrence and salient features. *Selbyana*. **2**(1): 1-13.

Marin, C. M. A. (2006). Establishment, reproduction and genetics of epiphytic bromeliad communities during premontane forest succession in Costa Rica. Institute for biodiversity and ecosystem dynamics (IBED). Amsterdam University. 198 pp.

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.

Migenis, L. E. and Ackerman, J. D. (1993). Orchid-phorophyte relationships in a forest water shade in Puerto Rico. *J. Trop. Ecol.* **9**: 231-240.

Mojiol, A. R., Jitinu, 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., Chacon, P., Perez, F., Barnert, S. E. and Armesto, J. J. (2003). Diversity and host tree preference of vascular epiphytes and vines in a temperature rainforestin southern Chile. *Austral. J. Bot.* **51:**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.

__________(2000). Colonization of stripped branch surfaces by epiphytes in a lower montane cloud forest. Monteverde, Costa Rica. *Biotro.* **32**:358-363.

Nkongmeneck, B-A (2002). Epiphyte diversity in primary and fragmented forests of Cameroon central African: preliminary survey. *Selbyana* **23**(1): 121-130.

Otero, J. T., P. Bayman, and J. D. Ackerman. (2005). Variation in mycorrhizal performance in the epiphytic orchid *Tolumnia variegata* in vitro: the potential for natural selection. *Evol. Ecol.* **19**: 29–43.

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.

Parker G. G. (1995). Structure and microclimate of forest canopies. In: Bader, M. (1999). A study on the distribution of vascular epiphytes in a secondary cloud forest. Central cordillera, Colombia. MSc. thesis, Wageningen University, Colombia. Costs Rica.

Reynolds, A. (2003). Epiphytes of the tropics. Miami University. Pre-course presentation of topic, Costs Rica. 1-6 pp.

Schubert, S. T. (1990). Epiphytic bromeliads on Florida trees. Plant pathology circular. 333 pp.

Sebsebe Demissew, Cribb, P., and Rasmussen, F (2004). *Field guide to Ethiopian orchid*. 1-300 pp.

Sillett, S. C. (1999). Tree crown structure and vascular epiphytes distribution in Sequoia Sempervirens rainforestcanopies. *Selbyana*. **20**(1): 76–9.

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.

Tadesse Woldemariam (2003) Conservation and use of coffee genetic resources in Ethiopia: challenges and opportunities in the context current global situations.1-23 PP.

__________(2003). Vegetation of the Yayu Forest in southwest Ethiopia: Impact of human use and implications for *in situ* conservation of wild *Coffea Arabica* L. population. *Ecol.and develop. Ser.* **10:** 1-163.

ter Steege, H. (2003). Long-term changes in tropical tree diversity: Studies from the Guiana Shield, Africa, Borneo and Melanesia. Wageningen, the Netherlands, Tropenbos. *Tropen. Ser.* 22.

ter Steege, H. and J. H. C. Cornelissen. (1989). Distribution and ecology of vascular epiphytes in lowland rainforestof Guyana. *Biotro.* **21**(4): 331–339.

Tesfa Alemayehu (2006). Diversity and ecology of vascular epiphytes in Karenna afromontane forest, Bale, Ethiopia. MSc. thesis, Addis Ababa University, Ethiopia.

Trapnell, D. W., and J. L. Hamrick. (2006). Variety of phorophyte species colonized by the Neotropical epiphyte, *Laelia rubescens* (Orchidaceae). *Selbyana*. **27**: 60-64.

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.

Werner, A. F. (2009). Effects of human disturbance on epiphyte assemblages in the Andes of Ecuador. Dissertation. Georg-August-Universität Göttingen. *Biodiv. and Ecol. Ser. B.* **2**: 1-154.

Whitmore, T. C. and Sayer J. A. (1992). *Tropical Deforestation and Species Extinction.* Chapman and Hall, London.

Whittaker R. H. (1972). Evolution 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. (2005). The response of epiphytes to anthropogenic disturbance of pine-oak forests. **212**: 376–393pp. In: proceedings of 4th international canopy conference Leipzig, Germany.

Wolf, J. H. D., Gradstein, S. R. and Nadkarni, N. M. (2009). A protocol for sampling vascular epiphyte richness and abundance. *J. Trop. Ecol.* **25**:107-121.

