Bryophytes in a Changing Landscape: Diversity, Use and Response to Different Land Management Systems in Tulu Korma, in Central-West Ethiopia

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ABSTRACT

The study was conducted at landholdings of the Center for Indigenous Trees Propagation and Biodiversity Development of Ethiopia (Restoring) and its surrounding area at Tulu-Korma, in central-west Ethiopia. In an Ethiopian context, there are largely limited studies on the bryophytes as an integral part of the natural vegetation and key component of ecosystem function. Although the floristic studies of Tulu Korma were carried out previously, bryophytes and their ecosystem services were not included. The current study was focus on the water interception capacity of selected taxa of this group. To measure species richness and dominance in bryophyte communities, we have used 24 quadrats, each having a size of 10 m^2. To investigate water interception capacity, we selected four taxa. All statistical analyses were carried out by R-2.15 Window and inbuilt Ms Excel. A total of 56 taxa of bryophytes were recorded from the study area. While the proportion of mosses is 44, that of liverwort is 11 and hornwort 1. Epiphytic bryophytes are the most microhabitat of bryophytes in the study area. The bryophyte community of the study area is grouped into five types. From selected four moss species, Leptodontium latifolium showed the highest water holding capacity over a period of 4 weeks. To have a high number of bryophyte species, restoring areas need to have key physical features such as moist ground, refugia with distinct microclimate, different substrata. It is only a small part of the Tulu Korma shrubland which is restoring leaving the larger area to disturbances such as cutting trees, encroachment of agricultural fields and heavy grazing by livestock. If the current trend continues, the micro-refugia of bryophytes inside the Carissa spinaru and Maytenus arbutifolia thickets will be lost with their associated bryophyte species and their ecological functions. Therefore, the Restoring area should also include the remaining area and restoration effort should also expand to this unrestored portion of this shrubland.

Keywords: Bryophytes, Habitat, Land management, Microhabitat, Refugia, Substratum, Tulu-Korma, Water interception capacity

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ACRONYMS

AAU	Addis Ababa University
Agr.	Agriculture
ENMSA	Ethiopian National Meteorological Station Agency
ETH	National Herbarium
EPV	Equivalence perception value
GPS	Geographical Position System
LCITPBD	Landholdings of the Center for Indigenous Trees Propagation and Biodiversity Development
ma.s.l	meters above sea level
WIC	Water interception capacity

CHAPTER ONE

1. Introduction

1.1. Background and Justification

Integrating biodiversity based activity is imperative for sustainable land use. Biodiversity related issues are set in the global context (Ramesh, 2003). However, the ongoing deforestation and habitat degradation in the tropics continue to cause losses of highly diverse flora and fauna (Myers *et al.*, 2000; Achard *et al.*, 2002; Laurance *et al.*, 2002). As alternative, timber plantations and agro forests may have a superficially similar structure to natural forests. Such cultivated forests have been suggested to provide surrogate habitats serving as tools in tropical biodiversity conservation (Greenberg, 1998; Barlow, *et al.*, 2007). On the present study site at Tulu Korma this kind of activities are currently being performed. Ethiopia is one of the most important centers of biodiversity (Misrak Tafesse, 2007), and is placed as having the fifth largest flora in tropical Africa (Eshetu Yirdaw, 2002). Currently, its place at the top level is going to change as a result of conversion of natural forests into arable lands and threat to its biodiversity. Biodiversity describes the variety of living organisms at different scales, including within-species diversity, between-species diversity, as well as diversity of ecosystems and diversity of the ecological processes which they sustain (Gaston & Spicer, 2004). Species diversity is considered to be one of the key parameters characterizing ecosystems and a key component of ecosystem functioning (Schulze & Mooney, 1994, Loreau, *et al*, 2002, Scherer-Lorenzen, *et al.*, 2005).

Bryophytes are an integral component of forest ecosystems and represent a characteristic part of the plant species diversity (Lesica, *et al.*, 1991). They are also being threatened through different ways.

Habitat destruction is in many countries the major threat to mosses, especially to species with narrow ranges and endemics. Deforestation is unquestionably a major factor in destroying vast areas of bryophytes habitat. Habitat conservation is therefore the only way to prevent a decline in many tropical taxa.

Human activity directly and indirectly influences environmental conditions causing changes in landscapes. Tropical forest is continually being invaded and encroached upon by an expanding human population, for habitation and use in agriculture (Hallingback & Hodgetts, 1996). Agriculture, urbanization, recreation, roads and many other human impacts cause loss of natural habitats. Natural habitats become increasingly fragmented into more numerous, but smaller remnant patches. Many plant species have declined as a result of habitat destruction, fragmentation and reduction and this influences the structure of bryoflora by altering natural habitats.

Bryophyte richness and community structure have been related to forest management (Pharo &Blanks, 2000; Pharo and Beattie, 2001; Humphrey, *et al.*, 2002; McGee &Kimmerer, 2002; Ross-Davis & Frego, 2002; Fenton & Frego, 2005) and land use intensity in agricultural landscapes (Zechmeister & Moser, 2001; Andersson &Gradstein, 2005). Forest management can have dramatic effects on biological diversity and has been shown to result in fragmentation and changes in age structure of forest stands across the landscape (Frisvoll & Prestø, 1997). The extirpation of managed forests altered temperature and humidity regimes resulting from canopy removal (Saunders, *et al.*, 1991) may exceed the tolerance limits for some of these bryophytes, especially those requiring high humidity (Busby, *et al.*, 1978; Söderström, 1988) and (or) specific moist substrates such as rotting wood (Lesica, *et al.*, 1991; Frisvoll &Prestø,1997; Rambo & Muir, 1998). Owing to their morphological and dispersal limitations, (Söderström, 1988; Herben, *et al.*, 1991), most bryophytes have very narrow habitat ranges and the managed landscape may present dispersal barriers for reestablishment (Frisvoll & Prestø, 1997) and are thus, extremely sensitive to changes in the quality of their habitat (Hallingbäck & Hodgetts, 2000: Vitt & Wieder, 2009). If species are lost locally, recolonization can occur only if propagules can cross large, presumably inhospitable, clear-cut areas to reach suitable available microsites (Fenton, *et al.*, 2003).

The degradation and loss of suitable habitats are the most serious threats to species worldwide (Millennium Ecosystem Assessment, 2005). Especially, clear-cut logging in particular can lead to marked changes in forest structure and function and to local extirpation of plant and animal species (Duffy & Meier, 1992; Halpern & Spies, 1995).

Anthropogenic changes in the structure of forest habitats generally involve canopy-thinning activities that are accompanied by increases in air circulation and solar radiation in lower vegetation layers, with consequent microclimatic changes (Green, *et al.,* 1995; Thomas, *et al.,* 1999). Thinning may also result in changed stem flow of precipitation water (Ford & Deans, 1978; Dietz *et al.,* 2006), with possible consequences for the epiphytic flora on tree trunks. Bryophytes are the most common corticolous epiphytes, of which indicator values for environmental changes have been evaluated in a wide variety of landscapes (Drehwald, 2005; Holz & Gradstein, 2005; Larsen, *et al.,* 2007). Because of their sensitivity to environmental changes, occurrences of bryophyte species have been related to microclimatic changes that relate to vegetation type (Vellak & Paal, 1999; Newmaster & Bell, 2002; Gonzalez-Mancebo, *et al.,* 2004; Pharo, *et al.,* 2004). Furthermore, the richness and composition of bryophyte communities may indicate forest quality in terms of forest structure and resource availability. In tropical America, no less than 30–50% of the occurring bryophyte species was lost after deforestation (Sillett, *et al.,* 1995; Acebey, *et al.,* 2003; No¨ske, *et al.,* 2008).

Currently, one of the most important focuses of ecology is an attempt to understand how worldwide deforestation affects the abundance, richness and distribution of organisms by neglecting old growth forest functions.

Old growth forests are a significant and unique part of the diverse ecological web formed by natural forest landscapes. As an important part of the landscape ecology of natural forests, old growth provides unique resources for plants and animals (including people) within the landscape (Harris, 1984). The timber industry generally encourages logging of "decadent" old growth forests so that they can be replaced by "vigorous" young tree farms. However, the unique structure and composition of old growth forests facilitate several critical ecological functions which cannot be duplicated in short rotation commercial tree farms. According to (Franklin, *et al.,* 1981) old growth forests generally contain an accumulation of biomass on the forest site, provide a continuous supply of diverse, durable structures (large trees, snags, and fallen trees) which enrich the forest soil over time and provide habitat for diverse plant and animal communities, high quality, naturally filtered water from stable creeks. These structures remain after natural events destroy an old growth forest and provide diversity in younger forests. Several species of bryophytes and lichens (particularly epixylics; species growing on wood) are dependent upon old-growth forests for their survival.

The total area of available habitat is the primary factor determining species abundance and landscape levels of biodiversity (Noss, 1996). In present study area landscape become extremely disturbed via anthropogenic related effects and change into smaller patches (refugias). Therefore, mostly bryophyte species thrive on refugia especially on managed forest landscape. The importance of refugia is increasingly being recognized (Ashcroft*, 2010).

During the subsequent recovery process such refugia constitute important biological legacies, which might play a crucial role as internal recolonization sources during the ecosystem recovery process (Franklin & McMahon 2000; Peterson & picket, 2000; Fuller & del moral, 2003) after all ecosystem are able to recover from disturbance. While the term ''refugia'' generally denotes restricted areas where species can survive inhospitable periods, ''biological legacies'' is a broader term that includes refugia, surviving individuals (Folke, *et al.*, 2002), as well as structures such as dead wood or soil profiles (del Moral & Eckert, 2005), which may influence the subsequent succession. Successional studies on species in mesic sites would be of particular interest because mosses may be more sensitive indicators of livestock grazing effects than vascular plants (Borchert & Norris, 1991).

Nevertheless, refugia did not contribute relict species to the adjacent vegetation, provided habitats for newly invading species to establish dense populations from which to expand (Moral, *et al.*, 2005). Refugias are areas where ecosystems are unaffected by, or Restoring from, stressors or disturbances that reduce resilience. Refugia help to maintain diversity and abundance by serving as sources for replenishing the disturbed populations that underpin connectivity, and serve as stepping stones for maintaining connectivity across larger scales. Important features of refugia include sufficient location and separation distances to ensure connectivity, adequate extent to provide sufficient source populations, and inclusion of comprehensive and representative examples of the different habitats within a region (Hughes, *et al.*, 2003 & 2007; Mumby, *et al.*, 2006).

Tulu Korma is the site of landholdings center for indigenous trees propagation and biodiversity development. Due to extreme expansion of agricultural practices and livestock grazing, land degradation is the main visible phenomena in this study site. Grazing-favoured successional bryophyte decrease (Austrheim, et al., 2007). Consequently, study area is characterized by disturbance plant floristic particularly unrestored remnant forest area.

There are many studies related to indigenous and endemic tree species of Ethiopia on a degraded site in central-west Ethiopia (Misrak Tafesse, 2007). However, bryofloristic composition and vegetation type plus detailed botanical components and ecological studies are needed to understand the ecosystem services of this area assemblage and to undertake appropriate comparison of bryophyte responses to different land management systems on the study is also a reason for urgent investigation side by side. The aim of this study is to ascertain the influence of management on bryophyte diversity in different land management types. Thus, the present study was initiated to answer the following questions: (1) does forest management affect species numbers of different bryophyte groups similarly? (2) does forest management influence the species composition of bryophytes in land management type? (3) their differences on the bryo- diversity (plant species richness) and structure of the bryophytes floristic composition along the three landscapes. Moreover, the study expressed the activities of LCITPBD in relation to conservation of biodiversity.

1.2. Objectives

1.2.1. General Objectives

To study bryophyte diversity in response to different land management at Tulu Korma Forest.

1.2.2. Specific Objectives

- To document the bryological diversity of the study area through standard taxonomic techniques;
- A comparative study of taxonomic composition of bryophytes among different land management with their microhabitats;
- To determine the distribution of each species across different microhabitat;
- To evaluate water interception capacity of selected taxa of bryophytes (using mosses as a model) in and around the Restoring area of Tulu Korma shrubland;
- To provide baseline information of the bryophytes that would help for further study and changing lenses to increasing awareness of the importance of bryophytes in ecosystems has heightened efforts to conserve rare bryophyte species.

