VEGETATION ECOLOGY AND LAND USE LAND COVER CHANGE IN WOMBERA DISTRICT, BENSHANGUL GUMUZ REGIONAL STATE, ETHIOPIA

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A Dissertation Submitted to the Department of Plant Biology and Biodiversity Management in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Biology

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The Late Prof.Ensermu Kelbessa

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By: Girma Gudesho Ofga

This is to confirm that the dissertation submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Plant Biology and Biodiversity management complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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DEDICATION

This thesis is dedicated to the communities in the forest patch area who have been conserving the forest resources by using indigenous knowledge, as well as to my family, who have supported me during hard working times.

Auther statement

This Dissertation, entitled **Vegetation Ecology and Land Use Land Cover Change in Wombera District, Benshangul Gumuz Regional State, Ethiopia,** was proposed, analyzed, and written by Girma Gudesho Ofga under the supervision of Prof. Zerihun Woldu and submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Plant Biology and Biodiversity management.

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Abbreviation

AAU Addis Ababa University

ABFP Ababuta Begondi forest patches

BMFP Bolele-Minjo forest patches

CBD Convention on Biological Diversity

CCA Canonical Correspondence Analysis

Chdis Climax highly disturbed

CInt Climax Intact

CMDIS Climax Moderately Disturbed

CSA Central Statistical Authority

DAF Dry Evergreen Montane forest

DBH Diameter at Breast Height

DSH Diameter at stump height

DCA Detrended Correspondence Analysis

DEM Digital Elevation Model

EBI Ethiopian Biodiversity Institute

EMSA Ethiopian Meteorological Services Agency

ETH National Herbarium

EGII Ethiopian Geospatial Information Institute

FAO Food and Agricultural Organization of the United Nations

FEE Flora of Ethiopia and Eritrea

FGD Focus group discussion

GMRD Grand Millennium Renaissance Dum

GPS Global Positioning System

GTFP Gesengesa-Tumi forest Patch

IBC Institute of Biodiversity Conservation

IHdis Intermediate highly disturbed

IInt Intermediate Intact

IMD Intermediate moderately disturbed

IPCC Intergovernmental Panel on Climate Change

IVI Importance Value Index

KII Key informant interview

LAL Lower altitude

LCT Lower canopy trees

LULCC Land use land covers change

MAL Middle altitude

masl Meter above sea level

MBFP Menesib-Babo forest patches

MCT Middle canopy trees

Pihd Pioneer highly disturbed

PInt Pioneer Intact

PMD Pioneer moderately disturbed

PMFP Pirea-Muse forest patches

SLFP Senkora-lopi forest patch

UCT upper canopy trees

USAG United states Geological survey

WARD Wombera woreda Agricultural and rural development

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Summary

Vegetation Ecology and Land use Land cover change in wombera District, Benshangul Gumuz regional state, Ethiopia

Girma Gudesho Ofga, PhD Dissertation

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The objectives of the study was to assess vegetation diversity, structure, composition, community type, and regeneration status in relation to land use and land cover changes in the Wombera district. The district has three agroecologies: higher, middle, and lower. For the whole study, six forest patches were selected. At higher altitudes, three forest parts were classified according to their succession stage: climax, intermediate, and pioneer. Depending on the intensity, frequency, and severity of disturbances, each succession class was divided into intact, disturbed, and highly disturbed forest patch parts. Data was collected using stratified systematic sampling procedures. Along altitudinal gradients, transect lines were laid every 300 m, and plots were laid every 150 m along transect lines. One hundred forty-two nested sampling plots (20 × 20 meters each) in six forest areas were used to collect vegetation and environmental data. In the main quadrates (20×20), trees with stem diameter at breast height (DBH) >2.5 cm and shrubs at diameter stump height (DSH) were collected. Landscape variables and disturbance factors were also ranked and recorded. In five (5 m × 5 m) quadrants nested in the larger quadrats, seedlings and saplings were recorded. In 5 (1 × 1 m) quadrates nested in the 5 × 5 m quadrates, herbs and grass species were recorded. For LULCC analysis, satellite images from EGII and USAG were obtained, including Landsat Mss 1973, Landsat TM 1985, Landsat ETM+2000, and Landsat OLI/TIRS 2016.In six forest patches interview were held with FGD confirmed by KII, five direct and six indirect driving forces were identified, and their impacts were evaluated. The regeneration potential and use values of woody plants were assessed and ranked. The species frequency, density, and structure of the forest patches were analyzed using descriptive statistical tools. Floristic diversity and evenness were computed using Shannon diversity and evenness indices, respectively. The similarities between forest patches and plant communities were computed using Sorenson’s similarity index. A nested ANOVA and regression model in R were used to compute the diversity and abundance of plants along succession and disturbance gradients. The R package (version 3.4.3) was used for the classification of the plant community types (clusters) and vegetation-environment relationships (ordinations). ERDAS version 15 and ArcGIS 10.3.1 were used for satellite image calibration and analysis. A total of 375 species, representing 90 families and 70 genera, were recorded from 142 plots and outside nearby plots in six forest patches. 314 species were recorded in plots, and 61 species were recorded outside the plots. Plant species diversity and richness significantly varied along the succession gradient (pioneer, intermediate, and climax) and disturbance gradients (intact, moderately disturbed, and highly disturbed).In Lower and middle-layer canopy tree abundances decline along the succession gradient. Upper canopy tree abundance increases along successional gradients. The highest IVI was found in the upper canopy trees of climax forests, followed by intermediate and pioneer forests, respectively. Seven major LULCC types were identified: forest, woodland (highest), scrub/bushland, grassland/rangeland, farmland, water bodies, and settlements. Six community types: Community I, Community II, Community II Community VI, community V, and Community VI were identified. The vegetation structure is determined by fire and altitudinal gradients. The result of LULCCS revealed an expansion of agriculture/settlement and a reduction of woodland and forest over the last 40 years, from 1973 to 2016. In the early 1970s, indirect driving forces: sociocultural practices and population growth contributed the most and had the highest impact. Among the direct or proximate causes, farming activity and fire had the highest impact in 1970 in the lower and middle altitudes. Thus, further studies should conducted that include soil nutrient analysis and vegetation modeling along successiona and disturbance gradients.LULCC should be done by using the latest satellite image version.

Key words: LULCCs, Vegetations, Disturbance gradients, Species diversity, age gradients, Forest patches, direct driving forces, indirect deriving force.

CHAPTER ONE

1. GENERAL INTRODUCTION

1.1. Background and justification

Ethiopia's high Rocky Mountains, flat-topped plateaus, deep gorges, carved river basins, and undulating plains make it a regional center for biological diversity (Ensermu Kelbessa *et al*., 1992; Zerihun Woldu, 1999). Species diversity and richness showed gradual change among communities as altitude changed (Zerihun Woldu *et al*., 1989; Kumelachew Yeshitila and Tamrat Bekele, 2002; Haile Yeneger *et al*., 2008). The most important environmental factor influencing the abundance and distribution of plant communities is altitude (Schmitt, C. B. *et al*.; 2010; Zerihun Woldu *et al*., 1989; Lisanework Nigatu and Mesfin Tadesse, 1989; Kumelachew Yeshitila and Tamrat Bekele, 2002; Haile Yeneger *et al.*, 2008; Tadesse Woldemariam *et al.*, 2008; Ermias Lulekal, 2014). Species richness reaches its maximum at intermediate elevations (Desalegn Wana, 2002; Motuma Didita *et al.*, 2010; Abiyu Tilahun, 2018). Therefore, an altitudinal gradient is the most determinate factor for the distribution of vegetation. According to Tadesse Woldemariam (2003), environmental factors such as altitudes, slopes, and landforms influence plant distributions. According to the intermediate disturbance hypothesis theory (IDH), plant diversity is positively impacted by low disturbance intensity that is close to natural disturbance levels (Connell *et al*. 2008). Thus, intermediate disturbances are imprtant distribution of plants.

Plant species that are dependent on their environment influence one another and modify their environment (Muller-Dombois & Ellenberg 1974).Measures of community diversity play a role in ecology and conservation biology (Magurran, 2004). Variations among the plant communities' types are the direct reflection of the effects of environmental variables and geographic locations (Suratman, 2012; Parthasarathy, 2001).Plant communities change gradually along complex environmental gradients (Whittaker, 1953; Curtis, 1959). Species richness appears as the most intuitive and basic parameter to measure biodiversity and provides an extremely useful and comprehensible expression of diversity (Magurran, 1988;

McCune and Grace, 2002; Kent, 2012). Early-successional species may modify the habitat's ecology or resource availability to favor the establishment of particular plant species (Holl, 2002). Pioneer shrubs facilitate the establishment of woody late-successional plant species and thus can positively affect reforestation success in many different ecological settings (Gómez *et al*., 2004). Some disturbance seeking plants *such Croton macrostachyus* (Tamrat Bekele, 1993; Gemedo Dalle & Masresha Fetene, 2004; Abiyot Berhanu *et al*., 2017), form secondary forests and forest borders. *Podocarpus falcatus, Apodytes dimidiata,* and *Prunus africana* cover the upper layer (Tamrat Bekele, 1993; Zerihun Woldu, 1999; Friis *et al*., 2010). Therefore, plants are organized in different successions and form different plant communities.

The regeneration status of the forests is determined by the forest population structure, DBH, and height pattern of tree species (Mesfine Woldearegay, 2017; Leul Kidane *et al.*, 2016; Gemedo Dalle, 2015; Abiyot Berhanu *et al*., 2017). Seedling and sapling density indicate the status and fate of the forest due to different factors such as overgrazing and over exploitation (example, Fekadu Gurmessa *et al*., 2012; Ermias Lulekal *et al*., 2008). An inverted J-shaped DBH and height classes indicate good regeneration (Silvertown and Doust, 1993; Rocky and Mligo, 2012; Abiyou Tilahun *et al*., 2015). Poor regeneration is characterized by a J-shape pattern of height and DBH (Tamrat Bekele, 1994; Feyera Senbeta, 2006; Tadesse Woldemariam *et al*., 2008). Selective cutting by local people for construction and firewood, and overgrazing resulted in different population structures: U-shaped (Kflay Gebrehiwot and Kitessa Hundera, 2014; Fikadu Gurmesa, 2010), irregular (Tesfaye Burju *et al*., 2010; Kflay Gebrehiwot and Kitessa Hundera, 2014), and inverted U-shape (Feyera Senbeta, 2006; Ensermu Kelbessa & Teshome Soromessa, 2008). Thus, seedlings, saplings, and DBH classes indicate the regeneration status of the forest.

Land-use change is one of the greatest environmental issues today, resulting from the natural and anthropogenic pressures that affect the sustainability of natural resources, carbon storage capacity, biodiversity, ecosystem services, and wildlife habitat (Sisay Nune *et al*., 2016). LULCC size varies based on the geographical location (Rindfuss *et al*., 2004), time considered (Weng, 2002), slope, and altitude (Poyatos *et al*., 2003; Mengistie Kindu *et al*, 2013). Belay Tegene (2002) identified up to eight major land cover classes, including shrubland, shrub grassland, grassland valley-rim vegetation, cropland, all-weather roads, dry weather roads, and towns. LULC constantly changes due to the dynamic interaction between underlying drivers and proximate causes (Lambin, 2005). According to Lambin *et al*. (2001), factors driving LULC include an increase in human population and population responses to economic opportunities.

Vegetation ecology varies with topography, location and agroecological variation (Friis *et al.,* 2010*)*. Thus, classification is crucial to distinguish distinctive types for study. By categorizing vegetation, it is feasible to identify different community types and the corresponding environmental circumstances, enabling stakeholders to choose the most appropriate management practices. The vegetation and LULC have not been studied and documented in Wombera district.Thus, the objective of this study was to assess and document vegetation composition, structure, regeneration, and community structure and types in association with anthropogenic impacts and environmental variables in the district.

Organization of the dissertation

This dissertation was divided into seven chapters, including the introduction and general discussion sections. The first chapter introduced the dissertation title, background and justification, literature review, statement of the problem, the objective, and the research questions. The second chapter assessed the vegetation composition, community type, and variables that determine the vegetation structure and diversity. This chapter also analyzed community diversity, richness, and a factor that determines vegetation distribution in the whole district.The third chapter assessed plant communities, population structure and regeneration status along age and disturbance gradients in dry Afromontane forest patches. Chapter Four evaluated land use, land cover change, and driving forces throughout the district from 1972 to 2016. Chapter 5: the Wood plants Rejuvenation, Use value and distribution along successional gadients selected patches. Chapter 6 assessed the vegetation structures of middle and lower altitudes .The general findings, conclusions, and recommendations were summarized in Chapter 7.

General methods

A reconnaissance survey was conducted, and six forest patches were selected: Gesengesa-Tumi forest patch (GTFP), Senkora-lopi patch (SLFP), Menesib-Babo patch (MBFP), Bolele-Minjo patch (BMFP), Ababuta-Begondi forest patch (ABFP), and Pire-Muse forest patch (PMFP) along altitudinal gradients in three agroecologies (Appendix-Table 5). The six forest patches were used for general assessment, whereas GTFP, SLFP, and MBFP were used for the analysis of forest patch dynamics along succession (pioneer, intermediate and climax) and disturbance gradients (intact, disturbed and highly disturbed. The magnitude of disturbance, fire, grazing, aspect, and anthropogenic disturbance were rated and ranked. Using GPS coordinates, the distance between forest patches and water bodies was calculated by superimposing on a Google map. Systematic surveys were employed along altitudinal and disturbance gradients. Nested plots of twenty by twenty were laid every 300 m along altitudinal gradients 150 m along transect lines.Vegetation and determining factors were collected in each plot. Satellite images of Landsat MSS 1973, Landsat TM 1985, Landsat ETM+ 2000, and Landsat OLI/TIRS 2016 were used to evaluate LULCC.All plant specimens were collected, temporarily tagged with plot numbers and labels assigned to species, pressed and brought to the National Herbarium (ETH) for identification.

1.2. Statement of the problem

Most vegetation ecology studies in Ethiopia conducted their research around accessible areas (DAF and MAF vegetation types): in central Ethiopia (e.g., Zerihun Woldu, 1985; Tamrat Bekele, 1993); in Northern Ethiopia (Alemayehu Wassie *et al*., 2005; Alemnew Alelign *et al.*, 2007; Abiyot *Berhanu et al.*, 2017); in the South and Southeast (Lisanework Nigatu and Mesfin Tadesse, 1989; Kitessa Hundera *et al*., 2007; and Ermias Lulekal *et al*., 2008); and in the Southwest (Kumilachew Yeshitela and Taye Bekele, 2003; Dereje Denu, 2006; Ensermu Kelbessa and Teshome Soromessa, 2008). Thus, north western border area vegetation has not been studied and documented.

Different studies (e.g., Kumilachew Yeshitila and Tamrat Bekele, 2002; Teshome Soromessa *et al*.; 2004; Tesfaye Awas, 2007; Haile Yineger *et al., 2008;* Fekadu

Gurmessa *et al*., 2012; Abraham Assefa *et al*., 2013; and Mamo Kebede *et al*.,2013) indicate vegetation surveys conducted across the nation to characterize various community types and their correlation with various anthropogenic and environmental factors. Only a few studies were conducted in the Benshangul gumuz region (for example, Tesfaye Awas and Sebsebe Demisew, 2007) to assess and document the vegetation Thus, no research was conducted that shows the anthropogenic and disturbace impacts in Wombera district.

Understanding of the dynamics of land use and cover can aid in the implementation of more appropriate policy interventions to enhance land management and the prediction of future changes in these areas (Lambin *et al*., 2001). However, no research has been conducted on land use and land cover changes to provide recommendations that may contribute to the sustainability of the vegetation and the conservation of biodiversity and wildlife habitats in the study area.Thus, our current and historic understanding of vegetation ecology and LULCC change in BGRS, particularly in the Wombera district, is inadequate. Therefore, this research was conducted to obtain information on vegetation composition, land use and land cover change, and socio-economic factors that influence land use and land cover change in the district.