Zapfack, L., Nkongmeneck, B., Villiers, F. J. and Lowman, M. (1996). The importance of pteridophytes in the epiphytic flora of some phorophytes of the Cameroonian semi-deciduous rain forest. ***Selbyana*** **17**: 76-81.

Zotz, G., (1995). How fast does an epiphyte grow? *Selbyana*. **16:** 150–154.

________(1997). Substrate use of three epiphytic bromeliads. *Ecogr.* **20**: 264-70 pp.

Zotz, G., and P. Hietz (2001). The physiological ecology of vascular epiphytes: current knowledge, open questions. *J. Exper. Botany.* **52**: 2067–2078.

Zotz, G. and B. Vollrath (2003). The epiphyte vegetation of the palm Socratea exorrhiza - correlations with tree size, tree age, and bryophyte cover. *J. Trop. Ecol.* 19: 81-90.

Zotz, G., Laube, S. and Schmidt, G. (2005). Long-term population dynamics of the epiphytic bromeliad. Werauhia sanguinolenta. *Ecogr.* **28**: 806-814.

8. APPENDICES

Appendix 1: List of Phorophyte species in Yayu Forest

No	**Phorophyte species**	**Families**	**Vernacular Name**
1	*Rothmannia urcelliformis (Hiern) Robyns.*	Rubiaceae	Bururi Dima
2	*Coffea arabica* L.	Rubiaceae	Buna
3	*Vangueria volkensii* K.Schum.	Rubiaceae	Bururi adi
4	*Trichilia dregeana* Sond.	Meliaceae	Luya
5	*Ekebergia capensis* Sparrm.	Meliaceae	Sombo
6	*Ficus mucuso* Ficalho.	Moraceae	Harbu (small fruit)
7	*Ficus lutea*Vahl.	Moraceae	Doqo Adii
8	*Ficus ovata* Vahl.	Moraceae	Doqo
9	*Trilepisium madagascariense DC.*	Moraceae	Loko guracha
10	*Ficus vasta* Forssk.	Moraceae	Ogda
11	*Ficus vallis-choudae* Del.	Moraceae	Harbu (big fruit)
12	*Ficus exasperata* Vahl.	Moraceae	Balantai
13	*Antiaris toxicaria* Lesch.	Moraceae	Dangi
14	*Morus mesozygia* Stampf.	Moraceae	Sacho
15	*Ficus thonningii* Blume.	Moraceae	Dambi
16	*Cordia africana* Lam.	Boraginaceae	Wadesa
17	*Ehretia cymosa* Thonn.	Boraginaceae	Ulaga
18	*Albizia grandibracteata Taub.*	Fabaceae	Alale
19	*Albizia schimperiana* Oliv.	Fabaceae	Ambabessa
20	*Millettia ferruginea* (Hochst.) Bak.	Fabaceae	Sotallo
21	*Acacia abyssinica* Hochst.ex Benth.	Fabaceae	Sondi
22	*Croton macrostachyus* Del.	Euphorbiaceae	Bakanisa
23	*Sapium ellipticum* (Krauss) pax.	Euphorbiaceae	Bosoqa
24	*Blighia unijugata* Bak.	Sapindaceae	Chuhcu
25	*Vernonia amygdalina* Del.	Asteraceae	Dhebicha
26	*Polyscias fulva* (Hiern) Harms.	Araliaceae	Kariso
27	*Mimosops kummel* A.Dc.	Sapotaceae	Qolati
28	*Flacourtia indica* (Brum.f.) Merr.	Flacourtiaceae	Akuku
29	*Spathodea campanulata* P.Beauv.	Bignoniaceae	Muka dire-D
30	*Stereospermum kunthianum* Cham.	Bignoniaceae	Botoro
31	*Bersama abyssinica* Fresen.	Melianthaceae	Lolchisa
32	*Olea welwitschii* (Knobl.)Gilg & Schellenb.	Oleaceae	Baha
33	*Prunus africanum* (Hook.f.) Kalkam.	Rosaceae	Homi
34	*Nuxia congesta* R. Bres. Fresen.	Loganiaceae	Qayisa
35	*Celtis africana* Burm.f.	Ulmaceae	Cayi