CHAPTER TWO

2. Review literature

2.1. Classification of bryophytes

Liverworts (Hepaticopsida or Hepaticae), hornworts (Anthocerotopsida or Anthocerotae) and mosses (Bryopsida or Musci) are collectively termed as bryophytes. A reasonable estimate suggests the existences of 24, 000 species, of which approximately 14,000, 6,000 and 300 are mosses, liverworts and hornworts, respectively (Asakawa, 2007) and exceeded only by the Magnoliophyta of flowering plants (350,000 species). In contrast, bryophyte diversity in boreal forests often exceeds that of vascular plants at a scale of 0.1 ha, especially in old forests (Berglund & Jonsson, 2001; Dynesius, 2001) and the most successful group of plants other than angiosperms in terms of their numbers of species, geographical distribution on all continents, their habitat diversification, including substrates on which vascular plants cannot live. As a group those familiar species are frequently encountered in mesic forests and along streams, as well as a number of less familiar species of tropical rain forests, arctic tundra, and desert boulders (Mishler, 2001). Many species are able to live in nutrient poor conditions, and are adapted to respond rapidly physiologically to intermittent periods favorable for photosynthesis. And, one could argue that bryophyte gametophytes are among the most "elaborate" of any phylum of plants (Renzaglia, *et al.* 2000).

Bryophytes are unique among land plants in that their dominant stage is the haploid green gametophyte rather than the much shorter-lived diploid sporophyte. They differ from vascular plants in other ways as well, in aspects that make them excellent environmental monitors. In bryophytes, the spore producing stage (the sporophyte) bears a single spore producing organ (the sporangium) that is largely parasitic on the gametophyte. In vascular plants, the sporophyte is generally perennial, physiologically independent, and produces innumerable sporangia. In most bryophytes, the spores are expelled into moving air when the sporangium is mature. The bryophytes share with the tracheophytes the development of an embryo within a multicellular reproductive organ, a covering of sporopollenin on their spores. Bryophytes are not well adapted to terrestrial life because they have no (or rudimentary) vascular tissues, have no guard cells (although some bryophytes have rudimentary stomata), lack true roots or leaves, are seedless (recall a seed is composed of an embryo, nutritive tissue, and a seed coat), and, because they require external liquid water to complete their life cycle because they have flagellated sperm. Bryophytes are distinguishable as plants because the gametophytes of bryophytes have complex and multicellular reproductive organs, the antheridia (male) and archegonia ("female"); the archegonium protects the egg, zygote, and embryo, hence bryophytes are embryophytes.

The three bryophyte groups may not form a monophyletic clade, but they share life history features including dominant free-living gametophytes and matrotrophic monosporangiate sporophytes (Shaw & Renzaglia, 2004 and Shaw, *et al.*, 2011) and distinguished from each other on variations of sporophyte structure and gametophyte morphology. Mosses are the largest of the three lineages of (Shevock, 2003) and the sporangium matures when restoring by the enveloping structures. The hornworts possess a thallose gametophyte in which the sex organs are completely embedded in the thallus. The sporophyte is always horn-shaped and consists mainly of a sporangium that matures from the apex downward to its foot in the thallus. The Hepaticae contain cellular oil bodies which are easily extracted with organic solvents, while the other two classes do not (Asakawa, 2007). Liverworts may also have thallose gametophytes, but most are leafy with leaves in two or three rows (Schofield, 1985).

2.2. Micro- habitat of bryophytes

Bryophytes are found in almost all terrestrial habitats (even in deserts!) but have their greatest diversity and most abundant in moist habitats (Hylander & Dynesius, 2006). Besides, they are also able to withstand cold season up to – 20^0c to 27^0c (Ochi, 1952) rather than vascular plants. Moreover, the stream channel adds a unique habitat for bryophytes which further increases species richness (Dynesius, 2001 and Vieira, *et al.*, 2005). Bryophytes are known to represent a considerable portion of plant diversity within northern forests. This is because bryophyte diversity is closely associated with microhabitat diversity.

Microhabitats are important for understanding bryophyte diversity patterns that are the components of environment upon which bryophytes grow, such as rocks (epilithic), snags & down logs (epixylic), ground (Terricol), epilythic (litter), epiphytic (in terms of stumps and trunks, branches) and epiphylls (Ramsay & Cairns, 2004). Tropical rainforests, especially montane forests, are rich in epiphytic bryophytes (Richards, 1984; Parolly & Ku¨rschner, 2004; Acebey, *et al.*, 2003). Due to the high relative humidity throughout the year, tropical rainforests form an excellent habitat for an epiphytic bryophyte species and epiphytic communities inhabit trees from the base to the outer branches of the canopy (Richards, 1984). Epiphytic bryophytes are known to be sensitive to microclimatic variations (Moe & Botnen, 2000). The most important factors affecting the distribution of epiphytic bryophyte species are forest stand age, tree age and diameter (Snäll, *et al.*, 2003; Kantvilas & Jarman, 2004; Johansson *et al.*, 2007), as well as tree species of their bark physical and chemical properties plus microclimate (John & Dale, 1995; Hazell, *et al.*, 1998; Hazell, *et al.*, 1999; Thomas, *et al.*, 2001; Bambe, 2002).

The spatial distribution of corticolous bryophytes is therefore determined by a network of fluctuating variables e.g. light intensity, temperature, relative humidity, air currents (Smith, 1982, Franks & Bergstrom, 2000). Terrícolous bryophytes (species of mosses, liverworts and hornworts that grow exclusively on the ground) play important roles in many ecosystems, including in grasslands (Thomas *et al.*, 2006).

Dead wood is another bryophyte ecology which is an important component of the forest ecosystem. The most important functional groups among dead wood dwelling bryophytes are obligatory dead wood species (true epixylics) or facultative dead wood species (epiphytes, terricolous and rupicolous species) that occur in all stages of dead wood and on other substrates. Decay stages, diameter of log and habitat humidity are factors determining epixylic bryophyte species richness (Humphrey, *et al.*, 2002). Unmanaged and managed forests differ considerably in the quality of dead wood (Söderström, 1988; Rambo & Muir, 1998; Kruys et al., 1999; Jonsson, 2000; Ódor & Standovár, 2001,) and their importance for bryophytes are expressed (Gustafsson & Hallingbäck, 1988; Lesica, *et al.*, 1991). A severe lack of deadwood in managed forests and inappropriate protected area management are key reasons for biodiversity loss areas.

Most bryophytes live on rocks and on decaying logs. Bryophyte vegetation was richer in the near-natural stand, especially in the moist rocky site (Ódor & Standovár, 2001). They are the secondary colonizers on barren rocks next to lichens in plant. The rainfall availability, size and texture of rocks are determinant agents to inhabit bryophyte species.

2.3. Significance of bryophytes

Even though, bryophytes have multipurpose, still they are neglected largely because of little direct commercial significance. Bryophytes are very important for the function and structure of an ecosystem. Bryophytes (mosses, liverworts, and hornworts) make up a significant portion of the biomass and annual production in temperate rainforests (Vitt, *et al.,* 1988). They play important ecological roles in hydrological cycle of an ecosystem, (i.e., they trap rain fall and duly release it to forests and facilitate the gradual drainage of water to the soil, as a result of play to prevent soil erosion while at the same time reducing the evaporation of water, making more available for succeeding plants) (Boucher & Nash, 1990; Norris, 1990;), and nutrient cycling (Nadkarni, 1985). Many bryophyte species demonstrate wide geographical distribution, grow under diverse ecological conditions, and often are pioneers in extreme habitats. Bryophytes are often good indicators of environmental conditions. They are also known to be sensitive to precipitation chemistry and air quality (Hawksworth & Hill, 1984). Consequently, they are crucial components of the long-term ecological monitoring rehabilitation of forest (Hutten, *et al.,* 2005). The survival of seed plant vegetation is also intimately linked to the bryophyte vegetation. Bryophytes are important in the retention of soil moisture, nutrient recycling, and seedling survival, as well as for providing habitat for other organisms that are vital for vegetation health.

Undoubtedly, those species played an important biota forming role in the settlement of land by plants (Troitsky, *et al.*, 2007). Besides these, also have great value for economical, medicinal, indicators of pollution and natural habitat quality, cultural and aesthetic qualities and as a food web for animals has been illustrated (Hallingbäck and Hodgetts, 2000; Saxena and Harinder, 2004). In all rainforest environments, bryophytes provide microhabitats and refugia for invertebrates and microorganisms, and sites for egg-laying and nurseries for insect larvae. Growth forms such as mats, cushions or pendent provide surfaces important for harvesting water from cloud and storing minute quantities of nutrients from exudates and droppings of insect larvae that are released slowly as lactates over time. The massive, often overhanging mats and cushions of epiphytic bryophytes cover forest trees, provide valuable sources as growing substrate and nutrition pool to entire communities of vascular epiphytes such as ferns and orchids, and serve as breeding and nesting space for wide ranges of animals such as birds, amphibians and insects (Richards, 1984). They also contribute to humus accumulation, all important to the maintenance of the rainforest as an ecosystem (Ramsay and Cairns, 2004). Furthermore, epiphytic bryophytes have the ability to store high amounts of precipitation water, causing a "delayed release" and to dissolve nutrients with capillary structures (Pócs 1976; Longton 1984; Clark et al. 2005; Köhler *et al.*,2007), thereby contributing to the stability of the forest ecosystem (Frego, 2007).

Bryophytes act as best bioindicators and biomonitors of environments consequently used as indicators of pollution and natural habitat quality. They have been used to monitor airborne pollution. Many are pioneer plants, growing on baré rock and contributing to soil development. Lacking transport tissue and a true cuticle they readily absorb whatever is around them and can serve as bio-indicators of pollution and environmental degradation caused by emissions from factories and absences of mosses, and most liverworts from urban areas is strongly correlated with air pollution (Gilbert, 1968; Hawksworth and Rose, 1970).

CHAPTER THREE

3. Materials and Methods

3.1. Study area

3.1.1. Description of the Study Area

The study is conducted within the landholding of the Center for Indigenous Trees Propagation and Biodiversity Development (Restoring) and surrounding area at Tulu-Korma (Ejere Wereda, West Shewa Zone, Oromia Region) – (Fig. 1.) Tulu-Korma is located at $09^{0}01'$ N latitude and $38^{0}\ 21'$ E longitudes and is about 3 km from Addis Alem. It is situated at about 50 km from Addis Ababa (Misrak Tafesse, 2007). The altitude of the study area is between 2153-2263 m a.s.l.