1.3. Literature Review

1.3.1. Vegetation classification

Many scholars in Ethiopia have studied vegetation from the perspective of vegetation distribution and community assembly throughout broad altitudinal ranges (Tamrat Bekele, 1993; Zerihun Woldu, 1999; Friis *et al.*, 1982; Sebsebe Demissew, 1988; Zerihun Woldu *et al*., 1989; Zerihum Woldu and Mesfin Tadesse, 1990), Recently, Friis *et al*. (2011) described twelve major potential vegetation types of Ethiopia. These are (1) Desert and semi-desert scrubland; (2) Acacia-Commiphora woodland and bushland; (3) Wooded grassland of the western Gambella Region; (4) Combretum–Terminalia woodland and wooded grassland; (5) Dry evergreen Afromontane forest and grassland complex; (6) Moist evergreen Afromontane forest; (7) Transitional rainforest; (8) Ericaceous belt; (9) Afroalpine vegetation; (10) Riverine vegetation; (11) Freshwater lakes (including lakeshores, marshes, swamps and floodplain vegetation) and (12) Saltwater lakes (including lake shores, salt marshes and pan vegetation).

1.3.2. Forest regeneration status indicators

Forest population structure (DBH and height) patterns of tree species indicate the regeneration status of the forests (Mesfine Woldearegay, 2017; Leul Kidane, 2016). An inverted J-shaped pattern is characterized by many individuals in low-size classes and a few in high-size classes. This implies that their populations are expanding through the active recruitment of individuals at lower sized classes (Abiyu Tilahun, 2015; Rocky and Mligo, 2012). Different scholars at different forest paches (for instance, Abiyou Tilahun *et al*., 2015; Tesfaye Bujura et *al*., 2013; Fekadu Gurmesa, 2013**;** Kflay Gebrehiwot and Kitessa Hundera, 2014; Leul Kidane, 2010; Abyot Dibaba, 2014; Mohammed Gedefa and Teshome Sormessa, 2014; and Feyera Senbeta *et al.,* 2014) had found similar findings. However, in some situations, unsustainable exploitation of the forest by the local communities has been critically evidenced by the very low density of higher class of DBH but the dominance of individuals at lower diameter and height classes (Alemnew Alelign et *al., 2007;* Mengistu Asmamaw, 2011). Poor regeneration is characterized by a J-shape pattern of height and DBH classes (Kflay Gebrehiwot and Kitessa Hundera, 2014; Abyot Dibaba, 2014; Tesfaye Burju *et al.,* 2013). Some species are represented by U-shape, which shows a type of frequency distribution in which there is a high number of lowest and highest diameter classes but a relatively low number in the intermediate classes (Tesfaye Burju *et al.*, 2010; Fikadu Gurmesa, 2010; Mengistu Asmamaw, 2011).

1.3.3. Canopy layers forests

Dry Afromontane forest is layered into multilayer strata known as "emergents" (Zerihun Woldu, 1999). Some other studies elaborate on specific characteristic plant species, including *Juniperus procera, Podocarpus falcatus, Apodytes dimidiata, Prunus africana,* and *Acacia abyssinica* (Tamrat Bekele, 1993; Zerihun Woldu, 1999; Friis *et al.,* 2010), that form the upper layer of the canopy. The moist evergreen Afromontane forest is characterized by one or more closed strata of evergreen trees (Feyera Senbeta, 2006; Sebsebe Demissew & Friis, 2009; Friis *et al*., 2010). Based on tree height, canopy length, side branching, and canopy crown level, Rahman *et al*.

(2009) divided canopy trees into four social classes: dominating, co-dominant, repressed, and intermediate.

1.3.4. Threats to plant diversity in Ethiopia

Ethiopia is one of the regional centers of biological diversity and genetic resources (Zerihun Woldu, 1999; IBC, 2009). However, the rapid population growth and the demand for natural resources have put high pressure on biodiversity (Aukema *et al.*, 2017). Ethiopian highland agriculture has developed largely in the Afromontane areas that resulted in degradation of the Afromontane forests and further replacement by bushland and scrub in most areas (Friis et al., 2010). The greatest threat to the remaining natural forests in Ethiopia is man-made factors such as clearing for expansion of agricultural and grazing lands and uncontrolled exploitation of timber and fuel wood (Tamrat Bekele, 1993).Thus anthropogenic impacts are the main threats for forest vegetation.

1.3.5. Plant communities

The concept of plant community is extremely important in the study of vegetation science. The plant community is described by Kent and Coker (1992) as "*the association of plant species growing together in a specific location and demonstrating a definite association or affinity with one another*."As a result, a community is a collection of plant species that are dependent on their surroundings, affect one another, and change their environment (Muller-Dombois & Ellenberg, 1974).For a long time, people have been debating the nature of community organization. Two theories have been suggested to explain the structure of plant communities. These are Clements' (1936) community-unit theory and Whittaker (1951, 1953) and Curtis (1959) continuum theory, the latter based on Gleason's individualistic distribution of species (Gleason, 1939). According to the community-unit theory, "*communities are highly organised, repeatable, and recognizable groups of organisms that are influenced by environmental gradients*". Plant communities vary gradually along complex environmental gradients, according to continuum theory, hence no specific relationships of species can be recognized (Whittaker, 1953).

1.3.6. Community diversity, evenness and richness

Biodiversity indicators like species richness and evenness are extensively employed as indices of ecosystem health, and they play an important role in assessing the human effect on natural systems (Leitner and Turner, 2001). The number of species presents (species richness or species number) and the evenness with which individuals are dispersed among these species (species evenness or species equitability) determines community diversity (Pielou, 1966; Spellerberg, 1991). The diversity and equitability (evenness) of species in a given plant community are used to interpret relative variation across and within the community, as well as to help explain the underlying rationale for such a difference (Kent and Coker, 1992). Purvis and Hector (2000) define species diversity as a multidimensional concept that focuses on two essential parameters: the number of species and the number of individuals in each species (Hamilton, 2005). Species richness refers to the number of species in a given area without taking into account the number of individuals in each species. The most simple and basic criteria for measuring biodiversity appears to be species richness, which gives an incredibly useful and understandable expression of diversity (Magurran, 1988; McCune and Grace, 2002; Kent, 2012). Thus, species diversity, abundance, richness and eveness indicate the status forest ecosystem.

1.3.7. Plant communities BGRS

The woodland Vegetation in BGRS was classified into five plant communities: (1) *Hyphaene thebaica-Pterocarpus lucens*, (2) *Boswellia Papyrifera-Pterocarpus lucens,* (3) *Securidaca longepedunculata-Albizia malacophylla*, (4) *Croton macrostachyus-Albizia malacophylla* and *Breonadia salicina-Phoenix reclinata* (Tesfaye Awas *et al.,* 2007).

1.3.8. Ordination (community and ordination)

Ordination is used to study how species are distributed along specific environmental gradients of interest (Kent and Coker, 1992).Thus it primarily entails, the placement of plant samples in relation to one another based on species composition similarity and associations with environmental variables. Ordination can be regarded as constrained ordination (direct gradient analysis) and unconstrained ordination (indirect gradient analysis). Constrained ordinations are directly influenced by a set of environmental factors while unconstrained ordination techniques are not constrained by environmental factors (Zerihun Woldu, 2017). The primary goal of ordination is to arrange objects so that those that are near together correlated to sites with similar species compositions, and those that are far apart correspond to sites with divergent species compositions (Jongman *et al*., 1995).

Variation in species composition is related to variation in associated environmental and/or biotic parameters, which are commonly represented by environmental/biotic gradients, in ordination analysis (Jongman *et al*., 1995).Environmental factors that influence species distribution patterns can be identified and described using correlation analysis between environmental parameters and ordination axes scores (Kent and Coker, 1992; McCune and Grace, 2002). As a result, ordination approaches create concepts about plant community organization as well as probable incidental interactions between vegetation and its environment (Kent, 2012). Constrained ordination or direct ordination is ordination methods that use environmental variables to construct the ordination because the positions of the samples in the ordination are constrained by the environmental variables (UNEP, 1995).

RDA is the canonical or constrained form of PCA; It is asymmetric and predictive, since it maximizes predictions for a set of response variables (species data) given a set of predictive variables (environmental data) (Legendre and Legendre 1998). Explained variance is synonymous with redundancy (Gittins, 1985). When linear correlations between response variables and between response and predictor variables are predicted or proved, RDA is appropriate. CCA is a form of direct ordination in which the final ordination is a product of the variability of environmental data and the variability of species data (Kent and Coker, 1992).

RDA allows for the use of standardized and non-standardized analyses; standardization by samples allows us to distinguish variations in total cover from differences in species composition. RDA is not suitable for community data since it implies response variables are linearly related to predictors (McCune & Grace 2002). Canonical correspondence analysis (CCA) is the canonical or constrained version of CA, and is thus closely related to RDA (ter Braak and Prentice 1988; Legendre and Legendre 1998). Like RDA, the method uses multiple regressions to obtain linear combinations of the predictor variables that best explain sampling unit positions in species space (ter Braak and Smilauer 2002).

1.3.9. LULCC

Humans have been altering land cover since pre-history through the use of fire to flush out game and, since the advent of plant and animal domestication, through the clearance of patches of land for agriculture and livestock (Ellis and Pontius, 2006). In the past two centuries the impact of human activities on the land has grown enormously, altering entire landscapes, and ultimately impacting the earth's nutrient and hydrological cycles as well as climate (FAO, 2015). Thus, Land-use and land-cover changes are local and place specific, occurring incrementally in ways that often escape our attention.

Land use and Land cover is described as the distribution of vegetation, water, desert, ice and the immediate subsurface, including biota, soil, topography, surface, and groundwater (Chrysoulakis, 2004). It also includes those structures created solely by human activities such as mine exposures and settlement (FAO, 2000). However, some authors described, specifically, as an entire landmass area of the earth excluding the desert areas, water bodies, exposed rock surfaces, built-up areas, and other significant non-vegetation cover surfaces could be imagined to have been originally covered by vegetation (Oyinloye and Oloukoi, 2013). However, Land use and land cover (LULCC) is not homogeneous across all parts of the world (WIREs Climate Change, 2014). On global and local environmental changes, the LULCC varies across space and time (Bryan, 2013; Costanza, *et al*.2014). At the regional level, the LULCC can occur based on the altitudinal range, latitudinal range, and landscape. Some Land-use and land-cover changes are local and place specific (Jamal, 2012). Human land-use activities spread over 50% of the ice-free land surface starting, from the control over fire and domestication of animals and plants (Lambin and Geist, 2006). Thus the lands change from a primary forested land to a farming type, the loss of forest species within deforested areas is immediate and huge (Ellis and Pontius, 2006).

LULCC is a complex process triggered by the mutual interactions between environmental and social factors at different spatial and temporal scales (Valbuena *et al,* 2008; Rindfuss *et al,* 2004). Expansion of agriculture, urbanization, deforestation, and the day-to-day activities of humankind resulted in temporal and spatial changes in the land use land cover, which, in turn affects ecosystem services such as hydrological regulation and soil erosion losses (Rawat & Kumar, 2015). LULCC may also the result of various climate and physiographic conditions of an area and felt after an extended period (Bewket, 2002). In Ethiopia, the main agents of the observed for rapid LULCC over the last 40 years refer to the following categories: rapid population growth and resettlement, agricultural expansion, deforestation, and land clearing, and intensified anthropogenic fire regime (Tsegaye, 2010). Similarly, in wombera district, LULCC is caused by natural and humans induced factors.

LULCC is driven by multiple factors from environmental and social dimensions in a land system (Gong *et al.*, 2015). Land use changes are increasingly known as the consequence of actors and factors of interactions (Bakker MM and van Doorn, 2009). The causes LULCC were classified as proximate and underlying forces (Geist, and Lambin, 2002). Underlying causes of LULCC originate froma complex interaction of social, policy, institutional, economic, demographic, technological, cultural, and biophysical factors (Geist, and Lambin, 2002; De Sherbinin, 2002). Political, legal, economic structure, and traditional institutions and their interaction with individual decisionmaking also influence LULCC (Lambin and Geist, 2003: Lambin and Geist, 2007). Demographic fertility and mortality; changes in the household structure; the breakdown of extended families into multiple nuclear families dynamics; labour availability, migration, urbanization (Geist, and Lambin, 2002) caused a large impact on proximate causes. The population growth mainly caused LULCC particularly, forest cover change: forest clearing for agricultural land, forest products, and the settlement which, has resulted in fragmentation of natural forest habitat in Ethiopia (Edwards and Kelbessa, 1999). Cultural factors of populations encompass motivations, collective memories, personal histories, attitudes, values, beliefs, and perceptions of individuals, influencing communities and land managers (Lambin and Geist, 2007). All the underlying driving forces cause LULCC independently or in a synchronized way.

Proximate causes of LULCC are immediate actions of local communities and directly exerted on land resources due to different underlying causes (Geist, and Lambin, 2002, Shiferaw, 2011). Among the proximate LULCC, agricultural expansion, wood extraction, and infrastructure expansion are major ones (De Sherbinin, 2002). The agricultural expansion comprises permanent cultivation (large scale, smallholder subsistence, and commercial), shifting cultivation (slash & burn), and cattle ranching (large-scale and smallholder) (Geist, and Lambin, 2002). In the study area, Wombera district, proximate causes such as farming, Fire, logging, and firewood collection caused LULCC.

LULCC differs depending on the time period considered (Weng, 2002), geographical location (Poyatos *et al*., 2003), slope, and altitude (Kindu *et al*., 2013). In Ethiopia, LULCC varies from place to place based on altitude variation. Tegene (2002) identified up to eight major land cover classes, including scrubland, shrub grassland, grassland valley-rim vegetation, cropland, all-weather roads, dry weather roads, and towns. Fisseha *et al.* (2011) classified LULCC in the Debre-Mawi watershed at the upper catchment of the Blue Nile Basin, Northwest Ethiopia, as natural forest, shrub and bushland, grazing land, cultivated and settlement land, and plantations based on an aerial photograph and satellite image. In Northwest Ethiopia, Kidane *et al. (2012)* classified LULCC as natural forest, shrub and bush land, grazing land, cultivated and settlement land, and plantations using aerial photographs and satellite images. In the Bale Mountains, Kidane *et al*. (2011) classified the land cover as water bodies, a barren and burned area, agricultural lands, Afromontane grasslands, Afromontane dwarf shrubs and herbaceous formations, Afromontane rainforest, upper montane forest, Erica forest, isolated Erica shrubs, Afroalpine dwarf shrubs and herbaceous formations, and Afroalpine grasslands. Many authors indicated that the area under natural forest, shrub, and grazing lands were declining continuously while cultivation and settlement were expanding dramatically (Geist and Lambin, 2002; Tekle and Hedlund, 2000; Mekuria *et al*., 2011). However, in few areas, vegetation types are increasing, whereas bare land and croplands are declining (Friis *et al*., 2010).

1.4. Research questions

The study was concerned with the following research questions:

1. Which environmental variable affect the species composition, structure of vegetation and communities types?
2. Which factors determine the regeneration potential of a forest?
3. Is there significant difference in species diversity, abundance, among and within strata of forest?

4. What were the impact of anthropogenic disturbance (socio-economic values) on vegetation structure, species composition, and regeneration potential?
5. What type of land cover has been turned into other classes of land use/land cover and what are the causes?

1.5. Objectives of the study

1.5.1 General objective

The main objective of the study was to assess vegetation Ecology and land use Land cover changes in Wombera district, Benshangul Gumuz Regional. Ethiopia

1.5.2. Specific Objectives

1. To study plant species composition, structure, and diversity in selected forest patches
2. To identify plant community types of the vegetation in relation to environmental variables.
3. To determine vegetation (forest, Patches) dynamics in terms of species composition and structural variation along maturity gradients in selected forest patches
4. To investigate the regeneration status along successional gradients
5. To assess vegetation structure in relation in relation anthropogenic disturbance (Socio-economic uses)
6. To evaluate land use land cover changes and the driving forces

1.6. Significance of the Study

The study of vegetation ecology, land use and land cover change significantly provide relevant information to natural resources managers, conservationists, society, policymaker, environmentalists, and individual landowners. It is important to have an understanding of vegetation ecology and, land use and land cover patterns so as to plan for environmental conservation, land resource management, infrastructure development and agricultural transformation.

The altitude of wombera district ranges from 576 to 2615 masl and has three agro-ecological zonations. The district has two general physiognomic vegetation along the altitudinal gradients: the dry afromontane and the combretum-Terminalia woodlands.