Appendix 2: Vertical distribution of epiphytes on coffee hosts along disturbance gradient

No	Scientific Name	Core Zone			Buffer Zone			Trans. Zone		
		B	T	C	B	T	C	B	T	C
1	*Aerangis brachycarpa* (A.Rich) Th.Dur.& Schinz.	-	-	-	+	+	-	-	+	-
2	*Angraecopsis holochila* Summerh.	-	-	-	-	-	-	-	-	-
3	*Angraecopsis infundibulum* Lindl.	-	-	-	-	-	-	-	-	-
4	*Angraecopsis trifurea* (Rchb.f.) Schltr.	-	-	-	-	-	-	-	-	-
5	*Bolusiella iridifolia* (Rolfe) Schltr.	-	-	-	-	-	+	-	+	+
6	*Bulbophyllum lupulinum* Lindl.	-	-	-	-	-	-	-	-	-
7	*Calyptrochilum christyanum* (Rchb.f) Summerh.	-	-	-	-	-	-	-	-	-
8	*Cyrtorchis arcuata* (Lindl.) Schltr.	-	-	-	-	-	-	-	-	-
9	*Cyrtorchis erythraeae* (Rolfe) Schltr.	-	-	-	-	-	+	-	-	-
10	*Diaphananthe fragrantissima* (Rchb.f.) Schltr.	-	-	-	-	-	-	-	-	-
11	*Diaphananthe tenuicalcar* Summerh.	-	-	-	-	+	+	-	+	+
12	*Microcoelia globulosa* (Hochst.) L.Jonsson.	-	-	-	-	+	+	-	+	+
13	*Polystachya bennettiana* Rchb.f.	-	-	-	-	-	+	-	+	+
14	*Polystachya cultriformis* (Thou.) Sprengel.	-	-	-	-	-	-	-	-	-
15	*Polystachya eurychila* Summerh.	-	-	-	-	-	-	-	-	-
16	*Polystachya fusiformis* (Thou.) Lindl.	-	-	-	-	-	-	-	-	+
17	*Polystachya lindblomii* Schltr.	-	-	-	-	-	-	-	-	-
18	*Polystachya steudneri* Rchb.f.	-	-	+	-	-	-	-	-	-
19	*Polystachya tessellata* Lindl.	-	-	-	-	-	+	-	-	-
20	*Tridactyle bicaudata* (Lindl.) Schltr.	-	-	-	-	-	-	-	-	-
21	*Drynaria volkensii* Hieron.	-	-	-	-	-	+	-	-	+
22	*Lepisourus excavatus* (Willd.) Ching.	-	-	-	-	-	-	+	+	+
23	*Loxogramme abyssinica* (Baker.) M.G.Price.	-	-	+	-	+	+	-	-	-
24	*Peleopeltis macrocarpa* (Bory ex Willd.) Kaulf.	-	-	-	-	+	+	-	+	+
25	*Pyrrosia schimperiana* (Mett.ex Kuhn.) Alston.	-	-	-	-	+	+	-	+	+
26	*Asplenium aethiopicum* (Burm.f.) Bech.	-	+	-	+	+	+	-	+	+
27	*Asplenium sandersonii* Hook	-	+	-	-	-	-	-	-	-
28	*Asplenium theciferum* (Kunth.) Mett.	-	-	-	-	-	-	-	-	+
29	*Peperomia abyssinica* Miq.	-	-	+	-	-	-	-	-	-
30	*Peperomia molleri* C.Dc.	-	-	-	-	-	-	-	-	-
31	*Peperomia tetraphylla* (G.Forst.) Hook&Arn	-	+	+	-	+	+	-	-	-
32	*Arthropteris monocarpa* (Cordem.) C.Chr.	-	+	-	-	+	+	-	-	-
33	*Arthropteris orientalis* (Gmel.) Posth.	-	-	-	-	-	-	-	-	-
34	*Vittaria volkensii* Hieron	-	-	-	-	-	-	-	-	-