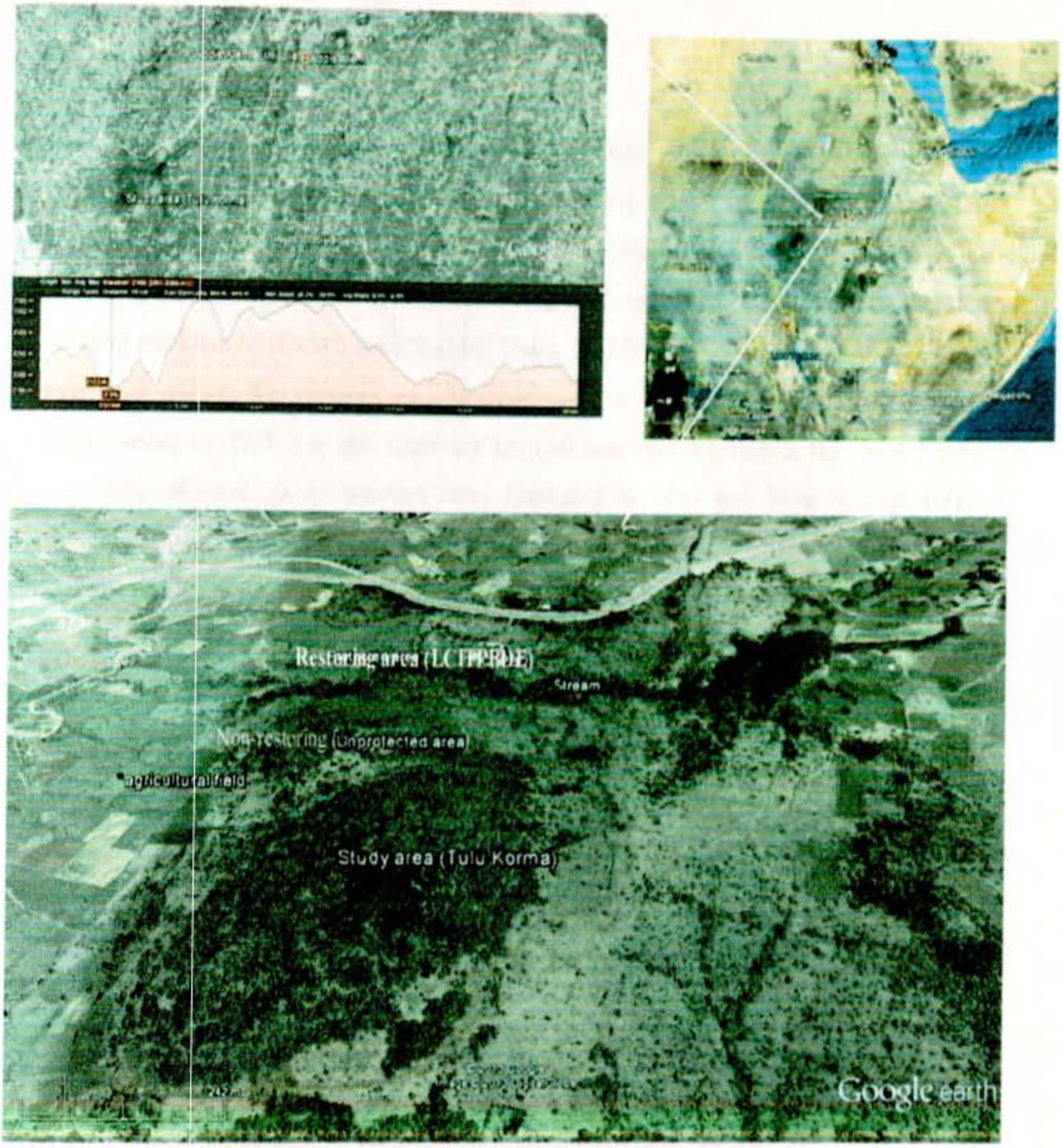


Figure 1: Maps of the study area. A) General overview and altitudinal profile of the study area; B) detail overview showing three lands management types (Restoring, non-restoring and agriculture).

3.1.2. Climate

The rainfall and temperature data for this study were collected from the nearest Meteorological Station, Addis Alem, which is about 47 km away from Addis Ababa. The meteorological data were collected from 2000 - 2009 by National Meteorological Service Agency (NMSA, 2013). Climate diagram was computed by using R for window version 2.10.1 statistical package (R-Development Core Team, 2007).

Tulu Korma falls within the western and bimodal rainfall region of Ethiopia. The mean annual rainfall value is 1094 mm and approach to1100 mm and it receives the short (Belg) rain and the long (Kiremt) rainy seasons from February to May and June to September, respectively. The mean maximum and minimum temperatures of the area are 26.0^{0}C and 7.1 ^{0}C, respectively. It has also a mean annual temperature of 16.8 ^{0}C (Fig.2).

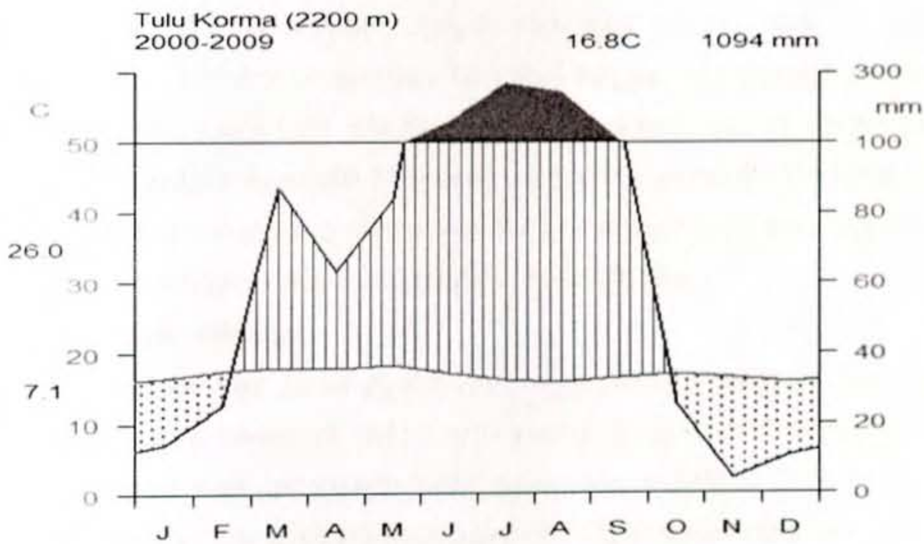


Figure 2: Climadiagram of Tulu Korma Site

Data Source: Ethiopian National Meteorological Station Agency (from 2000 to 2009).

3.2. Materials

Required materials that used during the actual plant data collection in the field and laboratory were folded papers, plastic bags, GPS, digital camera and aperture plastic containers, water, beam balance, plastic materials, respectively.

3.3. Methods

3.3. 1. Reconnaissance survey

Reconnaissance survey was started on August, 2012 in order to obtain an impression of the site conditions and to select sampling sites.

3.3.2. Sampling method

Systematic and random sampling designs were used for this study to collecte bryo-vegetation data. A total of 24 quadrants from Restoring and non-restored shrub land area of Tulu Korma were established. The Restoring quadrant has a size of 100 m^2 gap between each plot in managed forest was 10 m along each of the quadrants. Sample collected from Restoring area collected along stream whereas for managed areas were from the scattered microclimate modulated refugia with the help of the GPS (Fig.1).

Taxonomic data collection

Bryophyte species were collected from the entire areas of the three land management systems: Restoring, unrestored and strips (margins) of agricultural fields the surrounding areas. Specimens were collected in folded papers and brought to ETH for identification. Each key character was dissected and studied both under a dissecting and compound light microscope. The nomenclature of the bryophyte taxa is based on (Sloover and Chuah-Petiot, 2003). The identification was confirmed by an expert, Prof. Kristoffer Hylander (Stockholm University). All voucher specimens were correctly labeled and incorporated into the existing bryophyte collections of ETH.

3.3.3. Water interception capacity

Four different mosses species were selected for this study; three epiphytic and one terricol. The selection was based on the local abundance of these species. The same dry weight (10 g) of each species was considered for further water interception capacity study. Each sample was hold in aperture plastic container and saturated with water. Afterwards, they were left for half an hour on plastics materials until the excess water trickled down. Then, each samples were removed from the plastic material, the water remover from samples via aperture and left to stand at Green House Condition. This practice continued repeatedly for three consecutive initial days of every week. Each sample on the last day of week was weighted on a beam balance after drying. This experiment was repeated for one month. Water holding capacity over this time was calculated for each species.

3.3.4. Bro-vegetation data collection from microhabitats

Sample collection took place in September- October 2012. The habitat types were categorized into six (Table 1) and each type are characterized. These are rocks, snags & down logs, ground, litter, epiphytic and Riparian.

Table 1: Criteria used to define and characterize the six microhabitats investigated.

Microhabitat	Criteria
Rocks	Detached stone
Snags & down logs	Any dead woody debris
Epiphytic	Includes stumps, trunks and branches
Litter	Covered decomposed leaves and twigs
Riparian	Includes special water flow area
Ground	Forest floor not occupied by other microhabitats

At each plot, the total number of microhabitat types was determined. But for stream sides selective sites were proportially selected to ensure comparison among habitat types in terms of species diversity.

For each of the six habitat types, bryophytes species presence and abundance was determined using a grid composed of 10 m × 10 m^2. The abundance of each species in each square was recorded.

The presence-absence and cover abundance data, defined here as the proportion of area in a quadrat covered by every species recorded and gathered from each quadrat were later converted to cover abundance values using the modified 1-9 Braun- Blanquet scale (van der Maarel, 1979) as follows.

- 1: Rare, generally one individual;
- 2: Occasional, with less than 5% cover of the total;
- 3: Abundant, with less than 5% cover of the total;
- 4: Very abundant, with less than 5% cover of the total;
- 5: 5-12% covers of the total area;
- 6: 12-25% covers of the total area;
- 7: 25-50% covers of the total area;
- 8: 50-75% covers of the total area;
- 9: 75-100% covers of the total area;

3.4. Data analysis

3.4.1. Floristic data

Hierarchical cluster analysis is one of the most commonly used multivariate techniques to analyze community ecological data. It helps to group a set of observations (vegetation samples) together, based on their floristic similarities (Kent and Coker, 1992). For this study, agglomerative hierarchical classification using similarity ratio cluster analysis was performed using R for windows version 2.15 (Venables *et al.*, 2010) to classify the vegetation into plant community types based on abundance data of the species in each quadrat.

Biological diversity can be calculated in various ways. Species diversity has two basic components: richness, or number of species in a given area, and evenness, or how relative abundance or biomass is distributed among species (Magurran, 2004). In this study, the Shannon-Wiener diversity index, species richness and Shannon's evenness were computed to describe species diversity of the plant community types ((Shannon and Wiener, 1949)).

The Shannon-Wiener diversity index was calculated as follows.

Where, Richness Index (R= S-1/ln n),

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

H' = Shannon diversity index,

S = the number of species,

Pi = the proportion of individuals or the abundance of the ith species expressed as a proportion of total cover and

Ln = Natural logarithm

Evenness (Equitability) J = H'/H' max, where;

J = Evenness,

H' = Shannon-Wiener diversity index and

H' max = lns, where s is number of species

Following Kent and Coker (1992), Sorensen's similarity index was used to determine the pattern of species turnover between the communities. It was being described as follows:-

Ss = **2a/ (2a+b+c) where,** **Ss=** Sorensen's similarity coefficient;

□ **a** = Number of species common to both samples;

□ **b** = Number of species in sample 1 only;

□ **c** = Number of species in sample 2 only

3.4.2. Responses of different land management systems

The responses of bryophytes to land management practices in the study area were compared by comparing species richness. Total species richness was computed for each land management practices by using simple asthmatics embedded in MS Excel.

3.4.3. Water interception capacity

The samples for this study were oven dried and 10 g of each species was taken for further experiment. Four species (1 acrocarpous and 3 pleurocarpous) were selected for this study. The sample that measured in procedure of Simulation of rainfall in nature was dried in an oven at 80^0C and weighed. The water interception capacity of mosses is equal to water uptake after watered divided by dry weight multiplied by 100. This value is the percent water interception capacity (WIC) at one occasion.

$$\text{WIC} = \text{Water uptake after watered} / \text{DW} \times 100$$

This value is the percent water interception capacity (WIC) at one occasion. For practical purposes, this value will be converted into 1 hectare and the number of rainy days will also be calibrated to allow the comparison of WIC of bryophytes with annual precipitation records to be obtained from the meteorological corporation of Ethiopia over 10 years period. This comparison results in the equivalence perception value (EPV) of bryophytes per annum. The EPV is equal to the total percent water interception per hectare multiplied by the number of rainy days. This EPV will answer a question such as how many percents precipitations are intercepted by bryophytes.