The vegetation at the lower and middle altitude is influenced by fire while the vegetation at higher altitude is highly disturbed by human activities. The findings of this research would serve as an input for policy and decision makers to address the challenges imposed on the vegetation and Great Ethiopian Rennaissance Dam (GERD) watershed in particular. The finding would also provide additional information to the local community to use their indigineous knowledge and practices in conserving the biodiversity and and playing a vital role in the rehabilitation of the degraded landscapes.

1.7. Scope of the Study

The study was conducted in the Wombera district, which has an area of 723246 hectares and its altitudes lies between 650 and 2616 meters above sea level. Plant species, environmental, and topography variables were collected in six forest patches. Landsat raster images of 1973, 1985, 2000 and 2016 were analyzed using Erdas version 15 and ArcGIS version 10.3. The data was analyzed using R-software, SPSS version 24 and Microsoft Excel. The driving forces of LULCCs were assessed and categorized into direct and indirect driving forces of land use cover changes.

1.8. Limitation of study

Remoteness of the district from the center, the undulating nature of the landscape, and a lack of transportation were challenging during data collectiom. Soil seed bank and soil nutrient analysis were not conducted due to budget deficit.

CHAPTER TWO

Floristic composition, diversity and richness of selected Forest patches in Wombera district, Benshangul Gumuz Regional State, Ethiopia

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ABSTRACTS

Floristic composition, diversity and community types of six forest patches in three agro-ecologies were studied in Wombera district, Benishangul Gumuz Regional State. The district was stratified into higher, middle and lower agro-ecologies. Transect lines were laid 300m apart along altitudinal gradients; and plots were laid every 150m along the transect lines. Cover-abundance, height, DBH of woody plant species, and landscape variables were recorded in 142 (20× 20) main plots. Seedlings and saplings were recorded from five 5 × 5 m plots nested inside 20 × 20 m plots: four at corners and one in the center. Herbs and grass were recorded from 1 × 1 m plots that were nested inside of 5 × 5 m plots, four at corners and one in center. Shannon diversity and Evenness indices were used to compute Floristic diversity and evenness. The Multivariate tool of R package (ver. 3.4.3) was used for community analysis. Three hundred seventy five species representing 90 families and 70 genera were recorded from 142 plots in six forest patches within three agro-ecologies. One hundred forty-four species were identified in higher altitudes, representing 52 families of which Asteraceae, Poaceae, Fabaceae, and Polygonaceae were the dominant. In middle attitude, 115 species representing 49 families were identified with Fabaceae, Asteraceae, Poaceae, and Moraceae among the dominant families. A total of 123 species were identified at lower altitudes, which represented 45 families. The dominant families were the Fabaceae, Poaceae, and Combretaceae. The hierarchical classification analysis identified six communities, named after two or *more indicator species. Community VI was the richest, followed by community II and Community V. Community VI is in steep slope landscape, intermediate moisture and temperature. Therefore, it can be concluded that plant communities are assembled by altitudinal gradients in which higher altitude is dominated by communities I, II, and II, lower altitude by communities IV and V, and middle altitude by community VI.*

Key words: Agro-Ecology; Community; Diversity; Forest patches; Vegetation

1. INTRODUCTION

Ethiopian owns altitudinal ranges from lowland below sea level (Danakil Depression, 110 mbsl) to top mountains [Ras Dashen (4532masl) (Teketay, 1996; Woldu, 1999)]. The Great Rift Valley is also the other landscape that runs from northeast to southwest of the country and separates the country into Northwestern and Southeastern highlands enabling the country owning semi-arid lowlands to the east, south, and west of the country (Friis, 1986; Bekele, 1993). Such diversified landscapes and altitudinal ranges have given rise to diversified agro-ecological zones, temperature, rainfall patterns, soil texture, and wind patterns in Africa (Friis *et al*., 2010). The diversified environmental conditions and landscapes also resulted in diversified flora and fauna (Bekele *et al*., 1999; Woldu, 1999).

Ethiopia is home to about 6027 species of higher plants with approximately10% endemism, and hence one of the six plant biodiversity-rich countries in Africa (Kelbessa ans Demissew, 2014). Ethiopia also has two of the 34 global biodiversity hotspots, namely the Eastern Afromontane and Horn of Africa biodiversity hotspots (Myer *et al*., 2000). The country is a regional center for biological diversity due to its wide range of altitude, its high geographical diversity with high and rugged mountains, flat-topped plateaus and deep gorges, incised river valleys and rolling plains (Kelbessa *et al.*, 1992; Woldu, 1999).

In contrast, many studies have show that most of the vegetation covers of the country have been deforested, and few remnant high land forests remain in southwestern and western parts and as patches in conservation areas, churches (Bekele, 1993) and sacred sites in the country (Friis, 1992; Wassie *et al*., 2005; Senbeta, 2006; Demissew and Friis, 2009; Friis *et al*., 2010). Environmental variables determine vegetation Structure and composition. Altitude is the most determinant factor that influences the occurrence and distribution of the plant communities (Schmitt, *et al*., 2010). Species richness tends to peak at intermediate elevations (Didita *et al*., 2010). The main objective of the study was to assess vegetation Types, composition, and community type along altitudinal and disturbance gradients (highly disturbed, intermediate, low disturbance level and intact). Current and historic understanding of vegetation ecology in Benshangul Gumuz particularly, in Wombera district was not adequate. Tesfaye Awas (2007) had made a study of the floristic composition and the ethnobotany in the lowland areas of Benshangul. However, no research has been conducted in Wombera district. Thus, this study filled the gap which addressed vegetation ecology status of the district with high significance to the scientific community, policy makers and other stake holders to conserve, study, rehabilitate, and utilize the vegetation.

2. MATERIALS AND METHODS

2.1 Descriptions of the study Area

Wombera ditrict is located 658km from Addis Ababa, capital city of Ethiopia. It is found in the Metekel administrative zone of Benishangul Gumuz Regional State in the northwestern part of Ethiopia. The district is one of the largest districts in Metekel administrative zone. The latitudinal and longitudinal position of the district are between 9^{0} 57' $30^{"}$ to 11^{0} 08' $45^{"}$ N and 35^{0} $09^{'}$ 09” to 35^{0} 50' 25'' E, respectively (Figure 1).

2.1.1. Topography

The topography of the study area is undulating and has only a few plain fields. The altitudes of Wombera district ranges between 576 to 2615masl. The district is stratified into: higher, middle and lower agro-ecologies based on an altitudinal range, vegetation strata, and crop productivity. In the lower ranges (576 to 1200 masl), *Combretum-Terminalia* forest and woodland is the most dominant vegetation. The majority of the study area falls within the lower altitude. The higher altitudes range between 2001-2615 masl. Dry Afromontane forests with different sub-layers are the dominant vegetation. Middle agro-ecology altitudes range between 1201 and 2000 masl. Coffee, fruits, spices and vegetables are abundant in the middle altitude.

The vegetation layers middle altitude is mainly dominated by *Albizia schimperiana*, *Albizia gummifera*, *Millettia ferruginea*, *Cordia africana*, and *Ficus sp.*

2.1.2. Climate and Temperature

Twenty years of climate data (1999-2016) were taken from the Ethiopian metrological agency. Climate data were drawn using the Walter climadiagram program of R software version 3.4.2 (R Software Developing Team 2017) and library climatol (Woldu, 2017).The altitude of the study area ranges between 576-2615 masl. The average annual temperatures for the high altitude, middle and lower altitude were 15.9^{0}C (7.2^{0}C - 26^{0}C), 20.7^{0}C (11.9^{0}C -30.6^{0}C), 25.7^{0}C (18.8^{0}C-37.2^{0}C), respectively. Likewise, the average annual rainfalls for the three altitudes were 1942mm, 1560 mm, and 1210mm, respectively (Figure 2).

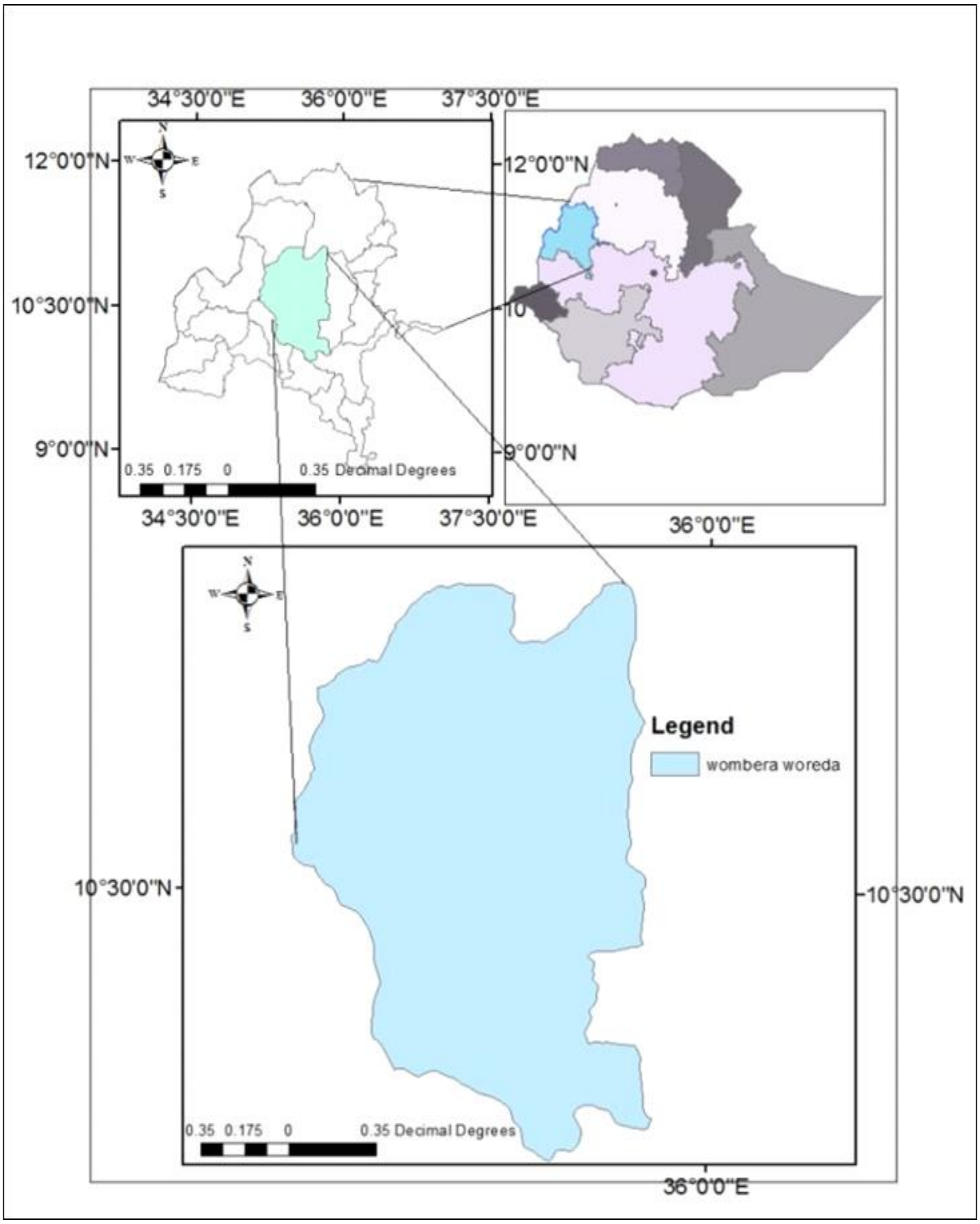
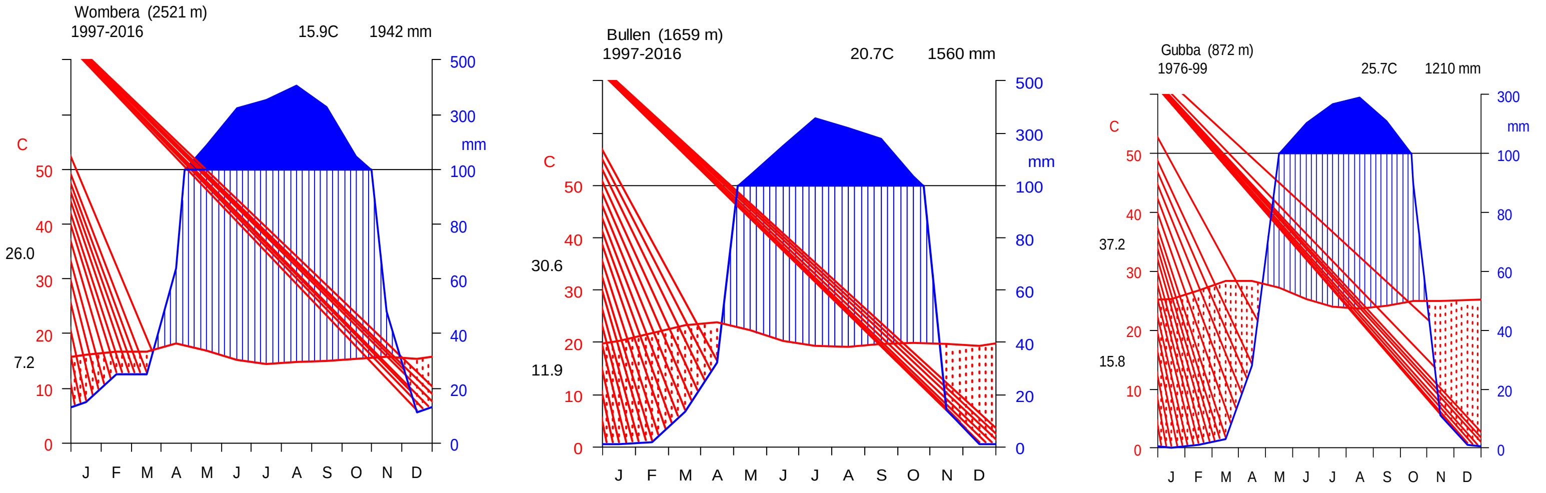


Figure 1. Map of Wombera district



A)Wombera B) Bullen C) Guba

Figure 2. Climate diagram of three of districts

2.2. Method

2.2.1. Reconnaissance Survey

During the reconnaissance survey, general prerequisite works were carried out: A reconnaissance survey of the study area was made from June to November, 2018 to obtain an impression of the study site condition and physiognomy of the vegetation. Sampling sites were selected and determined based on the accessibility of forest patches.

2.2. 2.Geographical data

The environmental variables were measured for every plot designed along the transect lines of each stratum. Altitude was measured using Garmin GPS; the slope was measured using clinometers; aspect (exposure) was determined using Suunnto compass or GIS analysis as a possible indicator of total solar energy; and the percentage was converted based on Zerihun Woldu *et al*. (1989), which was defined as N = 0; E = 2; S = 4; W = 2.5; NE = 1; SE = 3; SW = 3.3; and NW = 1.3).

2.2.3. Disturbance factors

Factors that influence the distribution of vegetation were ranked based on their intensity and frequency. The following factors were identified: Grazing by domestic animals, anthropogenic impact, and incidences/frequency of fire, Grazing and anthropogenic factors were ranked based on severity, intensity, and rate. The magnitude of disturbance was rated from 0 to 3, following Feyera Senbeta *et al*. (2007) and Ermias Ayenekulu (2011), based on visible signs of disturbance such as livestock grazing, fire, tree stumps (tree cutting), and the collection of firewood. In forest patches where grazing animals and humans could not access them or there were very low disturbances, a value of zero was assigned, and low = 1, medium = 2, while where the impacts were very severe, a value of 3 was assigned.

2.2.4. Distance from the rivers or wetlands

The distances were measured in relation to nearby rivers and wetland areas in order to investigate the effects of moisture on the distribution of various plant species.The distance of forest patches from water bodies was measured by taking GPS points on the plots and superimposing them on Arc maps and Google Maps following Ermias Ayenekulu(2011).

2.2.5. Fire occurrence

The frequency and incidence of the fire were assessed by interview and further confirmed by the scare it left behind on the bark of the tree. The impact of a fire burn less than three year is more visible than 4-6 and 7-9 years,however the impact is invisible above nine years.The frequency of fire was classified into three-year intervals 1-3 = 3, 4-6 = 2, 7-9 = 1 and 9 years above = 0 were assigned.

2.2.6. Grazing

Interviews were used to determine the number and event of grazing, and the damage to plant species and the scene left behind served as additional confirmation. Based on the impact's severity, a classification was made. It was categorized as follows: no at all = 0, moderate = 2, low = 1 and high = 3.