Appendix 2: Continued…

35	*Chlorophytum comosum* (Thunb.) Jaeq.	-	-	-	-	-	-	-	-	-
36	*Coleochloa abyssinica* (Hochst.ex.A.Rich) Gilly	-	-	-	-	-	-	-	-	-
	Vertical sum	-	4	4	2	9	13	1	9	11
	Total sum in forest zones	7			14			12		

Phorophyte sections: **B** = basal, **T** = trunk and **C** = canopy

Appendix 3: Lists of epiphytes recorded from numbers of hosted plants

No.	Epiphyte species	Number of hosted plants
1	*Angraecopsis infundibulum* Lindl.	1
2	*Chlorophytum comosum* (Thunb.) Jaeq.	1
3	*Coleochloa abyssinica* (Hochst.ex.A.Rich) Gilly	1
4	*Polystachya cultriformis* (Thou.) Sprengel.	1
5	*Angraecopsis holochila* Summerh.	2
6	*Bolusiella iridifolia* (Rolfe) Schltr.	2
7	*Polystachya fusiformis* (Thou.) Lindl.	3
8	*Angraecopsis trifurea* (Rchb.f.) Schltr.	4
9	*Peperomia abyssinica* Miq.	4
10	*Microcoelia globulosa* (Hochst.) L.Jonsson.	5
11	*Asplenium theciferum* (Kunth.) Mett.	7
12	*Diaphananthe fragrantissima* (Rchb.f.) Schltr.	7
13	*Bulbophyllum lupulinum* Lindl.	8
14	*Calyptrochilum christyanum* (Rchb.f) Summerh.	8
15	*Tridactyle bicaudata* (Lindl.) Schltr.	8
16	*Cyrtorchis arcuata* (Lindl.) Schltr.	9
17	*Aerangis brachycarpa* (A.Rich) Th.Dur.& Schinz.	13
18	*Asplenium aethiopicum* (Burm.f.) Bech.	13
19	*Polystachya eurychila* Summerh.	13
20	*Peleopeltis macrocarpa* (Bory ex Willd.) Kaulf.	15
21	*Polystachya lindblomii* Schltr.	15
22	*Arthropteris orientalis* (Gmel.) Posth.	16
23	*Asplenium sandersonii* Hook	16

Appendix 3: Continued…

24	*Loxogramme abyssinica* (Baker.) M.G.Price.	18
25	*Polystachya tessellata* Lindl.	18
26	*Diaphananthe tenuicalcar* Summerh.	20
27	*Peperomia molleri* C.Dc.	21
28	*Polystachya steudneri* Rchb.f.	21
29	*Arthropteris monocarpa* (Cordem.) C.Chr.	22
30	*Cyrtorchis erythraeae* (Rolfe) Schltr.	23
31	*Peperomia tetraphylla* (G.Forst.) Hook&Arn	24
32	*Drynaria volkensii* Hieron.	25
33	*Lepisourus excavatus* (Willd.) Ching.	25
34	*Polystachya bennettiana* Rchb.f.	25
35	*Pyrrosia schimperiana* (Mett.ex Kuhn.) Alston.	25

Appendix 4: The relationship between number of vascular epiphyte species and host dbh

Description		DBH	**Epiphytes**
DBH	**Pearson Correlation (r)**	1	**.850**(**)
	R Square		.722
	Adjusted R Square		**.688**
	Sig. (2-tailed)		**.002**
	Std. Error of the Estimate		2.66686
	Sum of Squares and Cross-products	82.500	110.500
	Covariance	9.167	12.278
Descriptive statistics	**Mean**	5.5000	**23.1000**
	Std. Deviation	3.02765	4.77144
	N	10	**10**