CHAPTER FOUR

4. Results

4.1. Bryophyte diversity of the study area

A total of 56 bryophytes species belonging to 43 genera and 28 families are identified from the study area (appendix 2). Out of the total speciies Pottiaceae contributed nine (16.98%); seven Bryaceae (12.5%) species, Hypnaceae, Orthotrichaceae & Thuidiaceae, three (5.35%) species, whilst Bartramiaceae, Brachythecaceae, Fabroniaceae, Fissidentaceae, Frullaniacea e,Lejeuneaceae, Marchantiaceae, Leskeaceae each contributed two (3.57%) species the rest Hedwigiaceae, Dicranaceae, Cryphaeaceae, Entodontaceae, Lunulariaceae, Anthocerotaceae , Meteoriaceae, Plagiochilaceae, Mniaceae, Porellaceae, Racopilaceae, Sematophyllaceae, Targioniaceae, Metzgeriaceae, Neckeraceae each had one species (each contributing 1.78%). Among the total species 44 (78%) are Mosses (Bryopsida), 11 (20%) & one (2%) are liveerworts (Hepaticae) and Hornwort (Anthocerotae), respectively (Fig., 4)

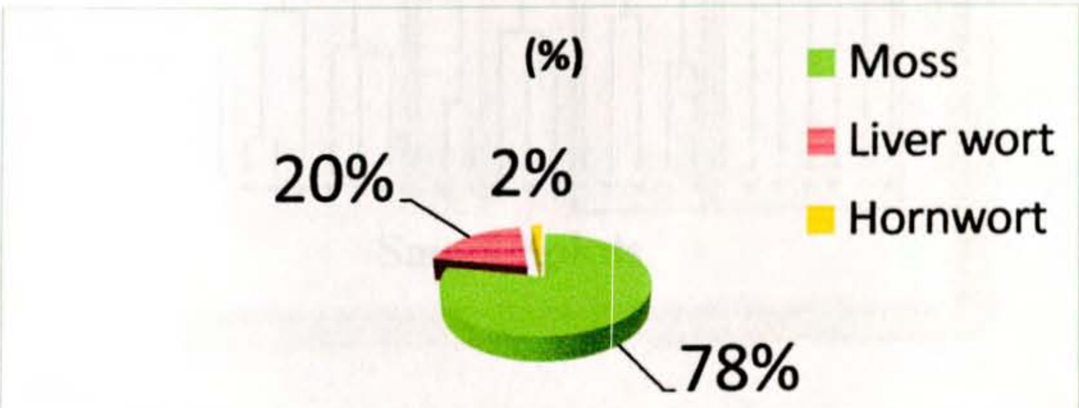


Figure 3 : Proportion of bryophytes group in the study area

4.2. Bryophyte Communities of Tulu Korma

There are five different bryophyte communities (associations) in Tulu Korma forest Site (Figure 5). These bryophyte communities were named based on two indicator species given below. The indicator species were those with highest cover- abundance value for a given community (Table 2). From whole species 52 species were used for vegetation classification. The results from cluster analysis as presented in the R-2.15 statistical data analysis output showed five different communities (clusters) for Tulu Korma forest site (See Figure 5). The communities were described based on their similar bryo - floristic values. The following plant communities were named based on the two indicator bryophyte species.

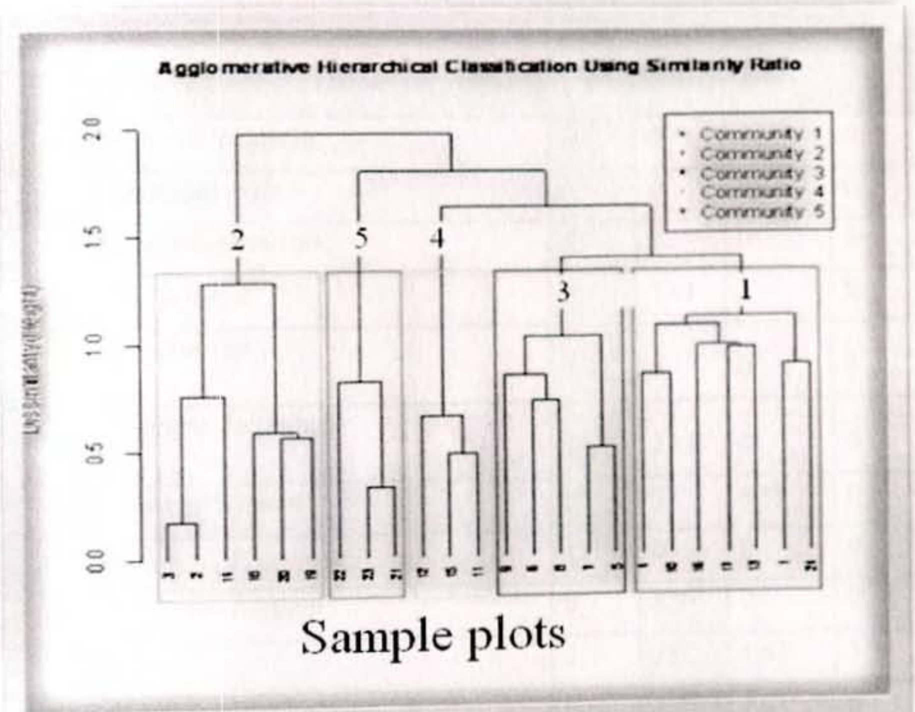


Figure 4: Dendrogram of the clusters (community types) of Tulu Korma Site

The communities contain the following plots,

- **C- 1:** 1,4,10, 13, 16, 17 & 24,
- **C- 2:** 2, 3, 14, 18, 19 & 20,
- **C- 3:** 5, 6,7,8 & 9,

- **C- 4:** 11, 12 & 15, and
- **C- 5:** 21, 22 & 23.

Table 2: Synoptic table of the communities (Figures in bold relate to the indicator species for each representative community).

Indicator Values (% of perfect Indication, based on combining Relative Abundance and Relative Frequency) of each species for each of the five groups and the Monte Carlo test (P*) of the significance observed for each species. (Bold values indicate indicator species at P*<0.05). The highest and lowest Shannon-Wiener values were significantly different since the P=0.05.

		Community Types					
s/n	Species	1	2	3	4	5	P value
1	*Anomobryum julaceum*	**6**	0	0	0	0	0.37
2	*Brachymecium exile*	**6**	0	0.83	0	0	0.37
3	*Didymodon australasiae*	**5**	0	0	0	0	0.32
4	*Fabronia pilifera*	**9**	1.43	1	0	0	0.25
5	*Leptodontium sp.*	**8**	0	0	0	0	0.28
6	*Leptodontium latifolium*	**10**	2.14	0	0	0	**0.03**
7	*Racopilum africanum*	**5**	0	0.83	0	0	0.30
8	*Hypanaceae 1. SP.*	**12**	0	0	0	0	**0.04**
9	*Brachythecium borgeni*	0	**8.57**	0	0	6.67	0.31
10	*Entodon* sp.	2	**25**	1.67	3.33	2.67	0.21
11	*Fissidens sp.*	0	**3.57**	1.67	0	0	0.21
12	*Livierella neckeroides*	0	**5.71**	1.67	0	0	0.19
13	*Macrocoma tenuis*	4	**5**	3.33	6.67	1	**0.01**
14	*Orthotrichum firmum*	2	**3.86**	0	13.33	2.33	0.14
15	*Plagiochila squamulosa*	1	**3.75**	0	0	0	0.26
16	*Racopilum africanum*	2	**4.29**	1.67	0	1	**0.03**
17	*Rhodobryum commersonii*	0	**3.57**	0	0	0	0.37

18	*Entodon* sp.	1	0	**7.5**	8.33	0	0.25
19	*Fissidens sp.*	0	1.43	**3.33**	0	0	0.22
20	*Livierella neckeroides*	0	0	**7.5**	0	0	**0.01**
21	*Lunularia cruciata*	0	2.86	**4.17**	0	0	**0.02**
22	*Lunularia cruciata*	0	0	**10.3**	0	0	0.01
23	*Macrocoma tenuis*	0	0	**4.17**	8.33	1.67	0.17
24	*Macrocoma tenuis*	4	5	**3.33**	6.67	1	0.15
25	*Marchantia polymorpha*	0	0	**6.83**	0	0	0.37
26	*Orthotrichum firmum*	1	1.43	**5.83**	0	0	0.20
27	*Rhodobryum commersonii*	0	0	**5**	0	0	0.37
28	*Rhodobryum commersonii*	1	0.71	**7.5**	0	0	0.27
29	*Anacolia laevisphaera*	0	0	0	**3.33**	0	0.37
30	*Brachythecium borgeni*	0	2.49	2.5	**5**	0	0.37
31	*Didymodon australasiae*	2	0	0	**6.67**	0	**0.01**
32	*Entodon* sp.	1	0	7.5	**8.33**	0	0.15
33	*Fissidens sp.*	2	25	1.67	**3.33**	2.67	0.21
34	*Macrocoma tenuis*	0	0	4.17	**8.33**	1.67	0.17
35	*Macrocoma tenuis*	4	5	3.33	**33.33**	1	0.37
36	*Orthotrichum firmum*	2	3.86	0	**13.33**	2.33	**0.04**
37	*Pilotrichella cuspidate*	0	0	0	**10**	0	0.37
38	*Racopilum africanum*	0	0.43	1.67	**3.33**	0	0.16
39	*Braunia secunda*	0	0	0	0	**18.33**	0.37
40	*Brachythecium borgeni*	0	0	0	0	**5**	**0.03**
41	*Braunia secunda*	0	0	0	0	**10**	**0.04**
42	*Brachythecium borgeni*	0	8.57	0	0	**6.67**	0.31
43	*Brachymecium longicolle*	4	1.43	0.83	0	**9**	0.37

44	*Campylopus pyriformis*	0	0	0	0	**30**	0.37
45	*Hypnum cupressifirme*	0	0	0	0	**3.13**	0.27
46	*Hypnum cupressifirme*	0	0	0	0	**3.33**	0.37
47	*Targionia sps.* (L.)	0	0	0	0	**6.75**	0.37

4.2.1. *Leptodontium latifolium- Hypanaceae* Community Type I

This community type ranks third with regard to species richness and found at the un restored forest area. Its altitude ranges from 2159 – 2263m a.s.l. seven plots were grouped together in this community. There are also 31 species recorded from this community type. In addition to the dominant species (Plate 1), the other associated bryophyte species include *Anomobryum julaceum, Brachymecium exile, Didymodon australasiae, Leptodontium latifolium* and *Racopilum africanum.*

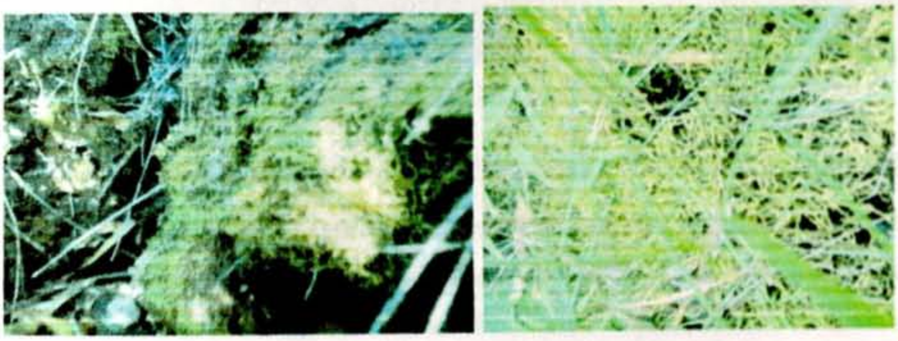


Plate 1: The dominant species of community type 1.

4.2.2. *Macrocoma tenuis- Racopilum africanum* Community Type II

It is the second species rich community type in the study area. It consists of 6 plots and 36 species and falls between 2162 and 2214m a.s.l. The community is entirely confined to the Restoring forest area of Tulu Korma. In addition to the dominant species, the associated bryophyte species in this community are *Brachythecium borgeni, Entodon sp., Fissidens sp*$_1$*, Livierella neckeroides, Orthotrichum firmum, Plagiochila squamulosa and Rhodobryum commersonii.*

4.2.3. *Livierella neckeroides - Lunularia cruciata* Community Type III

The first richest community type in the study area .This community comprises of 5 plots and 43 species distributed between the altitudinal range 2159-2183m a.s.l. This community is found along the river line. In addition to the dominant species (Plate 2), the associated bryophytes species in this community are *Enodon sp., Fissidens*$_{l}$. *Macrocoma tenuis, Marchantia polymorpha, Orthotrichum firmum, Rhodobryum commersonii. Marchantia polymorpha, L. cruciata* and *R. commersonii* are confined to the Restoring part of the study area.