2.3. Vegetation data collection

A series of nested plots were established following previous study (Stohlgren *et al.,* 1995) at 300 m intervals along attitudinal gradients. The plots were laid 150m apart along parallel transect lines. Data were collected from 142 Plots. In 20 × 20 m plots, trees with stem diameter at breast height (DBH) >2.5 cm and shrubs at diameter stump height (DSH) were collected. Canopy cover of each tree species was estimated and computed to the total area of the plot. Seedlings and saplings were recorded in five 5 × 5 m plots nested inside 20 × 20 m plots with four at corners and one in center. Herbs and grass were recorded in 1 × 1 m plots that were nested inside of 5 × 5 m plots with four at corners and one in center (Appendix-Figure 1).

All plant specimens were collected, temporarily tagged with plot numbers and temporary labels were assigned to species (fast method), pressed and brought to the National Herbarium (ETH) for identification and storage. The species were identified at the National Herbarium (ETH) of Addis Ababa University by using the taxonomic keys in the various volumes of the Flora of Ethiopia and Eritrea (Hedberg & Edwards, 1989; Edwards *et al*., 1995; Phillips, 1995; Edwards *et al*., 1997; Hedberg *et al*., 2003; Tadesse, 2004; Hedberg *et al*., 2006, 2009a, 2009b). The species were confirmed with authenticated specimens published in the flora of Ethiopia and Eritrea. Botanical names and authorities were verified using the species and family lists in Volume 8 of the Flora of Ethiopia and Eritrea (Hedberg *et al*., 2009).

2.4. Data Analysis

2.4.1. Vegetation data preparation

Cover/abundance (ground cover) for each plant species was estimated following the procedure of Braun-Blanquet (1965) and Kent and Coker (1992) to determine different vegetation parameters. The percent canopy/foliage cover was transformed to ordinal scales and assigned value one to nine cover-abundance classes according to the modified 1-9 Braun-Blanquet scale (Van der Maarel, 1979). The scales are 1 ≤ 0.1%, 2 = 0.1 to 1%, 3 = 1 to 2%, 4 = 2 to 5%, 5 = 5 to 10%, 6 = 10 to 25%, 7 = 25 to 50%, 8 = 50 to 75%, and 9 >75%. The three-column data, abundance or cover, were imported to R Package 3.4.3 (R Core Team, 2017) and modified to carry out the analysis for various vegetation parameters.

2.4.2. Floristic Composition and Diversity analysis

The Floristic richness, diversity and evenness indices of plant communities were analyzed by using R Package 3.4.3 (Woldu, 2017). Among the various coefficients widely used to compute the diversity of a community, species diversity and turnover (β diversity) are the most commonly used (Krebs, 1999). It is sometimes used for identifying areas of High natural or human disturbances. The value usually falls between 1.5 and 3.5, rarely exceeding 4.5 (Maguran, 1988; Økland, 1990; Krebs, 1999). A high Shannon index indicates high diversity and often low disturbance whereas; a low Shannon index shows low diversity and often high disturbance.

Species turnover (β diversity) measures the change in species compositions from patches to patches along Environmental gradients (vertical height, soil depth etc) (Whittaker, 1972). Thus, in this altitude (low, middle and high) and disturbance (low, intermediate and high) gradient were used. In other words, β–diversity measures the changes in species diversity among sets of habitats. A high β–diversity index indicates a low level of similarity among areas or communities, while a low beta diversity index shows a high level of similarity (Økland, 1990). The Values of ß-diversity less than one are lower and, greater than five can be considered as higher (Woldu, 2017).

2.4.3. Vegetation Classification (plant communities)

Cluster analysis is a multivariate technique widely used to group a set of observations (plots or vegetation samples) based on their attributes or floristic composition (Kent and Coker, 1992; McCune and Grace, 2002).In this study, hierarchical (agglomerative) cluster analysis was executed using the free statistical software R version 3.4.3 (R Development Core Team, 2017) to classify the vegetation into plant community types. The cover-abundance of the species was used for analysis. Plant communities were classified using the Hierarchical clustering method using similarity ratio, ward clustering algorithms. To determine the optimal number of groups in the cluster analysis, different classification methods were carried out. Ward produces a nicely compact community (Woldu, 2017). Validation of the community was analyzed using the package called "clv" in R software. The intra-cluster and inter-community distances were also performed. This function helps to deduce the cohesiveness or dispersion as well as the relative proximity of the community to each other. All analyses were carried out using R programs updated in Woldu (2017).

2.4.4. Vegetation-environment relationship (Ordination)

The ordination method was used to precisely understand the interaction between plant communities and the environment. The ordination method (unimodal or linear model) is often selected based on the length of the first DCA axis in various ecological studies (Woldu, 2017). Accordingly, a gradient length exceeding four implies a strong unimodal response between the species and environmental variables (Legendre & Legendre, 1998). On the other hand, if the length of an axis is < 4, the data are homogeneous, and a linear response is expected. RDA assumes that response variables are linearly related to predictors; it is not generally suitable for community data (McCune & Grace, 2002). RDA is important where linear relationships among response variables and between response and predictor variables are expected or demonstrated. CCA allows simultaneous ordering of sample units and species based on a linear relationship between unimodal patterns of redundant co-occurrence in species data and explanatory variables. RDA enables the use of standardized and non-standardized analyses; by standardizing samples, we can separate differences in total cover from differences in species composition.

3. RESULTS

3.1. Species accumulation curve

In ecological studies, as the number of sampling plots increases, the number of species recorded increases proportional to the number of plots; however, the numbers of species in specific ecology are limited due to species-specific conditions and resource requirements, and the caring capacity of the area. The numbers of species were increasing as the number of sampling plots increased. However, the rate increment of new species records declined and tends constantly, as the numbers of sampling plots increase in wombera district study plots.The species accumulation curve is useful in determining whether or not the number of sampling plots is sufficient to collect the total number of species in the study area. The graph of species accumulation curve tends to asymptote at 100 the sampling Plots (Figure 3).

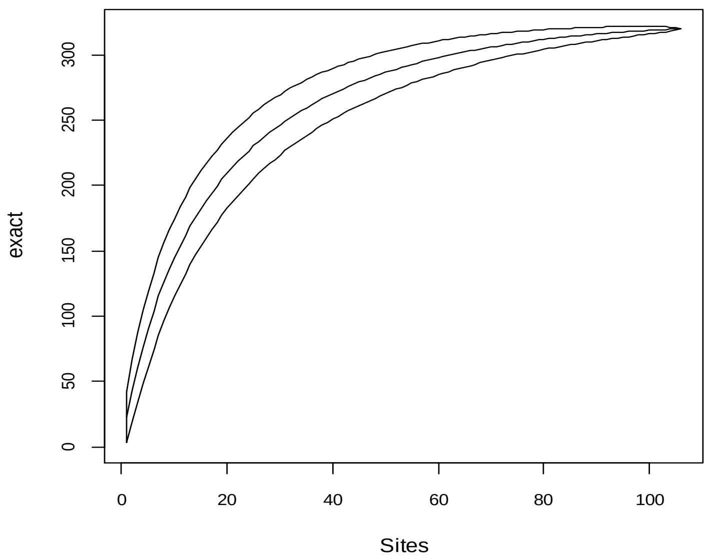


Figure 3. Species accumulation curve of six forest patches

3.2. Floristic Composition

A total of 375 species representing 90 families and 70 genera were recorded from 142 sampling plots within three agro-ecologies (lower, middle and higher altitude).Angiosperms, gymnosperms, and Pteridophytes were represented by 363, 1, and 7 species, respectively. Among the angiosperm families, Fabaceae (36 species) were the richest, followed by Asteraceae (species 35); and Poaceae (33 species). Pteridophytes were represented by four families and seven species, namely

Aspleniaceae (two species), Polypodiaceae (two species), Pteridaceae (one species) and Selaginellaceae (two species). *Juniperus procera* (Cupressaceae) was the only species of Gymnosperms that was recorded in a few plots.

One hundred forty four species were identified in higher altitude: 37 woody, 30 shrub, 15 liana and 62 herbs. They were categorized under 52 families among which Asteraceae, Poaceae, Fabaceae, and Polygonaceae are the dominant family. From 115 species recorded in middle altitude, 46 trees, 23 shrubs, 41 herbs, and five lianas were identified. These species represent 49 families dominated by Fabaceae, Asteraceae, Poaceae, and Moraceae. In lower ago-ecology forest patches, a total of 123 species: 40 Trees, 27 shrubs, 45 Herbs, and nine lianas representing 45 families were recorded dominated by family Fabaceae, Poaceae and Combretaceae (Figure 4).

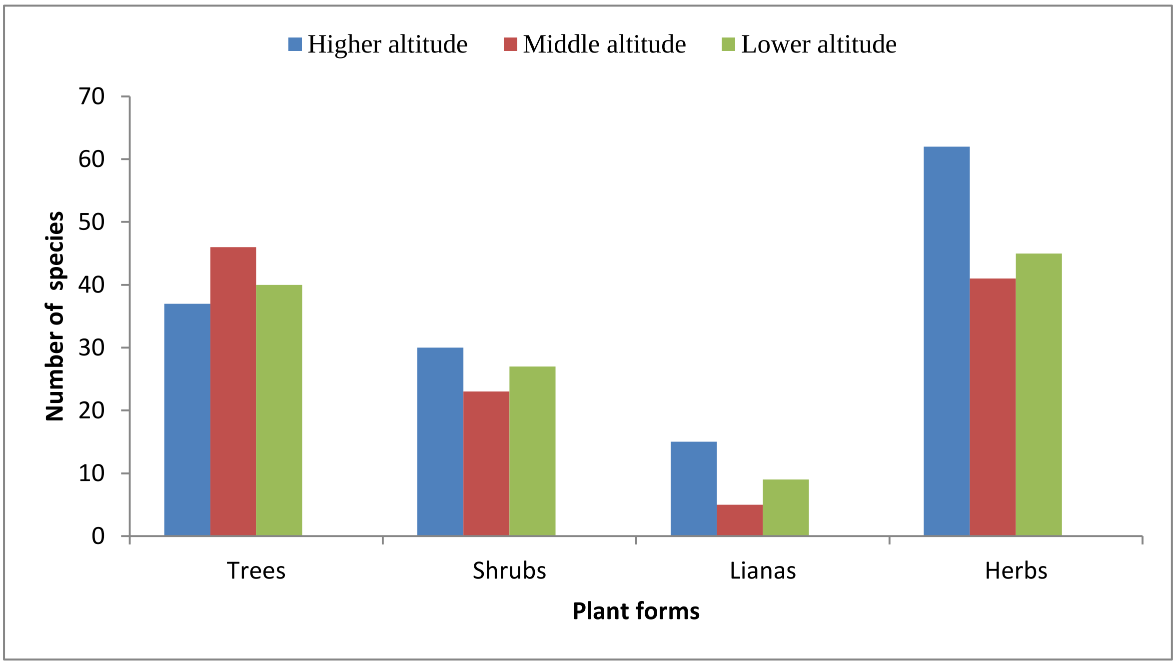


Figure 4. Plant growth forms along altitudinal gradients

3.3. Families in six Forest Patches

In higher altitude forest patches, Asteraceae (22 species, 15.83 %) was the dominant families followed by Poaceae (12 species, 8.63%) and Fabaceae, Polygonaceae, and Solanaceae had an equal number of species (6 each, 4.32%). In middle altitudes, Fabaceae (15 species, 13.27%) was the dominant, followed by Poaceae and Asteraceae (8 species, 7%). In the lower altitudes, Fabaceae (15 species, 12.20%) followed by Poaceae (13 species, 10.57%) and Combretaceae (7, 5.69%) (Figure 5).

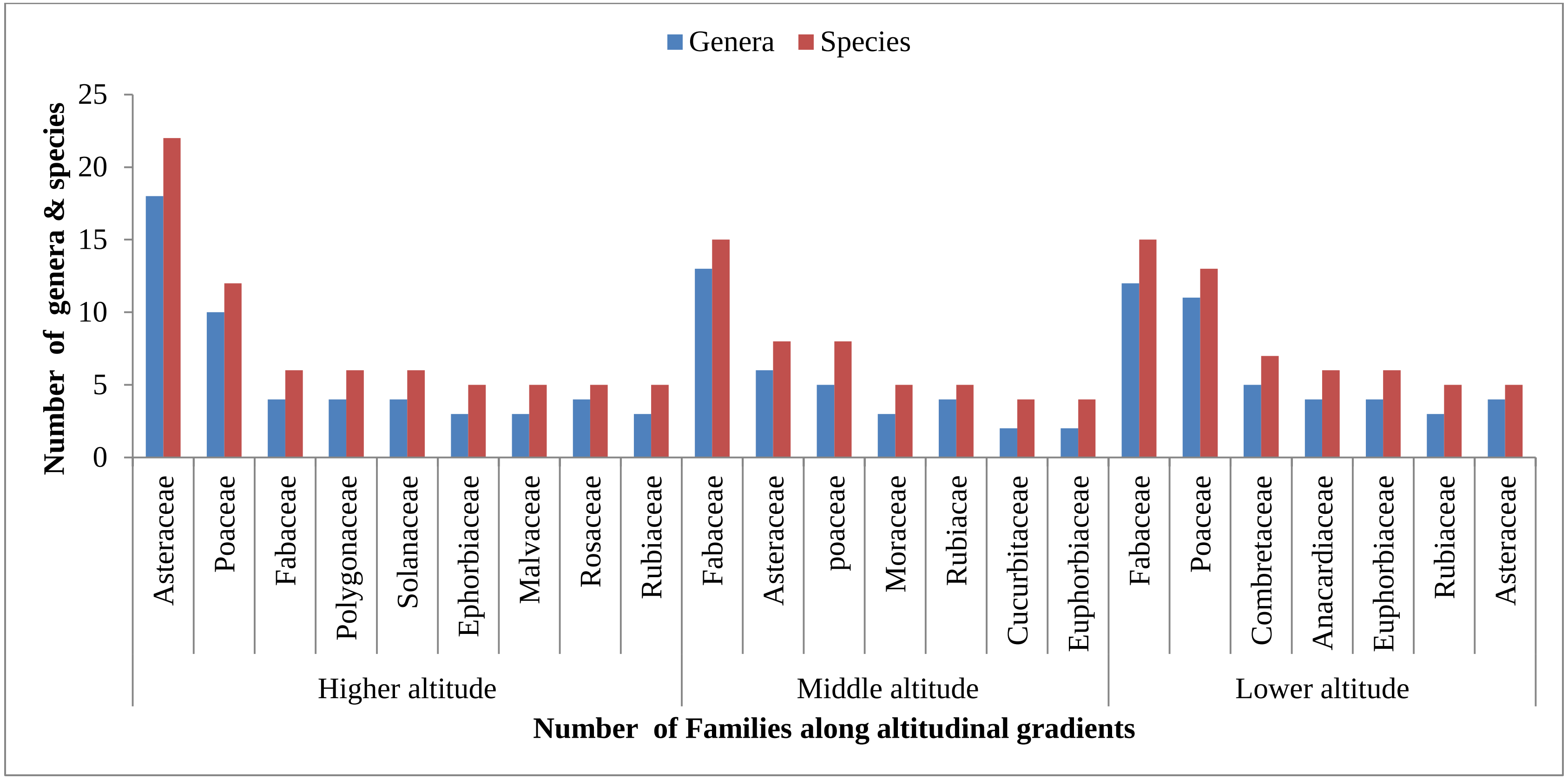


Figure 5 . Families and species along altitudinal gradients

3.4. Vegetation Classification (Plant Communities)

The hierarchical classification analysis resulted in six plant community types in the study area (Figure 6). They were named after two or more indicator species (Table1). Community I, Community II and Community III are closely related; Community IV and community V are more similar than other communities. The detailed description of each community type and their altitudinal ranges, indicator species, dominant species and examples of other species in different vegetation layers (tree, shrub, grasses and herb); the similarity between the six communities: richness, diversity, and evenness are described within the following subsections.

Community I: *Nuxia congesta- Maesa lanceolata* Community type: This community is in the dry Afromontane forests occurring in altitudes range of 2000-2600. Indicator species include *Nuxia Congesta*, *Maesa lanceolata, and Accacia abyssinica* were significantly varied ($P < 0.001$).