** Correlation is significant at the 0.01 level (2-tailed).

Appendix 5: Patterns of altitudinal distribution of vascular epiphyte species

No.	Epiphyte species	Altitudinal ranges							
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
1	*Aerangis brachycarpa* (A.Rich) Th.Dur.& Schinz	-	+	+	+	+	+	+	+
2	*Angraecopsis holochila* Summerh.	-	-	-	-	-	+	-	-
3	*Angraecopsis infundibulum* Lindl.	+	-	-	-	-	-	-	-
4	*Angraecopsis trifurea* (Rchb.f.) Schltr.	+	-	+	+	-	+	-	-
5	*Bolusiella iridifolia* (Rolfe) Schltr.	-	+	-	-	+	+	-	+
6	*Bulbophyllum lupulinum* Lindl.	+	+	+	+	-	-	-	-
7	*Calyptrochilum christyanum* (Rchb.f) Summerh.	+	+	-	+	+	+	-	-
8	*Cyrtorchis arcuata* (Lindl.) Schltr.	-	+	+	-	+	-	-	-
9	*Cyrtorchis erythraeae* (Rolfe) Schltr.	+	+	+	+	+	+	+	-
10	*Diaphananthe fragrantissima* (Rchb.f.) Schltr.	-	+	+	+	-	-	-	-
11	*Diaphananthe tenuicalcar* Summerh.	-	+	+	+	+	+	+	+
12	*Microcoelia globulosa* (Hochst.) L.Jonsson.	-	+	+	+	+	+	+	+
13	*Polystachya bennettiana* Rchb.f.	-	+	+	+	+	+	+	-
14	*Polystachya cultriformis* (Thou.) Sprengel.	+	-	-	-	-	-	-	-
15	*Polystachya eurychila* Summerh.	+	+	+	+	+	+	+	+
16	*Polystachya fusiformis* (Thou.) Lindl.	-	-	-	-	-	+	+	-
17	*Polystachya lindblomii* Schltr.	-	+	+	+	+	+	+	-
18	*Polystachya steudneri* Rchb.f.	+	+	+	+	+	+	+	+
19	*Polystachya tessellata* Lindl.	+	+	+	+	+	+	+	-
20	*Tridactyle bicaudata* (Lindl.) Schltr.	-	+	+	+	+	+	-	-
21	*Drynaria volkensii* Hieron.	+	+	+	+	+	+	+	+
22	*Lepisourus excavatus* (Willd.) Ching.	-	+	+	+	+	+	+	+
23	*Loxogramme abyssinica* (Baker.) M.G.Price.	-	+	+	+	+	+	+	-
24	*Peleopeltis macrocarpa* (Bory ex Willd.) Kaulf.	-	+	+	+	+	+	+	+
25	*Pyrrosia schimperiana* (Mett.ex Kuhn.) Alston.	-	+	+	+	+	+	+	+
26	*Asplenium aethiopicum* (Burm.f.) Bech.	-	+	+	+	+	+	+	+
27	*Asplenium sandersonii* Hook	+	+	+	+	+	+	+	-
28	*Asplenium theciferum* (Kunth.) Mett.	-	-	-	-	+	+	+	+
29	*Peperomia abyssinica* Miq.	-	+	+	+	-	+	-	-
30	*Peperomia molleri* C.Dc.	+	+	+	+	+	+	+	-
31	*Peperomia tetraphylla* (G.Forst.) Hook&Arn	+	+	+	+	+	+	+	-
32	*Arthropteris monocarpa* (Cordem.) C.Chr.	+	+	+	+	+	+	+	+
33	*Arthropteris orientalis* (Gmel.) Posth.	-	+	+	+	+	-	-	-
34	*Vittaria volkensii* Hieron	-	-	-	-	-	+	-	-

Appendix 5: Continued…

35	*Chlorophytum comosum* (Thunb.) Jaeq.	-	-	-	+	-	-	-	-
36	*Coleochloa abyssinica* (Hochst.ex.A.Rich) Gilly	-	-	+	-	-	-	-	-
		14	27	27	27	25	28	21	13

Classes of altitudinal ranges: **A** = 1300-1350, **B** = 1351-1400, **C** = 1401-1450, **D** = 1451-1500, **E** = 1501-1550, **F** = 1551-1600, **G** = 1601-1650, **H** = 1651-1700

DEDICATION

This thesis is dedicated to both my mother Ade **Giditu Gamachu** and father Obo**Tafa Etisa** who had devoted their precious lifetime to care for their children (us); however, passed away before we tried to lend a hand and make them take a rest while alive, a black scar in heart of kin.

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 duly acknowledged.

Author: ______________________________________
Abuna Tafa

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

Thesis Advisors: ______________________________________
Prof. Sileshi Nemomissa

____
Dr. Tadesse Woldemariam

Place: Department of Bioilogy, Addis Ababa University

Date: July 2010