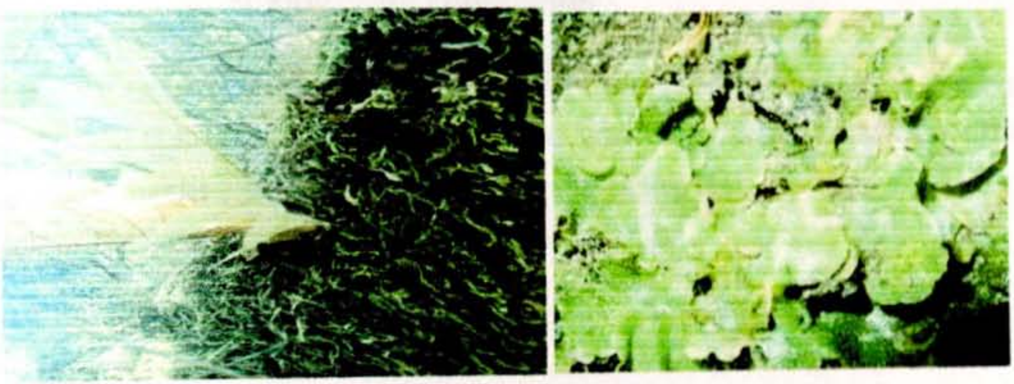


Plate 2: The dominant species of community type Community Type III.

4.2.4. *Didymodon australasiae- Orthotrichum firmum* Community Type IV

It is least rich community type in the study area. This community comprises of 3 plots and 13 species distributed within the altitudinal range from 2171-2186m a.s.l. In addition to the dominant species (Plate 3), the associated bryophytes species in this community are species *Anacolia laevisphaera, Brachymecium longicolle, Enodon sp., Macrocoma tenuis, Pilotrichella cuspidate, Racopilum africanum.*

Plate 3: The dominant species of community type Community Type IV.

4.2.5. *Brachythecium borgeni -Braunia secunda* Community Type V

It is the fourth level richest community type in the study area. This community type is the least species rich of the community types in the area. This community consists of 3 plots and 18 species within the altitudinal range 2187-2238 m a.s.l. The community is found at the highest altitude of submanaged forest area and associate by bryophytes species *Brachymecium longicolle, Campylopus pyriformis, Hypnum cupressifirme, Targionia sps.*

4.3. Similarity among plant communities

Sorenson's similarity coefficient was used to determine the similarities among bryophyte communities (Table 3). Accordingly, Community types 1 and 2 have the highest similarity ratio. Communities 3 and 5 are the least similar in the current study.

Table 3: The Sorensen's similarity of the communities

Similarity among community

Community	1	2	3	4
2	0.59			
3	0.03	0.56		
4	0.26	0.33	0.23	
5	0.49	0.10	0.46	0.23

4.4. Species richness, diversity and evenness of the plant communities

From the five community types, community type 3 has the highest species richness and diversity value but its evenness value is intermediate (Table 4). On the other hand, community 4 has the least species rich and has the lowest diversity index but its evenness value is even greater than community 2 which is much more species rich than it. The highest value of evenness is recorded for community 1 which and the lowest for community 5. It is to be noted that has more species than community 4 but much less than the other communities. Community type 2 is the second least in species evenness. Community type 5 has the second lowest in species richness and diversity but has the least species evenness value.

Table 4: Species richness, diversity and evenness of the communities based on their descending order of richness

Community	Richness	H (diversity)	Shannon Evenness
1	31	3.09	0.90
2	36	2.91	0.81
3	43	3.31	0.88
4	13	2.15	0.84
5	18	2.27	0.79

4.5. Bryophyte species diversity across microhabitat

Species richness on different habitat types and substrates are recorded along each plot (Appendix 3). The most species diverse substrate type is phorophytes (trunks and branches of flowering plants occurring in the study area) (Fig. 6). Epiphytic species and those which are adapted to contact presence of moisture are not recorded from the disturbed part of the study area. On the other hand, terricol bryophytes are the most dominant in selected sites around the study area.

Species richness on different microhabitats and substrates are recorded along each plot (Appendix, 3). The highest species richness conducted from epiphytic microhabitat and followed with terricol and epilithic and the least had show on riparian (Fig.6).

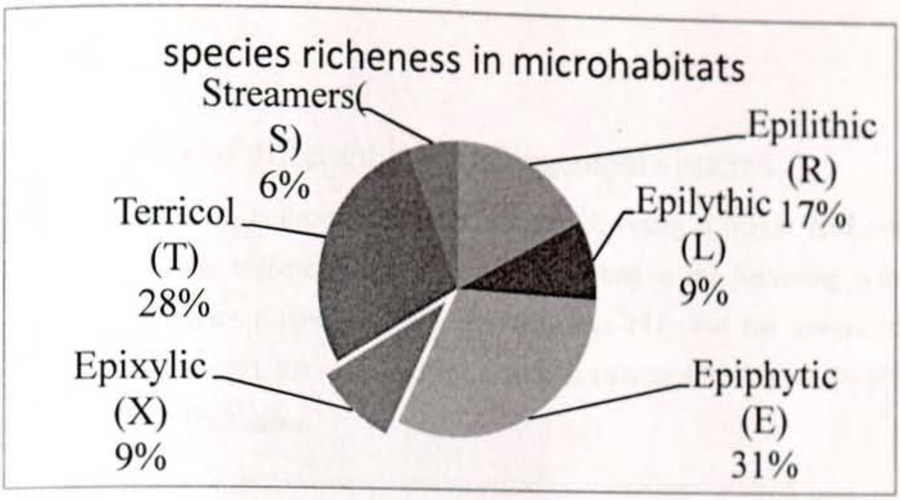


Figure 5: Proportion of species richness dominance in different microhabitat (n=24)

Bryophyte species diversity across microhabitat

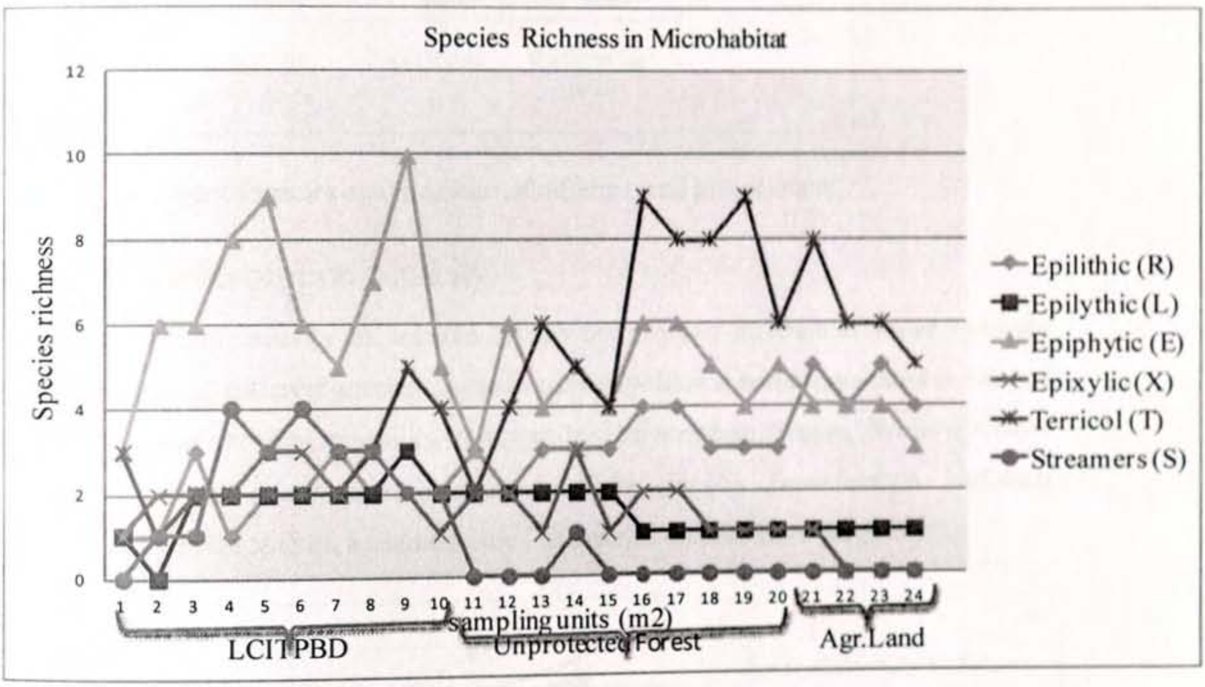


Figure 6: Proportion of species richness dominance in different microhabitat along plots

4.6. Responses of different land management systems

As shown in (Fig. 8), collecting included substrates among different land management landscape that 1) the highest species richness was found in the Restoring area (50), the second highest species richness in non Restored area (41) and the lowest diversity in agricultural landscape (9); the most important families collected from those are pottiaccceae, bryaceae and orthotrichaceae.

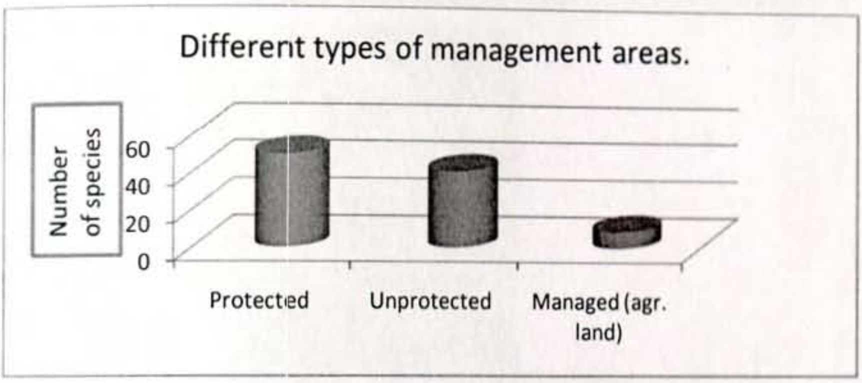


Figure 7: Number of species on the aspects of different land management

4.7. Water interception capacity

Water interception capacity of selected bryophytes displays differential water retention capacity of among different species. *Leptodontium latifolium* is acrocarpus moss is showed the greatest water holding capability, followed by *Orthotrichum firmum, Neckera remota and Orthostichella pandurifolia,* respectively show (fig.10). *Leptodontium latifolium* exhibited the highest lengths, a characteristic that enabled them to cover large areas.

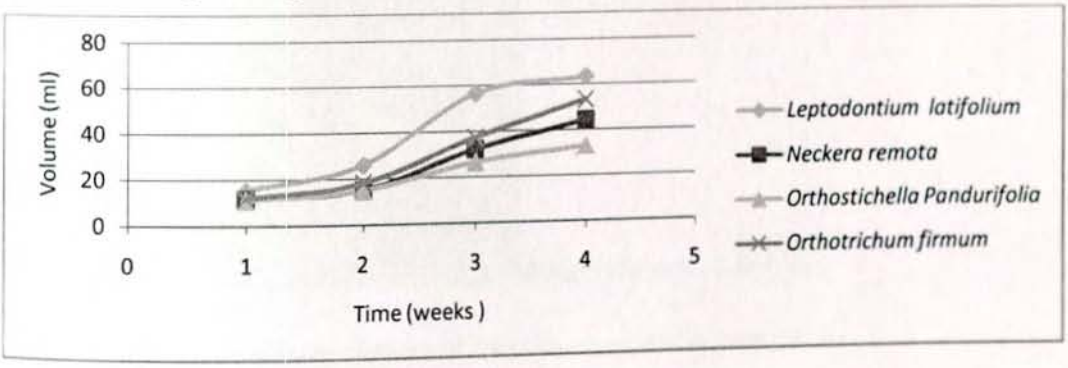
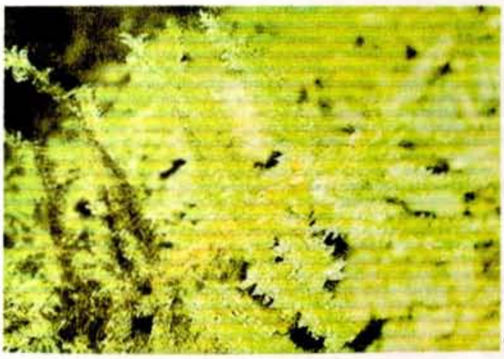


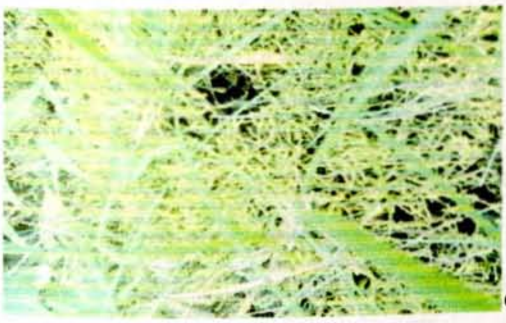
Figure 8: Water interception capacity of mosses.

a) *Orthostichella pandurifolia*

b) *Orthotrichum firmum*



c) *Neckera remota*



d) *Leptodontium latifolium*

Plate 4: The sample pictures of water interception capacity of a-d.