Community II: *Allophyllus abyssinicus-Hagenia abyssinica* community type. This community type is in the same altitudinal range with community I and community III. They are older than community I and younger than community III. Indicator species are *Allophyllus abyssinicus-Hagenia abyssinica* which, were significantly varied ($P<0.001$).

Community III: *Apodytes dimidiata- Prunus africana community type.* Indicator species were *Prunus africana* and *Apodytes dimidiata* and significantly varied ($P < 0.001$). This community was dominated by: the most upper canopy tree such as *Syzygium guineense, Ficus sur, Olea europaea* near the river border and *Prunus africana*, *Apodytes dimidita,* and *Ekebergia capensis* away from the river.

Community IV: *Combretum collinum-Pterocarpus lucens* community type. Pterocarpus lucens, *Sterculia africana* and *Boswellia papyrifera* significantly varied ($P < 0.01$). They are the lower altitude plant assemblages ranging from 600m-1000masl. They are within the *combretum-Terminalia* woodland vegetation types. The upper canopy trees species are *Combretum collinum*, *Combretum molle, Pterocarpus lucens*, *Sterculia africana* and *Boswellia papyrifera*. The middle layer is *Ziziphus abyssinica* and others.

Community **V**: *Ficus sycomorus-Acacia hecatophylla* and *Syzygium guineense community type.* They are significantly varied P<0.001. They occupy at an altitudinal range of 1000-1200 masl. The dominant woody species of these communities were*: Terminalia macroptera, Acacia hecatophylla, Stereospermum kunthianum, Ficus sycomorus, Cordia africana and Piliostigma thonningii.* The middle layers are covered by woody shrubs *Grewia mollis, Ziziphus abyssinica, Grewia mollis* and *Vernonia hochstetteri.*

Community VI: *Albiza schimperiana- Millettia ferruginea* community type. The Indicator species are Albiza *schimperiana- Militia ferruginea* which were significantly varied at P < 0.001. *This community extends from 1600-1800 altitudinal ranges. The upper canopies: Albiza schimperiana, Millettia ferruginea, Albiza gummifera, Fagaropsis angolensis, Ficus sycomorus, Cordia africana, Croton macrostachyus, Stereospermum kunthianum,* and *Sapium ellipticum.* The middle layer is consists of *Vernonia amygdalina*, *Vernonia thomsoniana*, *Clausena anisata*, and *Dodonaea angustifolia*. The ground layer of these community covered by grasses and herbs such as: *Rubia cordifolia, Zehneria scabra,* and *Datura stramonium*.

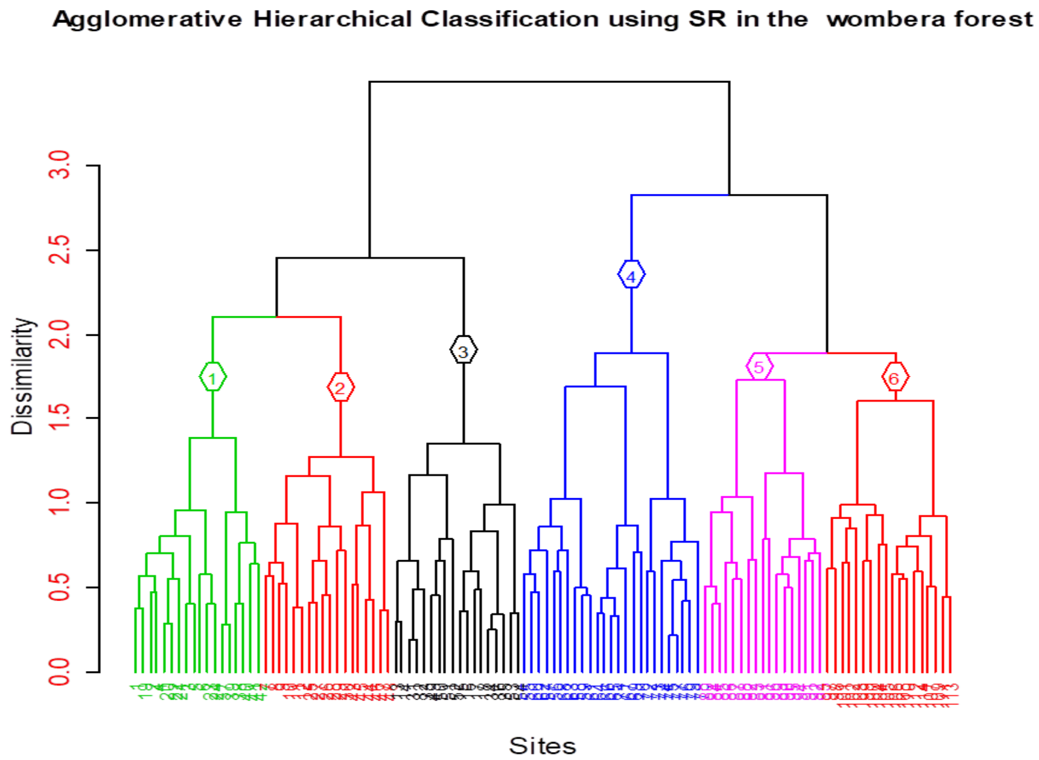


Figure 6. Dendrogram showing plant communities

Table 1.Synoptic and indicator values of species in each community type (CI – CVI)

Species	Synoptic value*						Indicator value %**						
	CI	C II	CIII	CIV	CV	CVI	CI	C II	CIII	CIV	CV	CVI	P value
Nuxia congesta	5.33	0.78	0	0	0.3	0	76.8	2.6	0	0	0	8	0.001
Maesa lanceolata	5.22	1.11	0	0	0.4	1.3	65.3	57	0	0	0	6.3	0.001
Allophyllus abyssinicus	0.83	5.44	1.67	0	0	0	0	73.7	9.3	0	0	0	0.001
Dombeya torrida	1	4.83	0	0	0	0	5.7	68.5	0	0	0	0	0.001
Hagenia abyssinica	1	3.33	0	0	0	0	5.8	57	0	0	0	0	0.001
Apodytes dimidiate	1.44	1.39	4.83	0	0	0	10.5	70	54.7	0	0	0	0.001
Prunus africana	1	1.44	4.67	0	0	0	5.5	7.9	52.5	0	0	0	0.001
Pterocarpus lucens	0	0	0	3.92	0.6	0	0	0	0	58.1	0	0	0.001
Sterculia africana	0	0	0	2.96	0.6	0	0	0	0	56	34	0	0.001
Combretum collinum	0	0	0	2.44	0	0	0	0	0	48	0	0	0.001
Syzygium guineense	1.28	1.28	3.56	0	3.2	0.2	3.8	3.8	19.6	0	19.6	4.8	0.001
Ficus sycomorus	0	0	0	0	3	0	0	0	0	0	29.7	22	0.001
Albizia schimperiana	0	0.67	0.94	0	0	5.8	0	25	35	0	0	61.1	0.001
Millettia ferruginea	0	0	0	0	0.1	4.7	0	0	0	0	0	50	0.001
Albizia gummifera	0	0	0	0	0.3	4.4	0	0	0	0	0	50	0.001

CI=community one, CII= community two, CIII= community three, CIV= community four, CV= Community five and CVI= community six

* The mean values of the species cover-abundance in each community. ** The product of the relative frequency and relative cover-abundance values in eachCommunity.

3.5. Diversity and Evenness of Plant Communities

Community VI was the richest, followed by community II and Community V. Community II was the highest in evenness, followed by Community VI, community V and community II. Community VI highest in diversity followed by community II and community V (Table 2).

Table 2. Species diversity richness in communities

Community	Richness	Sh.H	Evenness
I	96.00	4.20	0.92
II	113.00	4.41	0.95
III	61.00	3.67	0.89
IV	89.00	3.88	0.91
V	103.00	3.95	0.92
VI	138.00	4.43	0.93

SH. H Shannon diversity

3.6. Results of RDA for wombera district vegetation

All environmental factors significance tests of a backward and forward selection of seven variables indicate that all are significant ($P<0.001$- 0.009) except grazing ($P<0.0933$). Disturbance, grazing, Fire, slope, aspect, moisture content, and Altitude determine the distribution of vegetation at $p<0.001$. Figure 7 shows the results of RDA with coloured clusters constrained by species score Eigenvalues using library vegan. Community VI and community V were highly constrained by Fire and followed by slope and aspect in the first quadrant. Community I, Community II, and community III were constrained by Altitude in the second and fourth quadrants. Community four was constrained by Moisture (riverside) in the fourth quadrants. Table 3 shows the results of the analysis of variance of the vegetation and environmental data and the fitting of linear models.

Table 3 Environmental factors F model, R^2 and Pvalue

Factors	Df	SumsOfSqs	MeanSqs	F.Model	R2	Pr(>F)
Slope	1	3.44	3.4403	12.1646	0.07455	0.001 ***
Aspect	1	2.42	2.4197	8.5557	0.05243	0.001 ***
Disturbance	1	1.155	1.1551	4.0844	0.02503	0.001 ***
Moisture	1	1.29	1.2898	4.5607	0.02795	0.001 ***
Fire	1	5.061	5.0608	17.8945	0.10966	0.001 ***
Grazing	1	0.559	0.559	1.9766	0.01211	0.012 *
Altitude	1	2.247	2.2468	7.9445	0.04869	0.001 ***
Residuals	106	29.978	0.2828	0.64959		
Total	113	46.15	1			
Signif. codes:	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

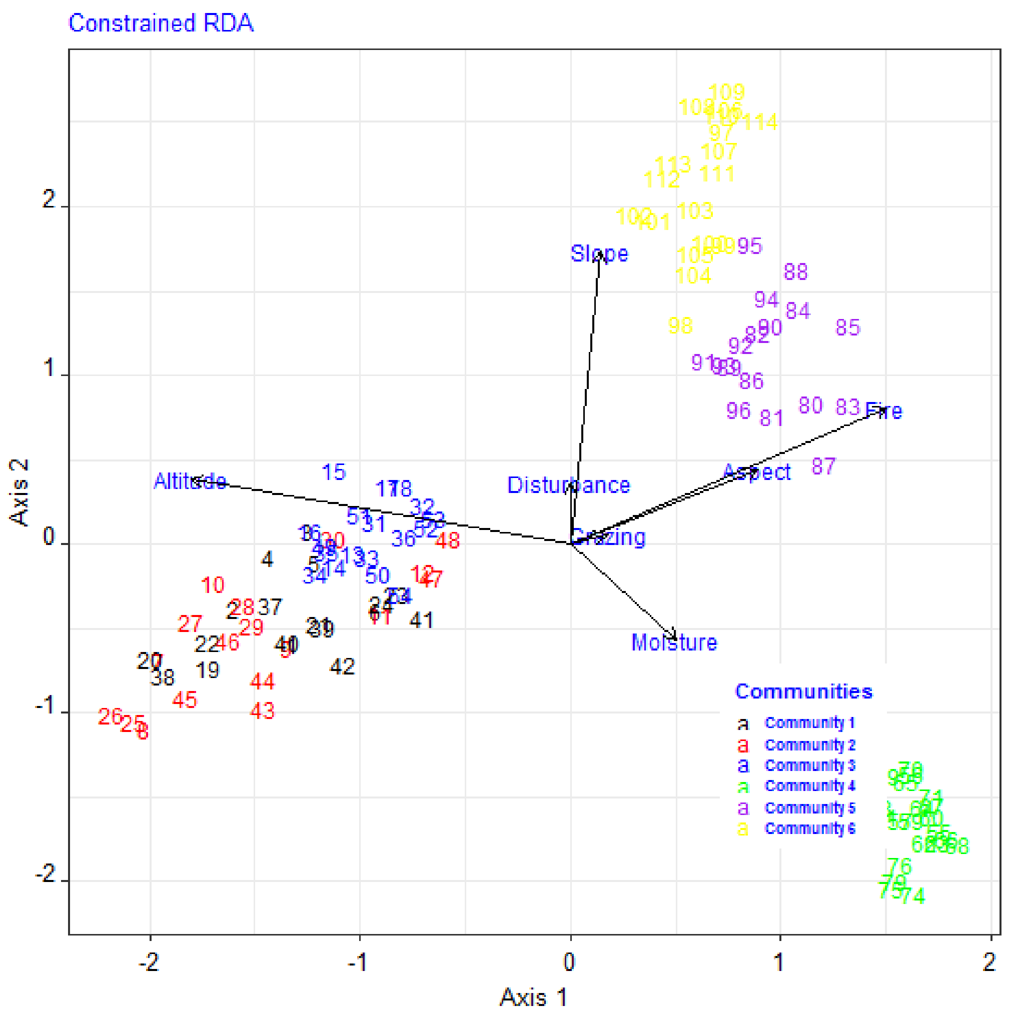


Figure 7. Constrain RDA Vegan library wombera forest patches

4. DISCUSSION

4.1. Floristic Composition and Diversity

The 375 species representing 90 families and 70 genera recorded from the Wombera district are under the two general categories of broad vegetation types. They are the Dry evergreen Afromontane forest and grassland complex, and the Combretum-Terminalia woodland and wooded grassland among twelve vegetation types of Ethiopia classified by Friis *et al.* (2011). Similarly, the general vegetation richness of the district is mainly related to an altitudinal range which resulted in diversified agro-ecology. The topographic heterogeneity: undulating landscape, deep gorges, mountain peaks, plains, river and river gorges created sort microclimates which harbour different species.

The total woody species (145) recorded from four forest patches at higher and middle altitudes were similar to Berhanu *et al*. (2017) from dry Afromontane Forest Patches in Awi Zone. Wombera district and Awi zone share boundaries. The altitudinal range of wombera dry Afromontane forest patches ranges from 1765-2650 (current study) masl and Awi zone altitudes also range from 1830-2660. The altitudinal range may contribute to the similarity of woody vegetation in the two study areas. On the other hand, wombera district dry Afromontane has a significant difference of woody vegetation composition than similar agro-ecology: Zege Peninsula forest (Aleign *et al*., 2007), Adelle and Boditi forests (Yineger *et al*., 2008), Amba Mariam forest (Tilahun *et al*., 2011), Tara Gedam and Abebaye forests (Zegeye *et al*., 2011), Zengena forest (Tadele *et al*., 2013), and Kuandisha forest (Berhanu *et al*., 2017).The, 77 woody species identified from Lower altitudes in *Combretum–Terminalia* woodland and wooded grassland vegetation are similar to the study by Awas (2007) in western Ethiopia. The difference in species richness among these patches could be mainly related to the dissimilarities of the sites in terms of location, altitudes, human impact, rainfall, and other biotic and abiotic factors, as discussed by Kidane (2005).

The highest proportion of Asteraceae family, Poaceae, and Fabaceae in dry Afromontane higher altitude forest; Fabaceae, Asteraceae and Poaceae, in middle latitudes, and Fabaceae, Poaceae and Combretacea in the lower altitudes respectively

(Figure 4)were in line with families recorded in the flora of Ethiopia and Eritrea Volumes. The result is similar to other studies (Tadesse, 2004; Gurmessa *et al.*, 2012; Yineger *et al*., 2008). The Combretaceae family had a higher proportion (Awas, 2007) in Beshangul gumuz western Ethiopia that is also in line with the family recorded in the flora of Ethiopia and Eritrea Volumes.

4.2. Plant communities

Measures of community diversity play a role in ecology and conservation biology (Magurran, 2004). It is an important parameter of a plant community that is related to ecosystem dynamics and environmental quality (Liu and Brakenhielm, 1996). The hierarchical classification analysis resulted in Six plant community types in Wombera district Forest patches (Figure 5). They were named based on synoptic and indicator values (Table 2). The Six plant community types of wombera district forest patches showed variation in their species richness, diversity, and evenness (Table 3). Variations among the plant communities' types are the direct reflection of the effects of the environmental variables and geographic locations (Suratman, 2012; Parthasarathy, 2001). However, in the Wombera district, higher altitude forest patches, community I, community II and, community III are found on similar geographic locations and environmental conditions (altitude, aspect, slope, moisture and soil type) (mixed forest). They are in higher altitude study sites that have a similar ecosystem. The variation among the three communities is mainly age gradient (succession).

Community I: mainly dominated by shrubs and lower layer canopy trees: *Nuxia congesta*, *Maesa lanceolata, and Accacia abyssinica.* These species can invade virgin grasslands; abandon farmland and any bare land under poor soil conditions. The lower layer canopy trees are well-known soil layer builders for the succeeding species of middle and upper canopy trees. The lower layer canopy trees and shrubs form pioneer forests or primary plant communities. It is partly in line with the definition of Facilitation definition, "when later species can become established and grow only; after earlier species have suitably modified the environment (Connell and Slatyer 1977). The lower canopy tree species grow faster than upper canopy and middle canopy trees. They produce seed in mass and dispersed at faster rate than other tree species. With respect to pioneer and climax tree species, Whitmore (1989) observed that climax species typically have bigger seeds while seeds of herbs, grasses and sedges have small seeds.Thus small seeded tree species especially pioneer trees produce relatively large quantity of seeds and increase their survival on bare lands.

Community II is on a similar altitudinal range with community I and community III. They are grown on the ecology of community I. In intact forests of community II, the middle layer canopy trees dominate the forest patches with a few or absent lower layer canopy trees. Grasses and herbs are rare on the ground layer in intact forests. However, the herbs and grasses cover the disturbing parts of the forest patches.

Community III: These communities are the successor of community I and community II. Community II (middle layer canopy trees) built-in community I, Community III (upper canopy trees) built-in Community II. It is similar to the finding of Muller-Dombois & Ellenberg (1974), plant species that are dependent on their environment and influence one another and modify their environment. These communities are dominated by the most upper canopy tree such as *Syzygium guineense, Ficus sur,* and *Olea europaea* nearer to the river border; *Prunus africana and Apodytes dimidiate,* and *Ekebergia capensis* away from the river. This is similar to the finding of Gebre Egziabher (1988) who stated that the vegetation of dry Afromontane are dominated by *Juniperus procera, Olea europaea* subsp. *cuspidata, Podocarpus falcatus,* and *Prunus africana.* Thus upper canopy trees are the dominant in climax forest patches due their long life span. Their canopies also protrude above lower and middle canopy trees and suppress their growth pattern and dominate the climax forests. In intact climax forests, there are no middle layer and lower layer canopy tree species. However, in disturbed parts of the forest patches, the Lower layer strata are dominated by *Maytenus arbutifola, Teclea nobilis, Brucea antidysenterica, Bersama abyssinica*, and sapling of upper canopy trees. It is partly in line with the definition of inhibition by Connell and Slatyer (1977), i.e. togetherness completely eliminates the role of tolerance. In highly disturbed climax forests, the *Schefflera abyssinica* and *Croton macrostachyus united upper canopy trees.* The ground layer of intact climax forests had no vegetation except a few shade-tolerant herbs. However, in highly disturbing climax forests, the ground layer is dominated by *Solanecio gigas, Echinops ellenbeckii, Solaneciomannii, Solaneciotuberosus, Solanumanguivi,* *Echinops giganteus Eriosema scioanum, Cyathula uncinulata, Impatiens aethiopica, Nicandra physaloides,Pavonia procumbens, and Urtica simensis.*

The assemblage difference among Community I, Community II and Community III are due to disturbance and age gradients. Community I is the youngest, and Community III is the oldest in the forest patches. The similarity in species composition in lower, middle and upper layer canopy trees in the three communities are in line with the Community-unit theory. It stated that they are highly structured, repeatable, and identifiable associations of species controlled by environmental gradients (Clements, 1936). On the other hand, the association and replacement of lower, middle, and upper layer canopy trees along age gradients in pioneer, intermediate, and climax forests correspondingly support continuum theory. It stated that plant communities change gradually along complex environmental gradients, such that no distinct associations of species can be identified (Whittaker, 1953; Curtis, 1959).

Community IV: the communities are the lower altitude plant assemblages ranging from 600-1200 masl.They are within the Combretum-Terminalia woodland vegetation types. This community is the largest in area coverage. The dominancy of upper canopy trees: *Combretum collinum, Combretum molle, Pterocarpus lucens, Sterculia africana* and *Boswellia papyrifera*; middle layer canopy trees: *Ziziphus mauritiana, Grewia velutina, Commiphora pedunculata, Grewia mollis,* and *Grewia velutina* were related to fire adaptation.

Community V: is also in *Combretum-Terminalia* woodland and grassland. *Terminalia macroptera-Acacia hecatophylla* were the indicator species of these communities. They assembled at an altitudinal range of 1000-1200. The dominancy woody tree species: *Terminalia macroptera, Acacia hecatophylla, Stereospermum kunthianum, Ficus sycomorus, Cordia africana* and *Piliostigma thinning*; the middle layers of woody shrubs: *Grewia mollis, Ziziphus abyssinica, Grewia mollis* and *Vernonia hochstetteri* were also an indication of their association or adapted to the high frequency and intensity of the fire.

Community VI: *Albiza schimperiana- Millettia ferruginea* community types. These communities extend from 1200-1800 altitude rage. The dominant upper canopy trees: *Albizia schimperiana, Millettia ferruginea, Albiza gummifera, Fagaropsis angolensis,* *Ficus sycomorus, Cordia africana, Croton macrostachyus, Stereospermum kunthianum,* and *Sapium ellipticum.*; The middle layer canopy trees: *Vernonia amygdalina, Vernonia thomsoniana, Clausena anisata, Dodonaea angustifolia*, and the ground layer grasses and herbs such as *Rubia cordifolia, Zehneria scabra, and Datura stramonium* were dominant to middle altitude adaptation. Community IV and community V exist in the lower altitude. They mainly adapted to high intensity and frequency of fire, high temperature, low rainfall and shallow soil layer. Community VI is in steep slope landscape, intermediate moisture, and temperature and soil layer. In Community VI the dominate species particularly, *Albizia schimperiana, Albizia gummifera, Sapium ellipticum, and Millettia ferruginea* had the highest regeneration potential; The seed bank germinates massively, and the root proliferates when the steam part of the plant is damaged or slashed. The edible seeds of these species are widely dispersed by wild animals. The adaptation mechanism of the species helps them to dominate the middle altitude.

4.3. Community species diversity

The diversity and equitability of species in given plant communities are used to interpret the relative variation between and within the communities. These help to explain the underlying reason for such a difference (Kent and Coker, 1992). Species richness appears as the most intuitive and basic parameter to measure biodiversity and provides an extremely useful and comprehensible expression of diversity (Magurran, 1988; McCune and Grace, 2002 and Kent, 2012). Among the communities, Community VI (H=4.48, S=138) is in middle altitudes, which shares species with the higher altitude and lower altitudes communities; the environmental conditions mean of the lower and higher agro-ecologies. Community II is at a higher altitude and the second in richness and diversity (H=4.2, S=113), followed by Community I (H=4.20, S=96) Community II is an intermediate forest patch between community I and community III along age gradients. It consists, species of both communities. The comparative richness of Community V (H=3.95, S=103) than Community IV (H=3.88, S=89) was the relative location of community V at mountain foot of middle altitudes even, they found in the lower altitudes. Relatively communities V are in moist environment than community IV. Most species are moving along altitudinal gradients following the climate change. The higher evenness community II (0.95) followed by Community VI (0.93), community V and I each with 0.92, community IV (0.91) and the least community III (0.89) is the relative number of each species. As community II is a descendant of community I, the soil is richer and can support any species that has migrated out from other forest patches. Climax forests, which cover the growth of lower and middle layer canopy trees, predominate in Community III. Communities V and IV are located at lower elevations where fire can alter the distribution of vegetation equally. In community III, unequal distribution results from the overexploitation of some economically valuable species. These are similar to the finding of different authors (Pielou, 1966; Spellerberg, 1991) who stated Evenness as an indicator of equitable distributions among these species.

4.4. Factors affecting vegetation distribution

Aspect, Fire, Altitude, Moisture, and Slope were highly significant ($P<0.001$), and Grazing was moderately ($P<0.012$). The first and second RDA axes determined the majority of the variation in plant species composition patterns, as per the ordination results; among the variables, the distribution of vegetation is significantly influenced by Fire and altitude. Thus, Fire is the major environmental variable in explaining variations in plant species distribution and patterns of plant community formation. Fire is highly associated with the culture of society and their livelihood. Low moisture content, low pressure and greater temperatures brought on by stronger sun intensity all contribute to the worsening of the Fire in lower altitudinal gradients. Because of this, the vegetation in this area has been exposed to it and has grown to tolerate it. Consequently, the Wombera vegetation is dominated at lower elevations by grassland and combretum-Terminalia trees. Slope and and aspect are the second and third important factor in determining vegetation distribution.

The fourth most important variable affecting the distribution of vegetation was altitude. Higher altitudes and low fire frequency were strongly compatible with Communities I, II, and III. At lower altitude, higher fire adaptation was consistent with Communities IV and V, while community VI favored middle altitudes and intermediate fire adaptability. Other studies (Woldu *et al*., 1989; Nigatu and Tadesse, 1989; Yeshitila and Bekele, 2002; Yeneger *et al.*, 2008; Didita *et al.*, 2010; Woldemariam *et al.*, 2008; Lulekal, 2014) testify that altitude is the most determinant of vegetation distributions. The slope was the third variable to arrange the vegetation of the Wombera district. According to Woldemariam (2003), environmental factors such as altitudes, slopes, and landforms influence the plant groups in the Yayu forest. Moisture was the fourth determinant of Community 4. Riverside vegetation is highly correlated with moisture (riverside). Thus, altitude determines atmospheric pressure, moisture content, rainfall, temperature, and even the soil layer. The combination effect affects plant growth, developments, regenerations, compositions, and arrangement patterns (community).

5. Conclusion and recommondation

5.1. CONCLUSION

A total of 375 species representing 90 families and 70 genera were identified in six forest patches of Wombera district. Among the families Fabaceae were the richest, followed by Asteraceae and Poaceae.The Six plant community types showed variation in their species richness, diversity, and evenness. The assemblage difference among Community I, II and II community is due to disturbance and age gradients. Community I is the earlier successor and Community III is the oldest community or the final climax of the community. Community I is dominated by Lower canopy tree: *Acacia abyssinica*, *Nuxia congesta*, *Maytenus arbutifola* and *Maesa lanceolata*, which were able to invade non forest areas and form pioneer forests. Community III are dominated by upper canopy such as: *Syzygium guineense*, *Ficus sur*, *Olea europaea*, *Prunus africana*, *Apodytes dimidiata* and *Ekebergia capensis*.Communities VI are located at a middle altitude and share species with communities at higher and lower altitudes; their environmental conditions range somewhere between lower and higher agroecologies. Communities IV and V are located at lower elevations. They are mostly adapted to conditions with high fire intensity and frequency, high temperatures, little rain, and shallow soil layers.The vegetation distribution determined by altitudinal gradient and fire in district.

5.2. Recommendations

These study attempts to assess floristic structural composition, diversity and richness of in six forest patches of wombera district, however there were some forest patches that are inaccessible to study.Thus further study should cover the gap. The soil composition on vegetation distribution has not yet studied. Therefore further study of the vegetation should include soil composition carbon stock and soil seed bank.

CHAPTER THREE

Plant community, population structure and regeneration status along age and disturbance gradients of Dry Afromontane forest patches of Wombera district, Benshangul Gumuz, Ethiopia

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Abstract

The plant community's distributions were determined by topographic factors, soil composition, and physical factors. This study intended to investigate plant community assembly along topography, age, and disturbance gradients. The higher altitude forest patches of the Wombera district were classified into pioneer, intermediate, and climax based on age gradients, canopy height, and layer. Each age class was ranked into three disturbance gradients: intact, medium, and highly disturbed, based on intensity, frequency, and severity of disturbances. Transact lines were laid every 300 m, *along altitudinal gradients, and plots were laid every 150 m along transects. Woody plants' cover abundance, height, and DBH were measured from 54 (20 × 20 m each) nested sampling plots. In five (5 m × 5 m) quadrates nested in the larger quadrates, shrubs, seedlings, and saplings were recorded. In 5 (1 m × 1 m) quadrates nested in the 5 m × 5 m quadrates, herbs and grass species were collected. Agglomerative hierarchical cluster analysis and nested ANOVAs with R software were used to identify plant communities and analyzed the relationship between plant richness and diversity along age and disturbance gradients. Woody (85) and herbaceous (65) species were classified into three plant communities.* Age (succession) and disturbance gradients were also determinates of pant communities. J-shaped population structure of lower canopy tree species in pioneer forests shows poor regeneration status of population distributions or maximum growth stage. The inverted J-shaped upper and middle-layer canopy trees show good regeneration and

succession. Poorly regenerating species should be conserved. Thus, further study should be conducted on soil seed bank and soil nutrient composition.

Plant species diversity and richness significantly varied along age and disturbance gradients. The RDA result showed that the variation of species distribution and plant community formation was related to age, altitude, and disturbance. The maximum species diversity was found in patches of moderately disturbed forest, followed by intact and highly disturbed forest patches along with disturbance gradients.

Key Words: Community-Pioneer-Climax-Diversity-Species richness

1. INTRODUCTION

Ethiopian own altitudinal ranges from lowland below sea level (Danakil Depression, 110 m.a.s.l) to top mountains (Ras Dashen, 4532 m.a.s.l) (Teketay 1996; Woldu 1999). The Great Rift Valley is also the other landscape that runs from northeast to southwest of the country and separates the country into Northwestern and Southeastern highlands, enabling semi-arid lowlands to the east, south, and west of the country (Friis 1986; Bekele 1993). These diversified landscapes and altitudinal ranges make for a diversified range of agro-ecological zones, temperatures, rainfall, soil structure, and wind patterns in Africa (Friis *et al.* 2010). The diversified environmental conditions and landscapes resulted in diversified flora and fauna (Bekele *et al*. 1999; Woldu 1999), and hence Ethiopia is believed to be home to about 6500 species of higher plants with approximately 12% endemism and hence one of the six plant biodiversity-rich countries of Africa (UNEP 1995). Ethiopia also shelters two of the 34 global biodiversity hotspots, namely the Eastern Afromontane and Horn of Africa biodiversity hotspots (Myers *et al*. 2000).

Dry Evergreen Afromontane forest (DAF) is a part of Afromontane vegetation characterized by a very complex vegetation type and a complex system of succession relating widespread grasslands rich in legumes on heavy black clay soils that are periodically inundated areas, shrubs, and small to large size trees to the closed forest with a canopy of several strata on slopes (Friis *et al*. 2011). The vegetation of DAF is dominated by *Juniperus procera* Hochst. ex Endl., *Olea europaea* L. subsp. *cuspidata* (Wall. ex G. Don.) *Cif*, *Podocarpus falcatus (*Thunb.) R.B.ex Mirb. and *Prunus africana (*Hook. f.)

Kalkam. Grass vegetation types are *Hyparrhenia hirta* (L.) Stapf, *Eragrostis schweinfurthii* Chiov., *Sporobolus africanus* (Poir.) Robyns and Tournay, and *Pennisetum thunbergii* Kunth (Egiziaber 1998), whereas legumes include species of *Trifolium simense* Fresen., *Indigofera rothii* Baker, *Tephrosia interrupta* Hochst. and Steud. ex Engl., and *Crotalaria laburnifolia* L. sub sp. *laburnifolia* (Friis *et al*. 2011). Lianas comprise *Urera hypselodendron (*A.Rich.)Wedd., *Ebelia schimperi* Vatke, and *Jusminum abyssinicum* Hochst. ex DC (IBC 2009). Dry evergreen montane forests experience long dry seasons (4–8 months), and the rainy period is unreliable. During the dry season, not only moisture stress but also temperature increases and daytime humidity are reduced (Teketay 1996).

Population structures such as DBH and height classes of plant species verify vegetation dynamics through time. The highest number of higher DBH and height class (J-shaped) patterns shows old age or poor regeneration status of the forest (Senbeta and Teketay,2003). On the contrary, the highest number of lower-class DBH and height (inverted J-shaped) are indicators of young age or good regeneration potential of the forest (Dibaba *et al*., 2014; Burju *et al*., 2010). However, irregular patterns (Broken inverted J-shape or U shape) (Gebrehiwot and Hundera, 2014; Adamu *et al*., 2012) are an indication of poor regeneration which is due to selective cutting by the local people for construction and firewood. Overgrazing which affects the seedlings under the mother trees could be another reason for such irregularities (Burju et *al*., 2010).