CHAPTER FIVE

5. Discussion, Conclusions and Recommendations

5.1. Discussion

5.1.1. Bryophyte species diversity

Mosses are the largest of the three groups of bryophytes (Shevock, 2003). Among the total species 44 (78.57%) in the study area are Mosses (Bryopsida), 11 (19.64%) & one (1.79%) are liverworts (Hepaticae) and Hornwort (Anthocerotae), respectively. Most of the bryophyte species in the study area are mosses whereas, Liverworts and Hornworts are less diverse and confined at the moist area. Out of 56 bryophytes species, Pottiaceae is largest families of the acrocarpous mosses (Stoneburnner, *et al.*, 1993; Shabbara, 2006; Churchill, 2009), the next is Bryaceae contributed four genera and species and thirdly Hypanaceae, Orthotrichaceae and Thuidiaceae are likewise represented by three species, while most of the other families are represented by one or two infrequent species, restricted to certain microhabitats, regardless of apparently abundant suitable habitat (Sagar and Wilson, 2007) (Appendix 2).

Except for the very small part of Tulu Korma, most parts are mainly grazed by livestock and affected by human activities such as expansion of agricultural land and cutting wood for various uses. Given the isolated stands of trees in the surrounding area and within this shrubland, the current record is lower than previous records from other parts of Ethiopia (personal communication). The 56 taxa recorded are the remnants of the previously relatively richer bryophyte flora. Furthermore, most of these species are also hardy with regard to dessication tolerance. It is also pertinent to note that the high diversity of substrates, microclimates and the stream running across the study area have influenced the current recorded species diversity. The community types (bryophyte associations) patterns and species diversity patterns (*Livierella neckeroides - Lunularia cruciata* community) could also be explained by the same local processes. It is obvious; however, floristic gradients corresponded to altitude, temperature, rainfall, geology and current condition (Whinam, *et al.*, 2003). Altitude could also explain the current observed patterns in the associations of bryophytes of the study area. The observed similarity between communities 1 & 2 could be due to substratum diversity, moisture availability and anthropogenic activities. Variations in their altitude, slope and aspect could be determining the least similarity of communities 3 and 5.

5.1.2. Microhabitat diversity and quality determines species richness

Species-rich sites (microhabitats) are characterized by high habitat quality for all species in certain groups (Hylander & Dynesius, 2006). Usually, natural forest has high diversity of bryophytes if it is conserved form disturbance. In the study area, the natural forest is exposed and the original forest stands are replaced by dense stands of thickets of *Carissa spinarum* and *Maytensu arbutifolia* species particularly at the surround area implies epiphytic mosses decline towards managed area. It is to be noted that the absence of typical epiphytic bryophytes as reported for Ethiopia (Hylander, *et* al., 2010) could be due to high desiccation regime of the study area. These two factors could account for the least diversity of bryophyte species in the stream sides outside the Restoring area of Tulu Korma. On the other hand, phorophytes of various species harboured the highest species diversity of bryophytes at LCITPBD. These phorophytes were located in areas that are unaccessible and well Restoring from sun. Most species of bryophytes were reported to be sensitive to extreme desiccation (Thomas, *et al.,* 2006). The high diversity of terricol is due to the occurrence of old and isolated stands of remnant trees in the study area provided refugia for these species. Most of the unrestoring area is unaccessible and not good for cultivation due to the presence of boulders or rocks. These rocks are highly Restoring from sun and provide a suitable microclimate for the growth and persistence of high diversity of epilithic bryophytes. The importance of moisture (local microclimate) to govern local diversity of bryophytes was reported (Cole, *et al.* 2008).

5.1. 3. The effect of land management on the species diversity of bryophytes

It is significant to determine which landscapes are important for understanding bryophyte diversity patterns. The Restoring forest area is richest in bryophytes diversity rather than the surrounding place, shows the effect of management on different landscape and conservation of bryophytes are extremely related with other type of plant protection. The total diversity was higher in the unmanaged forest than in the managed forest. The presence different microhabitat was the most important factor influencing the species diversity and composition of bryophytes in unmanaged and managed forests. In addition, covers of tree and shrub layer as well as the tree density as an expression of the light conditions were of great importance for the species composition and diversity. Indicator species for unmanaged forests were shade-tolerant, particularly epiphyte bryophytes. Forest management should therefore ensure the continuous presence of large and old, rough-barked trees enhance the diversity of whole bryophytes species particularly epiphytic and moisture habitat species (Friedel, *et al.*, 2006). The total bryophytes species diversity on Restoring area is greater than the disturbed forest area.

5.1.4. Differential water retention capacity of selected moss species

Measuring water interception capacity of different mosses species determine how much water they hold in a given time. Water relationships (water holding capacity, evaporation rate, and desiccation tolerance) in bryophytes are highly variable among species (Elumeeva et al. 2011), and communities (Rixen & Mulder 2005; Michel et al. 2012). It is considered that different life forms of bryophytes were able to store different amounts of interception water. Cushions had a high one, while fans have almost no interception water. Furthermore, water storage of bryophytes was also affected by their morphological and anatomical characters. However, it is to be noted here that the differentiation of biomass and water capacity are strongly affected by many factors in general, such as sampling method, forest structure, elevation, climate (annual rainfall, air temperature, and air humidity), and others (Michel, *et al.,* 2013). Therefore, Knowledge of the water holding capacity of selected species of bryophytes in Tulu Korma is useful for understanding their ecosystem services, especially in terms of the water budget of the study area. Bryophytes are known to slowly release water to the ecosystem, which is pertinent for ecosystem functions.

In the current study, *Leptodontium latifolium* exhibited the highest water interception capacity compared to the three remaining species. This species is also the most abundant in the study area. This trait, i.e., the ability to retain water for long period of time enabled this species to reproduce efficiently and occupy large area of the study area. Similar trends were also reported for epiphytic bryophytes (Hölscher et al. 2004; Pypker et al. 2006). *Orthostichella pandurifolia* has the lowest water interception capacity in the study area and this is due to its fast rate of evaporation (Elumeeva et al. 2011; Michel et al. 2012). When the recorded values of the water interception capacity of bryophytes are calculated over hectares of forest/scrublands per annum, the equivalence perception value (EPV) of bryophyte depicts the amount of precipitation intercepted by bryophytes (Chantanaorrapint & Frahm, 2011). In our case, it is premature to calculate this value due to limited sampling.

5.2. Conclusions

Tulu Korma is the site of landholdings of the center for Indigenous Trees Propagation and Biodiversity Development of Ethiopia. Its flora comprises 56 species in 43 genera and 28 families. Pottiaceae has the highest number of species followed by Bryaceae and Orthotrichaceae and Thuidiaceae.

The vegetation was grouped into five community types each of which had varying degrees of species richness, diversity and evenness. Plant community type 3 has the highest species richness and diversity value while the least evenness and diversity was observed for community type four. The variation among communities could be due to different factors (anthropogenic, altitude, soil moisture factors, substratum, microhabitat, etc).

Bryophyte species grow on six microhabitats of which overall bryophyte richness and abundance on epiphytic and least species richness along the riparian, respectively. Bryophyte richness on the open and managed habitat decline along in the order of the riparian, epiphyte, epilythic, epixylic microhabitats. Microhabitat spatial requirements that forest management incorporate leaving representatives of all forest microhabitats intact during harvest operations. This includes remnant microhabitats left scattered throughout the cut and also left together in unharvested patches that contain as many different microhabitats as possible. This is based on the premise that unharvested patches will act as refugia for bryophyte communities and upon canopy closure, bryophytes will be able to colonize the micro- habitats left scattered throughout the harvest areas.

Considering the floristic changes toward the three land management type, the Restoring forest has the first position for bryophyte richness diversity value followed by non- restoring and agricultural landscape, implies great factor of forest management on bryophyte diversity. The value of forest habitat shows significant difference compared with open habitat (manage landscape).

Much of non- restoring landscape has been permanently altered or destroyed by agricultural activities, and what remains is grazed by livestock as well as being subjected to industrial development pressures (flower industries). The common species for all land management type were not need special requiring to particular microsites which are found everywhere at any microhabitat. In Restoring territories they cannot survive without human activity, i.e. special management that satisfies special requirements of bryophyte species.

On the basis of bryo-vegetation features analyzed in these studies, we did detect changes of bryophyte floristic composition that can be explained by land management interference. Future studies of vegetation should concentrate on intense of bryophyte diversity in LCITPBD area to show its role as a result of protection from any disturbances.

Water holding capacity in bryophytes is highly variable among species through different life forms of bryophytes which are able to store different amounts of interception water even they grow in similar microhabitat, creeping had the higher one, while fans and hanging had low interception water. Furthermore, water storage of bryophytes was also affected by their morphological and anatomical characters. However, it is to be concerned here that the differentiation of biomass and water capacity are strongly affected by many factors in general, such as sampling method, forest structure, elevation, climate (annual rainfall, air temperature, and air humidity), and others.

5.3. Recommendations

Tulu Korma is the Site of Landholdings Center for Indigenous Trees Propagation and Biodiversity Development of Ethiopia. To minimize the present human influence on this unique area Tulu Korma and for the future management of the area in a sustainable manner, the following recommendations are suggested:

- Due the restoration practices at Site of Landholdings Center for Indigenous Trees Propagation and Biodiversity Development of Ethiopia decline biodiversity threat as a result should be more extend to surrounding area.
- To enhance the sustainable use of the area, ethnobotanical studies and exploration of indigenous knowledge on the diverse uses of the plants should be undertaken.
- To maintain habitat for this species by retaining occupied substrate, associated stand and microclimatic conditions near the populations and restricted activities that alter stand and microsite conditions or affect occupied substrate.
- Special conservation measures, such as recommendations for management of the sites with high concentration of rare species and preservation of substrates suitable for bryophyte diversity in non Restoring territories, are needed.
- Further investigation is needed on the patterns of functioning ecosystem; bryophyte diversity with plantation trees.

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APPENDICES

Appendix 1: List of plant species collected from Tulu korma (A= Anthocerotopsida or Anthocerotae, B= Bryopsida & H= Hepaticopsida or Hepaticca).