The DBH and height structure of trees is highly variable among different forests of the dry Afromontane forests of Ethiopia based on the location and status of disturbance. In undisturbed forests, the DBH of mature trees usually reaches up to 270 cm, while their height can reach up to 45 m (Yineger *et al*., 2008; Zegeye *et al*., 2011; Tadele. *et al.*, 2013).Tree species such as *Prunus africana, Juniperus procera, Schefflera abyssinica, Albizia schimperiana, Ekebergia capensis, Celtis africana, Hagenia abyssinica, Croton macrostachyus* and *Cordia africana* reach a DBH of between 80 – 270 cm and a height of 30 –46 m in the dry Afromontane forests (Bekele,1993). In disturbed forests, the upper canopy species except a few of them removed for various purposes, and only short mature trees in the middle and lower canopy that have a DBH less than 50 cm and height less than 21 m remain in the forest (Bekele,1993; Friis *et al.,* 2010).

Fundamental ecological process, regeneration is essential to the dynamics and restoration of forest ecosystems. According to Teketay (2005) high seedling and sapling density indicated a good understanding of natural regeneration in any forest ecosystem. Thus, the density or proportion of seedlings, saplings, and different DBH trees or shrubs of woody species can all be used to project the regeneration of trees. When the number or density of seedlings is greater than the number of saplings and saplings is greater than that tree or shrub state, the patterns represent good regeneration and recruitment (Gebrehiwot and Hundera, 2014; Kebede *et al.,* 2014). Poor regeneration can exist with no individual in the seedling and sapling stages but relatively many individuals in the tree or shrub (Tilahun *et al*., 2015). The distribution of species would exhibit a reverse J-shaped pattern, which is a sign of healthy or good regeneration if regeneration is occurring continually (Teketay, 1997). Senbeta (2006) identified a regeneration pattern in forest tree species that is linked to varying degrees of disturbance of forest species. The main objective of this study was to assess the structure and regeneration status of woody plant species using, seedling, sapling and, DBH along successional gradients.

The Ethiopian highland encompasses over 50% of the African land area covered by Afromontnae vegetation (Bekele 1993), of which dry Afromontane forests comprise a large part (Teketay 2005). According to Friis (1992) and Woldu (1999), vegetation at an altitude of 1350–3550 m above sea level with an average annual temperature and rainfall of 14°C and 700–1100 mm, respectively, represents a complex system of successions that includes extensive grasslands rich in legumes, shrubs, small to large trees, and closed forests. In Ethiopia, different researchers have studied the general vegetation pattern in different agro-ecologies; however, the objective of this study focused on: (a) vegetation diversity, structure, compositions, and community type, along with age (maturity) and disturbance gradients; and (b) forest patch dynamics in terms of species composition and structural variation along age and disturbance gradients. The study addressed the following concerns: (a) the impact of anthropogenic disturbances (socio-economic values) on vegetation structure and species composition and (b) the significant difference in species diversity, and abundance, along age and disturbance gradients.

2. METHODS

2.1. Description of study area

The study area, Wombera district, is 658 km from Addis Ababa, the capital city. Wombera is in the Metekel administrative zone of Benishangul Gumuz regional state in the northwestern part of Ethiopia. Wombera is one of the largest districts in the Metekel administrative zone. It shares a boundary with Guba and Dangur in the north, Bullen in the east, Agallometi and Yaso in the south, and Serba Abbay and Sherkole in the west. The latitudinal and longitudinal extension of the woreda ranges between 9°57' 30" to 11° 08' 45" N and 35° 09' 09’’ to 35° 50' 25" E (Figure 1).

The topography is undulating and has few plains. The altitudes of the Wombera district range from 576 to 2615. The aspects vary and are complex in all of the three agro-ecological zones. This study was conducted in higher agro-ecology. The annual temperatures range between a minimum of 7.2°C and a maximum of 26°C, with an average of 15.9°C. The average annual rainfall was 1942 mm (Figure 2).

2.2. Forest patches selection

Three forest patches were selected based on their accessibility and distance from roads and residents. Gesengesa-Tumi forest patch (GTFP), Senkora-lopi forest patch (SLFP), and Menesibu-Babo patch (MBFP) were selected. Each forest patch was delineated into three age gradients: pioneer (10–30 years), intermediate or transitional (30–50 years), and climax (above 50 years). Each age class was defined as 1 = pioneer, 2 = intermediate, and 3 = climax. Each age class was classified into three levels based on the degree, frequency, intensity, extent, and severity of the disturbance (Pickett & White 1985). The disturbances were assessed and ranked following (Althof 2005). Based on disturbance levels, forest patches were classified as intact, moderately disturbed, and highly disturbed.

Generally, Senbeta (2006) classified the vertical structures of moist evergreen Afromontane forests into 2-3 strata/layer: emergent/upper stratum (> 30 m tall), middle tree stratum (15-30 m tall), and lower stratum small trees and shrubs layer (2-15 m tall). Rahman *et al***.** (2009) visually inspected canopy trees as the social class of dominant, co-dominant, suppressed and intermediate based on tree height, canopy length, side branching and general level of canopy crown. In this study, tree height from 2.5-0 - 10, 10.5-25 and greater than 25m meters were classified as lower, middle and upper canopy trees correspondingly (Appendix-Table 26).

The magnitude of the disturbance was rated from 0 to 3 (Senbeta *et al.* 2007, Aynekulu 2011). Forest patches were defined based on the degree of disturbance as very low disturbances = zero, lower disturbances =one, medium disturbances =two, and very severe disturbances = three. The frequency and events of grazing were assessed by interview and further confirmed by the scene left behind on the damaged plant species. The degree of disturbances was defined based on their severity. It was defined as high = 3, moderate =2, low = 1, and no at all =0. The distance of forest patches from water bodies was measured by taking GPS points on the plots and superimposing them on the Arc map and Google map. The environmental variables were measured for every plot along the transect line of each stratum. Altitude was measured using Garmin GPS. The slope was recorded using clinometers. Aspect (exposure) was determined using a Suunto compass or GIS analysis as a possible indicator of total solar energy, and the percentage was converted following Woldu *et al*. (1989), which was defined as North = 0; East = 2; South = 4; West = 2.5; North East = 1; South-East = 3; South-West = 3.3; and North-West =1.3.

2.3. Vegetation data

From the classified forest patches of age or maturity level (pioneer, intermediate, and climax) and disturbance level (intact, disturbed, and highly disturbed), plant samples were taken during the end of the rainy season, from November to December, in tree forest patches. Nested quadrates were laid down 150 m following Stohlgren *et al*. (1995) intervals along transects. The transects were laid parallel at a distance of 300 m. Trees with a stem diameter at breast height (DBH) >2.5 cm were sampled in 20 by 20 plots. The canopy cover of each tree was calculated by measuring the side branches of trees at right angles. The side branches were taken as the sides of the square. The canopy cover for each tree species in a plot was computed to 400 m2. The layers of trees were classified based on height into the lower canopy (2.5–10.0 m), middle layer canopy (10.5–25.0 m), and upper canopy (above 25 m), following Feyera (2006). The visual inspection was adopted from Rahman *et al. (*2009). In 5 m × 5 m quadrates nested in the larger quadrates, seedlings were counted. In the 1 m × 1 m quadrates nested in the 5 m × 5 m quadrates, herbaceous and grass were sampled. Thus, vegetation was collected from 54 plots (3 patches, three age classes, and disturbance levels with two repetitions). The percentage of cover occupied by each woody plant (400 m^2), shrub (25 m^2), and herbaceous plant (1 m^2) were computed.

2.3.1. Population structure

Plant population structure was classified based on frequency and distribution of individual DBH and height classes of plant species. The population structure is an important indicator of forest reproduction and recruitment (Schulz *et al*., 2009). The classification was done following different authors methods (example Dalle, 2015; Berhanu *et al*., 2017). DBH classes were classified into 21 classes on 5m interval for lower DBH (2.5 to100 m) and at 25m interval for higher DBH (greater than 100) as : 2.5 – 10, 10.5 – 20, 20.5 – 30, 30.5 – 40, 40.5 – 50, 50.5 – 60, 60.5 – 70, 70.5– 80, 80.5– 90, 90.5– 100, 100.5– 125, 125.5– 150, 150.5– 175,175.5-200, 175.5-200, 200.5-225, 225.5-250, 250.5-275,275.5-300,325.5-350 and >350.

Height classes were also classified into ten classes of 5 m intervals: 2.5≤ H ≤5, 5.5 – 10, 10.5 –15, 15.5 –20, 20.5 – 25, 25.5 – 30, 30.5 – 35, 35.5 – 40, 40.5 –45 and > 45. The density of individuals in the DBH and height classes was summed up, and diagrams were produced using the Microsoft Excel spreadsheet program.

2.4. Data analysis

Using the R Package version 3.4.3, a nested ANOVA was used to calculate the vegetation diversity, richness, evenness, and abundance along the disturbance gradients (intact, moderately disturbed, and highly disturbed) and age gradients (pioneer, intermediate, and climax) of forest patches. A nested two-way ANOVA is used when there is one measurable variable and two or more nominal variables (Woldu 2017). The counted data were transformed to measurable data per plot.

Cluster analysis is a multivariate technique that is widely used to group a set of observations (plots or vegetation samples) based on their attributes or floristic composition (Kent & Coker 1992, McCune & Grace 2002). In ecology, cluster analysis is used to classify sites, species, or variables based on their similarities (Jongman *et al.* 1987). In this study, hierarchical (agglomerative) cluster analysis was performed using the free statistical software R version 3.4.3 (R Core Team (2017)) to classify the vegetation into plant community types.

2.4.1. Vegetation-environment relationship (Ordination)

The ordination method was employed to understand the relationship between the plant communities and the environment. The ordination method (unimodal or linear model) is often selected based on the length of the first DCA axis in various ecological studies (Feyera 2006). Accordingly, a gradient length exceeding four implies a strong unimodal response between the species and environmental variables (Berhanu *et al*. 2017). On the other hand, if the length is less than four, the data are homogeneous, and a linear response would happen. RDA is suitable where linear relationships among response variables and between response and predictor variables are expected or demonstrated. RDA enables the use of standardized and non-standardized analyses; by standardizing samples, it can separate differences in total cover from differences in species composition. RDA assumes that response variables are linearly related to predictors (McCune & Grace 2002).

2.4.2. Frequency and Relative Frequency woody species

Frequency is the probability or chance of finding a species in a given sample area or plot. Relative frequency is expressed as a percentage of the total number of plots in which individuals of a given species were recorded divided by the sum total number of the plots taken in the study area.

The following formulas were used in Microsoft Excel spreadsheet program.

$$\textbf{Frequency (F)} = \frac{\textbf{Number of plots in which species occure}}{\textbf{Total plots laid}}$$

$$\textbf{Relative frequency } (\mathbf{R_{fr)}} = \frac{\boldsymbol{Frequencyofspecies}}{\boldsymbol{Total\ frequencies}} * \mathbf{100}$$

2.4.3. Woody species density, basal area and dominance

Density (D) is the number of individuals per unit area. It was calculated from the count of all the individuals on a hectare basis (Mueller-Dombois and Ellenberg, 1974) to the total area. Woody species density was expressed as the number of individuals of a species per hectare. The density and relative density of woody species were calculated by using the Microsoft Excel Spreadsheet program. The total species density, which is expressed as the total of all Individuals of all species in a hectare was also computed to calculate the relative density.

Density was calculated using the following formula:

Density (Di) = Density (Di) = $\frac{\boldsymbol{Number of species counted}}{\boldsymbol{Sampled\ area\ in\ hectar}}$

A two-way nested ANOVA of R was used to analyze the significant differences in vegetation Seedling and sapling abundance along age gradients (pioneer, intermediate and climax) and along disturbance gradients (intact, moderately disturbed, and highly disturbed) of forest patches.

3. RESULTS

3.1. Taxonomic composition

A total of 37 woody plants, 30 shrubs, 15 lianas, and 62 herbs were identified in the plots. They were under the category of 52 families.In addition, 14 species were outside the plot. Asteraceae, Poaceae, Fabaceae, and Polygonaceae were the dominant families. Asteraceae had the highest number of species (22 species, 15.83%), followed by Poaceae (12 species, 8.63%), and Fabaceae. Polygonaceae and Solanaceae had an equal number (6 species, 4.32%).

3.2. Classification of plant communities

The hierarchical classification analysis resulted in three plant community types in the study area (Figure 8). Indicator species were named after two or more indicator species (P < 0.001) (Table 4).

Table 4. Synoptic and indicator values of species (C1 – C3)

Species	Synoptic value*			Indicator value %**			
	C1	C2	C3	C1	C2	C3	P Value
Nuxia Congesta	5.33	0.78	0	76.8	2.6	0	0.001
Maesa lanceolata	5.22	1.11	0	65.3	57	0	0.001
Allophyllus abyssinicus	0.83	5.44	1.67	0	73.7	9.3	0.001
Dombeya torrida	1	4.83	0	5.7	68.5	0	0.001
Hagenia abyssinica	1	3.33	0	5.8	57	0	0.001
Apodytes dimidiata	1.44	1.39	4.83	10.5	70	54.7	0.001
Prunus africana	1	1.44	4.67	5.5	7.9	52.5	0.001

* The mean values of the species cover-abundance in each community.

** The product of the relative frequency and relative cover-abundance values in each Community.

Nuxia Congesta-*Maesa lanceolata* **(***C1***)**

Indicator species were *Nuxia congesta* R.Br. ex Fresen, *Maesa lanceolata* Forssk., and *Acacia abyssiniea* Hochst. ex Benth. *(Significantly* varied, P < 0.001). This community is in the dry Afromontane forests, which occur in three forest patches. These woody species were twisted by *Clematis simensis* Fresen. *Rosa abyssinica Lindely, Jusminum abyssinicum Hochst. ex DC., and Stephania abyssinica Dillin and A.Rich.) Warp. The ground layer is covered by grasses Achyrospermum schimperi (Hochest.ex), Cyperus fischerianus A.Rich. Digitaria abyssinica (Hochest.ex), Pennisetum clandestinum Chiov, and herbs Carduus schimperi Sch. Bip. ex. A. Rich, Sporobulos pyramidalis P.Beauv, and Trifolium multinerve A.Rich.*

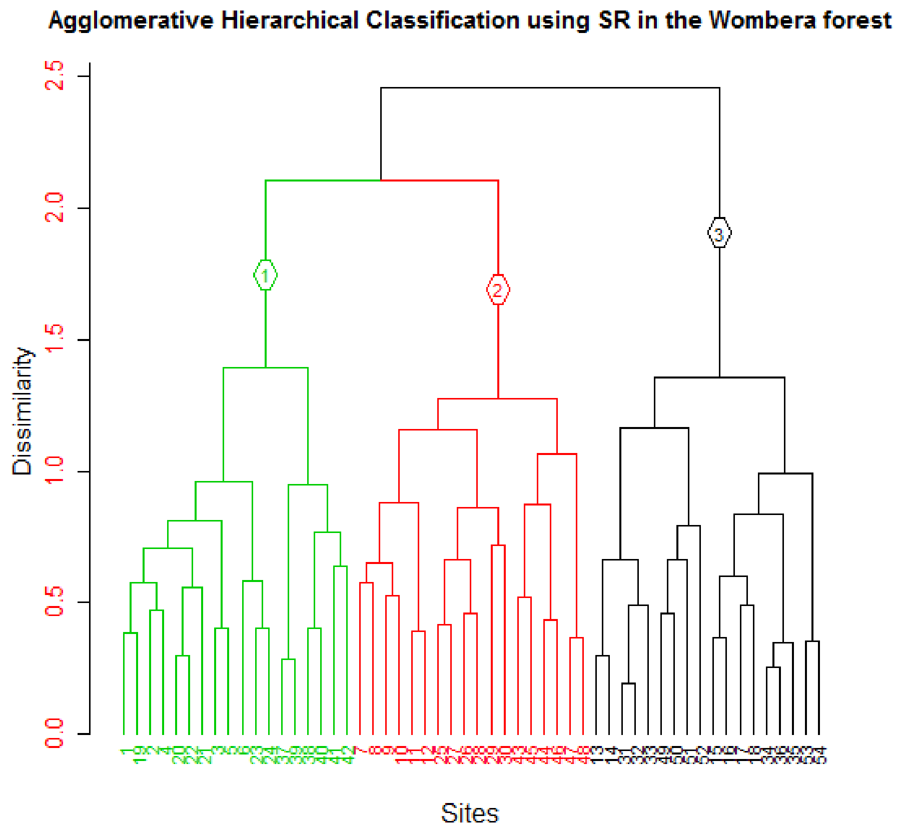


Figure 8. Dendrogram showing three communities of dry afromontane

Nuxia Congesta- Maesa lanceolata , community*; Allophyllus abyssinicus- Hagenia abyssinica and Dombeya torrida* community *and Prunus africana - Apodyte dimiditata* community.