No.	Species	Genus	Family	Taxo	Coll No.
1	*Anomobryum julaceum* (P. Gaertn. *et al.*)schim.*var. julaceum*	*Anomobryum*	Bryaceae	B	TH01
2	*Anacolia cf. laevisphaera* (Taylor) Flower	*Anacolia*	Bartramiaceae	B	TH02
3	*Brachymecium cf. exile* (Dozy et Molk.) Bosch *et* Sande Lac.	*Brachymecium*	Bryaceae	B	TH03
4	*Brachymecium cf. longicolle (Ther)*	*Brachymecium*	Bryaceae	B	TH04
5	*Brachythecium cf. afro-glareosum (broth.)par.*	*Brachythecium*	Brachythecaceae	B	TH05
6	*Brachythecium cf. borgeni (Hamper) Jaeg.*	*Brachythecium*	Brachytheciaeae	B	TH06
7	*Braunia secunda (Hook.)Bruch et Schimp.*	*Braunia*	Hedwigiaceae	B	TH07
8	*Bryum argenteum* Hedw.	*Bryum*	Bryaceae	B	TH08
9	*Bryum keniae* Mull.Hal.	*Bryum*	Bryaceae	B	TH09
10	*Bryum huillinse* Welw. et Duby	*Bryum*	Bryaceae	B	TH10
11	*Campylopus pyriformis (Schulz) Brid?*	*Campylopus*	Dicranaceae	B	TH11
12	*Cryphaea rutenbergii* Müll. Hal.	*Cryphaea*	Cryphaeaceae	B	TH12
13	*Didymodon australasiae (Hook. & Grev.) Zander*	*Didymodon*	Pottiaceae	B	TH13
14	*Entodon sp.*C.Mull.	*Entodon*	Entodontaceae	B	TH14
15	*Entodontella cf. Cameruniae* Broth.	*Entodontella*	Hypnaceae	B	TH15
16	*Fabronia pilifera* Hornsch	*Fabronia*	Fabroniaceae	B	TH16

17	*Fissidens sp1.* Hedw.	*Fissidens*	Fissidentaceae	B	TH17
18	*Fissidens sp2.* Hedw.	*Fissidens*	Fissidentaceae	B	TH18
19	*Frullania caffraria* Steph.	*Frullania*	Frullaniaceae	H	TH19
20	*Frullania tristis (*Steph). Slageren	*Frullania*	Frullaniaceae	H	TH20
21	*Haplocladium angustifilolium Hampe et Mull. Hal.) Broth*	*Haplocladium*	Leskeaceae	B	TH21
22	*Hypnum cupressifirme* Hedw.	*Hypnum*	Hypnaceae	B	TH22
23	*Lejeunea aetiopica* Lib.	*Lejeunea*	Lejeuneaceae	H	TH23
24	*Lejeunea sp.*Lib.	*Lejeunea*	Lejeuneaceae	H	TH24
25	*Leptodontium latifolium Broth*	*Leptodontium*	Pottiaceae	B	TH25
26	*Leptodontium sp.* Hampe	*Leptodontium*	Pottiaceae	B	TH26
27	*Levierella neckeroides* (Griff.) O'Shea & Matcham	*Livierella*	Fabroniaceae	B	TH27
28	*Lindbergia patentifolia* Dix.	*Lindbergia*	Leskeaceae	B	TH28
29	*Lunularia cruciata* (L.)Dum	*Lunularia*	Lunulariaceae	H	TH29
30	*Macrocoma tenuis* (hook.et grev.)	*Macrocoma*	Orthotrichaceae	B	TH30
31	*Marchantia polymorpha* L.	*Marchantia*	Marchantiaceae	H	TH31
32	*Marchantia sps* L.	*Marchantia*	Marchantiaceae	H	TH32
33	*Metzgeria sps.* Raddi	*Metzgeria*	Metzgeriaceae	H	TH33
34	*Neckera remota (bruch et schimp. Ex mull. Hal.)*	*Neckera*	Neckeraceae	B	TH34
35	*Orthotrichum aequatorum* Mitt.	*Orthotrichum*	Orthotrichaceae	B	TH35
36	*Orthotrichum firmum* venturi.	*Orthotrichum*	Orthotrichaceae	B	TH36
37	*Phaeoceros carolinianus* (Michx.)Prosk.	*Phaeoceros*	Anthocerotaceae	A	TH37
38	*Philontis sps.* Brid.	*Philontis*	Bartramiaceae	B	TH38
39	*Orthostichella pandurifolia* (Mull.HaL W.R.).	*Orthostichella*	Meteoriaceae	B	TH39
40	*Plagiochila squamulosa* Mitt.	*Plagiochila*	Plagiochilaceae	H	TH40
41	*Plagiomnium rhynchophorum* (Hook.) Kop.	*Plagiomnium*	Mniaceae	B	TH41

42	*Porella abyssinica* Pocs	*Porella*	Porellaceae	H	TH42
43	*Racopilum africanum* Mitt.	*Racopilum*	Racopilaceae	B	TH43
44	*Rhodobryum commersonii* (Schwagr.) Brid.	*Rhodobryum*	Bryaceae	B	TH44
45	*Sematophyllum subpinnatum* (Brid.)Britt.	*Sematophyllum*	Sematophyllaceae	B	TH45
46	*Streptogon erythrodontus* (Tayl.)Wils.	*Streptogon*	Pottiaceae	B	TH46
47	*Syntrichia fragilis* (Tayl.) Ochyra.	*Syntrichia*	Potticeae	B	TH47
48	*Targionia sps*. (L.)	*Targionia*	Targioniaceae	H	TH48
49	*Trichostomum brachydontium* Bruch	*Trichostomum*	Pottiaceae	B	TH49
50	*Thudium varians* Welw.et Duby	*Thuidium*	Thuidiaceae	B	TH50
51	*Thudium versicolor* (Mull.Hal).Broth.	*Thuidium*	Thuidiaceae	B	TH51
52	*Thudium ramusculosum* (Mitt). A. Jaeger	*Thuidium*	Thuidiaceae	B	TH52
53	Hypnaceae	-	Hypnaceae	B	TH53
54	Pottiaceae	-	Pottiaceae	B	TH54
55	Pottiaceae	-	Pottiaceae	B	TH55
56	Pottiaceae	-	Pottiaceae	B	TH56

Appendix 1: Families with their corresponding number of genera and species.

No.	Name of family	Genera		species	
		Number	%	Number	%
1.	Pottiaceae	8	18.60	9	16.98
2.	Bryaceae	4	9.30	7	12.5
3.	Orthotrichaceae	2	4.65	3	5.35
4.	Thuidiaceae	1	2.33	3	5.35
5.	Bartramiaceae	2	4.65	2	3.57
6.	Brachythecaceae	1	2.33	2	3.57
7.	Fabroniaceae	2	4.65	2	3.57
8.	Fissidentaceae	1	2.33	2	3.57
9.	Frullaniaceae	1	2.5	2	3.57
10.	Hypnaceae	3	6.97	3	5.35
11.	Lejeuneaceae	1	2.33	2	3.57
12.	Marchantiaceae	1	2.33	2	3.57
13.	Leskeaceae	2	4.65	2	3.57
14.	Hedwigiaceae	1	2.33	1	1.78
15.	Dicranaceae	1	2.33	1	1.78
16.	Cryphaeaceae	1	2.33	1	1.78
17.	Entodontaceae	1	2.33	1	1.78
18.	Lunulariaceae	1	2.33	1	1.78
19.	Anthocerotaceae	1	2.33	1	1.78
20.	Meteoriaceae	1	2.33	1	1.78
21.	Plagiochilaceae	1	2.33	1	1.78
22.	Mniaceae	1	2.33	1	1.78
23.	Porellaceae	1	2.33	1	1.78
24.	Racopilaceae	1	2.33	1	1.78
25.	Sematophyllaceae	1	2.33	1	1.78
26.	Targioniaceae	1	2.33	1	1.78

27.	Metzgeriaceae	1	2.33	1	1.78
28	Neckeraceae	1	2.33	1	1.78
Total	28	43	100	56	100

Appendix 2: R = Rocks (epilithic), X= snags & down logs (epixylic), T = ground (Terricol), L = epilythic (litter), E= epiphytic (in terms of stumps and trunks, branches) and S= Streamers. A= Acrocarpous, P =Pleurocarpous, Le = (Leafy) & Th= (Thalloid)

No.	Species	Ecology	Growth form
1	*Anomobryum julaceum* (P. Gaertn. *et al.*)schim.*var. julaceum*	T	P
2	*Anacolia laevisphaera* (Taylor) Flower	T	A
3	*Brachymecium exile?* (Dozy et Molk.) Bosch *et* Sande Lac.	T	A
4	*Brachymecium longicolle (Ther)?*	E, T	A
5	*Brachythecium afro- glareosum (broth.)par.?*	E	P
6	*Brachythecium borgeni (Hamper)? Jaeg.*	R, T	P
7	*Braunia secunda (Hook.)Bruch et Schimp.*	R, T	P
8	*Bryum argenteum* Hedw.	R, T	A
9	*Bryum keniae* Mull.Hal.	L	A
10	*Bryum huillinse* Welw. et Duby	L, T, E	A
11	*Campylopus pyriformis (Schulz) Brid?*	R, T	A
12	*Cryphaea rutenbergii* Müll. Hal.	E	P
13	*Didymodon australasiae (Hook. & Grev.) Zander*	E	A
14	*Entodon (geminides) sp*	E,L R,T,X	P
15	Entodontella cameruniae Broth	S	P
16	*Fabronia pilifera* Hornech	E	P
17	*Fissidens₁ (?)*	T	A

18	*Fissidens $_2$(?)*	S	A
19	*Haplocladium angustifilolium Hampe et Mull. Hal.) Broth*	T	P
20	*Hypnum cupressifirme* Hedw.	R, T	P
21	*Leptodontium latifolium Broth*	T	A
22	*Leptodontium?* Hampe	T	A
23	*Livierella neckeroides*	R, T	P
24	*Lindbergia patentifolia* Dix.	R	P
25	*Macrocoma tenuis* (hook.et grev.)	E	P
26	*Neckera remota (bruch et schimp. Ex mull. Hal.)*	E	P
27	*Orthotrichum aequatorum*	E	P
28	*Orthotrichum firmum*	E	P
29	*Philontis sps.* Brid.	S	A
30	*Orthostichella pandurifolia* (Mull.HaL W.R.).	E	P
31	*Plagiomnium rhynchophorum* (Hook.) Kop.	S	A
32	*Racopilum africanum* Mitt.	X,R	P
33	*Rhodobryum commersonii* (Schwagr.) Brid.	L	A
34	*Sematophyllum subpinnatum* (Brid.)Britt.	E	P
35	*Streptogon erythrodontus* (Tayl.)Wils.	E	A
36	*Syntrichia fragilis* (Tayl.) Ochyra.	R,T	A
37	*Trichostomum brachydontium* Bruch	T	A
38	*Thudium varians* Welw.et Duby	T	P
39	*Thudium versicolor* (Mull.Hal).Broth.	T	P

40	*Thudium ramusculosum* (Mitt). A. Jaeger	T	P
41	*Frullania caffraria* Steph.	E	Le
42	*Frullania tristis (*Steph). Slageren	E,X	Le
43	*Lejeunea aetiopica*	E	Le
44	*Lejeunea sp.*Lib.	E	Le
45	*Lunularia cruciata* (L.)Dum	S	Th
46	*Marchantia polymorpha* L.	S	Th
47	*Marchantia sps* L.	S	Th
48	*Metzgeria sps.* Raddi	S	Th
49	*Plagiochila squamulosa* Mitt.	E	Le
50	*Porella abyssinica* Pocs	E	Le
51	*Targionia sps*. (L.)	T	Th
52	*Phaeoceros carolinianus* (Michx.)Prosk.	T	Th

Appendix 3 : Species in different land management area (√=present, X= absent & ® =rare).

	Species	Restoring area	Unrestoring area	Managde area (agr. land)
1	*Anomobryum julaceum* (P. Gaertn. *et al.*)schim.*var. julaceum*	✓	✓	✓
2	*Anacolia laevisphaera* (Taylor) Flower	✓	X	X
3	*Brachymecium exile?* (Dozy et Molk.) Bosch et Sande Lac.	✓	✓	✓
4	*Brachymecium longicolle* (Ther)?	✓	✓	X
5	*Brachythecium afro- glareosum* (broth.)par.?	✓	X	X
6	*Brachythecium borgeni* (Hamper)? Jaeg.	✓	✓	X
7	*Braunia secunda (Hook.)*Bruch et Schimp.	✓	✓	X
8	*Bryum argenteum* Hedw.	✓	✓	✓
9	*Bryum keniae* Mull.Hal.	X	✓	X
10	*Bryum huillinse* Welw. et Duby	✓	✓	X
11	*Campylopus pyriformis (Schulz) Brid?*	✓	✓	X
12	*Cryphaea rutenbergii* Müll. Hal.	✓	X	X
13	*Didymodon australasiae* (Hook. & Grev.) Zander	✓	✓	✓
14	*Entodon sp.*	✓	✓	✓
15	Entodontella cameruniae Broth	✓	X	X
16	*Fabronia pilifera* Hornech	✓	X	X
17	*Fissidens sp.1*	✓	✓	X
18	*Fissidens sp.2*	✓	X	X
19	*Frullania caffraria*	✓	✓	X
20	*Frullanoides tristis*	✓	✓	X
21	*Haplocladium angustifilolium Hampe et*	✓	✓	X

	Mull. Hal.) Broth			
22	*Hypnum cupressifirme* Hedw.	✓	✓	X
23	*Lejeunea aetiopica*	✓	✓	X
24	*Lejeunea sp.*	✓	✓	X
25	*Leptodontium latifolium Broth*	✓	✓	X
26	*Leptodontium sp.*	✓	✓	X
27	*Livierella neckeroides*	✓	✓	X
28	*Lindbergia patentifolia*	✓	✓	X
29	*Lunularia cruciata (L.)Dum*	✓	X	X
30	*Macrocoma tenuis (hook.et grev.)*	✓	✓	✓
31	*Marchantia polymorpha L.*	✓	X	X
32	*Marchantia sps L.*	✓	X	X
33	*Metzgeria sps. Raddi*	✓	X	X
34	*Neckera remota (bruch et schimp.* Ex mull. Hal.*)*	✓	X	X
35	*Orthotrichum aequatorum* Mitt.	✓	✓	X
36	*Orthotrichum firmum* venturi.	✓	✓	X
37	*Phaeoceros carolinianus* (Michx.)Prosk.	X	✓	✓
38	*Philontis sps.* Brid.	✓	✓	X
39	*Orthostichella pandurifolia* (Mull.HaL W.R.).	✓	X	X
40	*Plagiochila squamulosa* Mitt.	X	✓	X
41	*Plagiomnium rhynchophorum* (Hook.) Kop.	✓	✓	X
42	*Porella abyssinica* Pocs	✓	✓	X
43	*Racopilum africanum* Mitt.	✓	✓	✓
44	*Rhodobryum commersonii* (Schwagr.) Brid.	✓	✓	X
45	*Sematophyllum subpinnatum* (Brid.)Britt.	✓	X	X

46	*Streptogon erythrodontus* (Tayl.)Wils.	✓	X	X
47	*Syntrichia fragilis* (Tayl.) Ochyra.	✓	✓	X
48	*Targionia sps*. (L.)	X	✓	✓
49	*Trichostomum brachydontium* Bruch	✓	✓	X
50	*Thudium ramusculosum* (Mitt). A. Jaeger	✓	✓	X
51	*Thudium varians* Welw.et Duby	X	✓	X
52	*Thudium versicolor* (Mull.Hal).Broth.	✓	✓	X
53	Hypnaceae	X	✓	X
54	Pottiaceae	✓	✓	X
55	Pottiaceae	✓	✓	X
56	Pottiaceae	✓	✓	X

Appendix 4: Sample plots and their geographical positions

Quadrant(plot)	G.F.		Alt.(a.s.l.) m
	N	N	
1	09^0 00' 09.3"	038^0 21' 25.8"	2161
2	09^0 01' 09.1"	038^0 21' 25.5"	2162
3	09^0 01' 08.7"	038^0 21' 25.3"	2163
4	09^0 01' 07.9"	038^0 21' 25.1"	2159
5	09^0 01' 06.4"	038^0 21' 24.6"	2163
6	09^0 01' 03.1"	038^0 21' 20.1"	2159
7	09^0 01' 00.0"	038^0 21' 14.5"	2179
8	09^0 01' 59.6"	038^0 21' 34.4"	2183
9	09^0 01' 01.8"	038^0 21' 32.0"	2162
10	09^0 01' 80.7"	038^0 21' 31.6"	2164
11	09^0 01' 03.0"	038^0 21' 37.8"	2171
12	09^0 01' 03.5"	038^0 21' 38.8"	2171
13	09^0 01' 03.2"	038^0 21' 39.8"	2172
14	09^0 01' 01.0"	038^0 21' 40.1"	2165
15	09^0 01' 02.8"	038^0 21' 34.9"	2186
16	09^0 00' 59.4"	038^0 21' 33.1"	2175

17	09^0 00' 58.8"	038^0 21' 34.4"	2186
18	09^0 00' 57.2"	038^0 21' 34.8"	2187
19	09^0 00' 57.2"	038^0 21' 34.8"	2187
20	09^0 00' 57.0"	038^0 21' 49.0"	2214
21	09^0 01' 03.2"	038^0 21' 39.8"	2187
22	09^0 00' 55.0"	038^0 21' 22.5"	2232*
23	09^0 00' 49.7"	038^0 21' 25.4"	2238
24*	09^0 00' 46.5"	038^0 21' 25.9"	2263*

- *= Pick (highest altitude in the study area)

Appendix 5: species and their geographical positions

No.	species	G.F.		Alt.(a.s.l.) m
		N	N	
1	*Anomobryum julaceum* (P. Gaertn. *et al.*)schim.*var. julaceum*	09^0 00' 07.9"	038^0 21' 47.0"	2214
2	*Anacolia laevisphaera* (Taylor) Flower	09^0 01' 03.0"	038^0 21' 37.8"	2171
3	*Brachymecium exile?* (Dozy et Molk.) Bosch *et* Sande Lac.	09^0 01' 08.7"	038^0 21' 25.3"	2163
4	*Brachymecium longicolle (Ther)?*	09^0 01' 07.9"	038^0 21' 25.1"	2159
5	*Brachythecium afro-glareosum (broth.)par.?*	09^0 01' 03.1"	038^0 21' 20.1"	2159
6	*Brachythecium borgeni (Hamper)? Jaeg.*	09^0 00' 55.0"	038^0 21' 22.5"	2230
7	*Braunia secunda (Hook.)Bruch et Schimp.*	09^0 00' 55.0"	038^0 21' 22.5"	2231
8	*Bryum argenteum* Hedw.	09^0 01' 03.1"	038^0 21' 20.1"	2154
9	*Bryum keniae* Mull.Hal.	09^0 01' 06.3"	038^0 21' 37.0"	2189
10	*Bryum huillinse* Welw. et Duby	09^0 01' 01.8"	038^0 21' 32.0"	2162
11	*Campylopus pyriformis (Schulz) Brid?*	09^0 00' 55.0"	038^0 21' 22.5"	2231

12	*Cryphaea rutenbergii* Müll. Hal.	09^0 01' 00.0"	038^0 21' 14.5"	2162
13	*Didymodon australasiae (Hook. & Grev.) Zander*	09^0 01' 03.2"	038^0 21' 39.8"	2172
14	*Entodon sp.*	09^0 01' 09.3"	038^0 21' 25.8"	2161
15	*Entodontella cf. cameruniae*	09^0 01' 04.5"	038^0 21' 30.0"	2174
16	*Fabronia pilifera* Hornsch	09^0 01' 00.1"	038^0 21' 14.5"	2163
17	*Fissidens sp1.* Hedw.	09^0 00' 07.9"	038^0 21' 25.1"	2159
18	*Fissidens sp2.* Hedw.	09^0 00' 57.2"	038^0 21' 34.8"	2187
19	*Frullania caffraria* Steph.	09^0 01' 00.0"	038^0 21' 14.5"	2162
20	*Frullania tristis (*Steph). Slageren	09^0 01' 09.3"	038^0 21' 25.8"	2163
21	*Haplocladium angustifilolium Hampe et Mull. Hal.) Broth*	09^0 01' 08.1"	038^0 21' 24.3"	2163
22	*Hypnum cupressifirme* Hedw.	09^0 00' 57.2"	038^0 21' 19.3"	2181
23	*Lejeunea cf. aetiopica*	09^0 01' 09.30"	038^0 21' 25.8"	2161
24	*Lejeunea sp.* Lib.	09^0 01' 09.30"	038^0 21' 25.8"	2161
25	*Leptodontium latifolium Broth*	09^0 00' 46.5"	038^0 21' 25.9"	2169
26	*Leptodontium sp.* Hampe	09^0 00' 59.4"	038^0 21' 33.1"	2175
27	*Livierella neckeroides*	09^0 01' 09.3"	038^0 21' 25.8"	2161
28	*Lindbergia patentifolia* Dix.	09^0 01' 01.0"	038^0 21' 29.1"	2170
29	*Lunularia cruciata* (L.)Dum	09^0 00' 59.6"	038^0 21' 34.4"	2183
30	*Macrocoma tenuis* (hook.et grev.)	09^0 01' 80.7"	038^0 21' 31.6"	2164
31	*Marchantia polymorpha* L.	09^0 00' 59.6"	038^0 21' 34.4"	2183
32	*Marchantia sps* L.	09^0 01' 03.5"	038^0 21' 38.8"	2158

33	*Metzgeria sps.* Raddi	09^0 01' 03.1"	038^0 21' 20.1"	2159
34	*Neckera remota (bruch et schimp. Ex mull. Hal.)*	09^0 01' 01.8"	038^0 21' 32.0"	2162
35	*Orthotrichum aequatorum* Mitt.	09^0 01' 03.0"	038^0 21' 37.8"	2157
36	*Orthotrichum firmum* venturi.	09^0 01' 06.4"	038^0 21' 24.6"	2162
37	*Phaeoceros carolinianus* (Michx.)Prosk.	09^0 01' 03.2"	038^0 21' 39.8"	2172
38	*Philontis sps.* Brid.	09^0 01' 03.1"	038^0 21' 20.1"	2159
39	*Orthostichella pandurifolia* (Mull. HaL W.R.).	09^0 01' 06.3"	038^0 21' 37.0"	2189
40	*Plagiochila squamulosa* Mitt.	09^0 01' 09.3"	038^0 21' 25.1"	2159
41	*Plagiomnium rhynchophorum* (Hook.) Kop.	09^0 01' 07.9"	038^0 21' 25.1"	2159
42	*Porella abyssinica* Pocs	09^0 00' 58.8"	038^0 21' 34.4"	2186
43	*Racopilum africanum* Mitt.	09^0 01' 07.9"	038^0 21' 25.1"	2159
44	*Rhodobryum commersonii* (Schwagr.) Brid.	09^0 01' 06.4"	038^0 21' 24.6"	2163
45	*Sematophyllum subpinnatum* (Brid.)Britt.	09^0 01' 07.9"	038^0 21' 25.1"	2159
46	*Streptogon erythrodontus* (Tayl.)Wils.	09^0 01' 03.1"	038^0 21' 20.1"	2154
47	*Syntrichia fragilis* (Tayl.) Ochyra.	09^0 01' 01.8"	038^0 21' 32.0"	2162
48	*Targionia sps.* (L.)	09^0 01' 03.1"	038^0 21' 20.1"	2154
49	*Trichostomum brachydontium* Bruch	09^0 01' 03.1"	038^0 21' 20.1"	2154
50	*Thudium varians* Welw.et Duby	09^0 00' 09.3"	038^0 21' 25.8"	2161
51	*Thudium versicolor* (Mull.Hal).Broth.	09^0 01' 08.7"	038^0 21' 25.3"	2163
52	*Thudium ramusculosum* (Mitt). A. Jaeger	09^0 01' 08.7"	038^0 21' 25.3"	2163

53	Hypnaceae	09^0 01' 06.4"	038^0 21' 24.6"	2163
54	Pottiaceae	09^0 01' 01.0"	038^0 21' 29.1"	2170
55	Pottiaceae	09^0 01' 01.8"	038^0 21' 32.0"	2162
56	Pottiaceae	09^0 01' 00.0"	038^0 21' 14.5"	2179