Allophyllus abyssinicus - *Hagenia abyssinica* **(C2)**

The indicator species were *Allophyllus abyssinicus (*Hochest.) Radlk., *Hagenia abyssinica (Brace),* J.F. Gmel, and *Dombeya torrida (J.F.* Gmel.*).* This plant community exists on the same forest patches as community one. It is older than Community One and younger than Community three. This community is the intermediary between the two communities. Community one was decreasing, and community three was increasing by species composition. The indicator woody species were *Allophyllus abyssinicus (*Hochest.) Radlk, *Hagenia abyssinica (Brace),* J.F. Gmel, and *Dombeya torrida (J.F.* Gmel.*)* which significantly varied (P < 0.001). These woody species are twisted by *Lagenaria siceraria (*Molina) Standley, *Urera hypselodendron* (A.Rich.) Wedd. *Kalanchoe petitiana A.Rich. near* the river, and by *Clematis simensis* Fresen. *Rosa abyssinica* Lindely, *Jusminum* *abyssinicum* Hochst. ex DC., and *Stephania abyssinica* Dillin and A.Rich.) Warp. are far away from the riverbank. In intact forests, the ground layer is covered by a few types of grass and herbs, and the disturbed patches are covered with herbs and grasses. Community two was mainly dominated by saplings and lower DBH plants of *Syzygium guineense* (Wild.) DC.*, Ficus sur* Forssk, and *Olea europaea* L. subsp. *cuspidata* (Wall. ex G. Don.) Cif, and nearer to the river border and *Prunus africana (*Hook. f.) Kalkam and *Apodytes dimidiata* E. Mey. ex Arn., and *Ekebergia capensis* Sparrm.*,* were far away from the riverside.

Apodyte dimiditata- Prunus africana **community** *(C3*)

It exists in the same forest patches as communities one and two. The indicator species were *Prunus africana (*Hook. f.) Kalkam and *Apodytes dimidiata* E. Mey. ex Arn*.* They were significantly varied (P < 0.001). The community was dominated by the most upper canopy trees, such as *Syzygium guineense (*Wild.) DC., *Ficus sur Forssk.,* and *Olea europaea L. subsp. cuspidata* near the river border; *Prunus africana (*Hook. f.) Kalkam; *Apodytes dimidiata* E. Mey. ex Arn.; and *Ekebergia capensis Sparrm., which were* away from the river bank. In intact climax forest, there were no middle layer, lower layer, or ground layer species; however, where there were disturbances, the lower layer was dominated by *Maytenus arbutifolia (A.Rich) Wilezek* and *Teclea nobilis* Del.; the shrub layer was covered by *Brucea antidysenterica* J.F. Mill.*;* and the sapling of upper and lower canopy trees. In highly disturbed climax forests, the *Schefflera abyssinica (*Hochst. ex A.Rich*.)* and *Croton macrostachyus Huchst. ex* Del. united upper canopy trees and the ground layer was dominated by: *Solanecio gigas (*Vatke) C.Jeffrey, *Echinops ellenbeckii* O. Hoffman*,* and *Solanecio mannii* (Hook.f.) C. Jeffrey*, Solanecio tuberosus (*Sch.Bip.) C. Jeffrey and *Solanum anguivi* Lam., *Echinops giganteus* A.Rich*. Eriosema scioanum* Avetta*, Cyathula uncinulata (*Schrad.) Schinz*, Impatiens aethiopica* Grey-Wilson*, Nicandra physaloides (*L.) Gaertn.*, Pavonia procumbens (*Wight & Arn.*), Solanum anguivi Lam., and Urtica simensis Steud.*

3.3. Species Diversity

Species diversity significantly varied along age gradients (pioneer, intermediate, and climax) in GTFP (P > 0.00939), SLFP (P > 0.0022), and MBFP (P > 0.0049). Species diversity also varied significantly along disturbances (intact, moderately disturbed, and highly disturbed) in GTFP (P > 0.00109), SLFP (P > 0.00512), and MBFP (P > 0.00710). The interactions of age and disturbance also varied significantly in GTFP (P > 0.00601), SLFP (P > 0.00415), and not significantly in MBFP (P > 0.0724) (Table 5).

Table 5 Statistical test Diversity along age, disturbance and their interaction

Factors	GTFP					
	Df	Sum sq	Mean sq	F value	Pr(>F)	Sig
Age	2	2.157	1.078	316.712	0.00939	***
Disturbance	2	0.302	0.151	44.444	0.00109	***
Age:Disturbance	4	0.580	0.145	42.644	0.00601	***
Residuals	18	0.061	0.0034			
	SLFP					
Age	2	3.264	1.632	41.459	0.0022	***
Disturbance	2	0.156	0.077	25.841	0.00512	***
Age:Disturbance	4	0.538	0.135	44.652	0.00415	***
Residuals	18	0.054	0.003			
	MBFP					
Age	2	2.189	1.094	116.8214	0.0049	***
Disturbance	2	0.319	0.159	17.0158	0.00710	***
Age:Disturbance	4	0.096	0.024	2.5808	0.07238.	
Residuals	18	0.16865	0.0093			
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

Gesengesa-Tumi forest patch = GTFP, Senkora-lopi patch = SLFP, and Menesibu-Babo forest patch = MBFP

3.4. Species richnes

Species richness significantly varied along age gradients (pioneer, intermediate and climax) in GTFP (P>0.00549), SLFP (P>0.0022) and MBFP (P>0.00667). Species richness also varied significantly along disturbance gradients (intact, moderately disturbed and highly disturbed) in GTFP (P>0.00511), SLFP (P>0.00383) and MBFP (P>0.00266). The interactions of age and disturbance also varied significantly at GTFP (P>0.00229), SLFP (P>0.00493) and not significantly varied in MBFP (P>0.2289) (Table 6).

Table 6. Statistical test of species richnes on age, disturbance and their interaction

Factors	GTFP					
	Df	Sum Sq	MeanSq	F value	Pr(>F)	Sig
Age(succession)	2	1426.07	713.04	437.546	0.00549	***
Disturbance	2	215.41	107.7	66.091	0.00511	***
Age:Disturbance	4	413.93	103.48	63.5	0.00229	***
Residuals	18	29.33	1.63			
	SLFP					
Age	2	1508.96	754.48	496.854	0.0022	***
Disturbance	2	154.96	77.48	51.024	0.00383	***
Age:Disturbance	4	265.48	66.37	43.707	0.00493	***
Residuals	18	27.33	1.52			
	MBFP					
Age	2	1085.63	542.81	148.040	0.00667	***
Disturbance	2	146.74	73.37	20.010	0.00266	***
Age:Disturbance	4	22.81	5.7	1.556	0.2289	
Residuals	18	66	3.67			
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

Gesengesa-Tumi forest patch = GTFP), Senkora-lopi patch = SLFP, and Menesibu-Babo forest patch = MBFP

3.5. Richnes and diversity along age and disturbance gradients

Along with age gradients, species diversity was highest in intermediate forest patches: GTFP, MBFP, and SLFP, followed by pioneer forest patches: GTFP, MBFP, and SLFP, and climax forest patches: GTFP, MBFP, and SLFP. Along disturbance gradients, species richness was highest in moderately disturbed intermediate forest patches: MBFP, GTFP, and SLFP, followed by the pioneer (GTFP, MBFP, and SLFP) and climax (GTFP, MBFP, and SLFP). Species evenness was highest in pioneer forests, followed by intermediate and climax forests (Table 7).

3.6. Richness along age gradients

The average total plant species abundances decline along age gradients in the tree forest patches: GTFP, SLFP, and MBFP ($y = 31–14x$ and $r^2 = 0.431$) (Figure 9a). The abundance of lower canopy trees also declines along age gradient regression ($y = 16–0.15x$, $r^2 = 0.431$) (Figure 9b). The middle canopy trees decrease along age gradients by regression ($y = 10–0.085x$, r2 = 0.473) (Figure 9c). However, the upper canopy trees increase along age gradients by regression $y=2.2+0.21x$, r2=0.882(Figure9d).

Table 7. Species diversity and richness along age and disturbance gradients

Forest Patches	Index	Forest age and disturbances gradients								
		Pioneer forest			Intermediate forests			Climax forests		
		PINT	PMDIS	PHDIS	IINT	IMDIS	IHDIS	CINT	CMDIS	CHDIS
GTFP	Richness	32	33	39	55	57	31	18	25	23
	H	3.26	3.31	3.43	3.86	3.88	3.25	2.65	3.11	3.01
	Sh. Evenness	0.95	0.95	0.94	0.96	0.97	0.95	0.91	0.97	0.96
SLFP	Richness	39	43	31	53	53	40	13	24	23
	H	3.49	3.59	3.27	3.79	3.79	3.60	2.38	2.97	2.92
	S. Evenness	0.98	0.953	0.95	0.96	0.95	0.98	0.93	0.94	0.93
MBFP	Richness	50	45	31	52	55	35	23	26	16
	H	3.77	3.647	3.27	3.76	3.85	3.45	3.01	3.14	2.71
	Sh. Evenness	0.96	0.958	0.95	0.95	0.96	0.97	0.96	0.97	0.98

PINT= Pioneer intact, PMDIS=pioneer moderately disturbed, PHDIS=Pioneer highly disturbed, IINT=Intermediate intact, IMDIS=Intermediate moderately disturbed, IHDIS= Intermediate highly disturbed, CINT= Climax intact, CDIS= Climax disturbed and CHDIS= Climax highly disturbed.
GTFP = Gesegesa-Tumi forest patch, SLFP = Senkora-Lopi forest patches and MBFP = Menesibu-babo forest patch.

3.7. RDA of Wombera at higher altitude

All environmental factor significance tests of a backward and forward selection of seven variables indicate that all are significant (P<0.001–0.009) except moisture (P<0.143) (Table 8). Among environmental variables, age (0.34) had the highest strength, followed by altitude (0.25), disturbances (0.20), grazing (0.19), aspect (0.14), slope (0.11), and moisture (0.09), respectively.

RDA with coloured clusters constrained with species score Eigenvalues using library vegan as shown in figure 10. Community three was highly constrained by age and aspect. However, Community One and community three are constrained by Slope, disturbance, and altitude.

Table 8. Significant factors of environmental variables

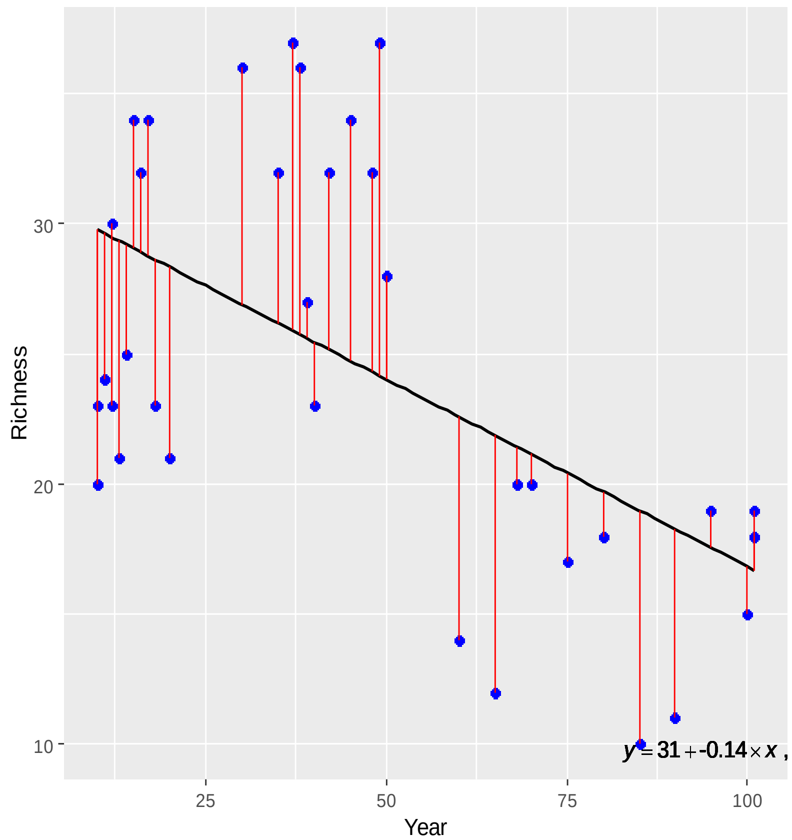
Factors	Factors result					
	Df	SumsOfSqs	MeanSqs	F.Model	R2	Pr(>F)
Slope	1.00	0.50	0.50	2.47	0.03	0.004 **
Aspect	1.00	0.76	0.76	3.77	0.05	0.001 ***
Grazing	1.00	0.48	0.48	2.38	0.03	0.009 **
Disturbance	1.00	0.60	0.60	3.01	0.04	0.003 **
Moisture	1.00	0.30	0.30	1.47	0.02	0.143
Age	1.00	2.24	2.24	11.17	0.15	0.001 ***
Altitude	1.00	1.23	1.23	6.15	0.08	0.001 ***
Residuals	46.00	9.24	0.20	0.60		
Total	53.00	15.34	1.00			
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1						

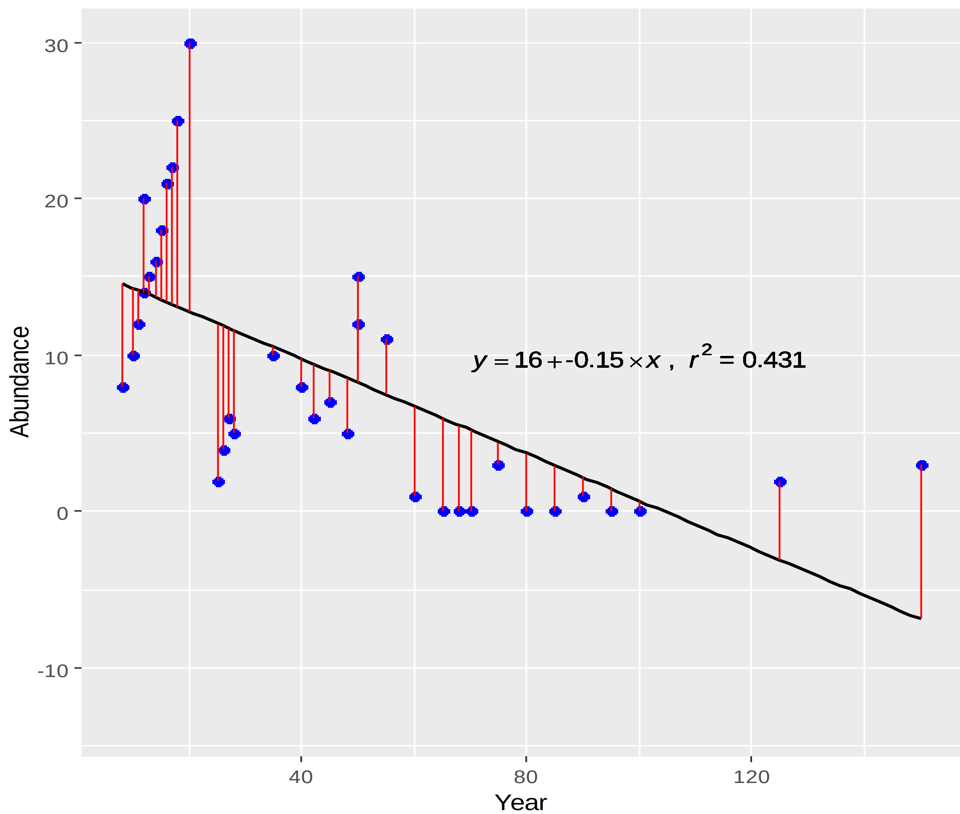
3.8. Correlation of environment at higher altitude

In higher altitudes, environmental factors, Disturbance, and Grazing were positively correlated followed by Age and Aspect, and Age and grazing. Age and Disturbance were negatively correlated followed by Moisture and Disturbance, and aspect and Grazing (Table 9).

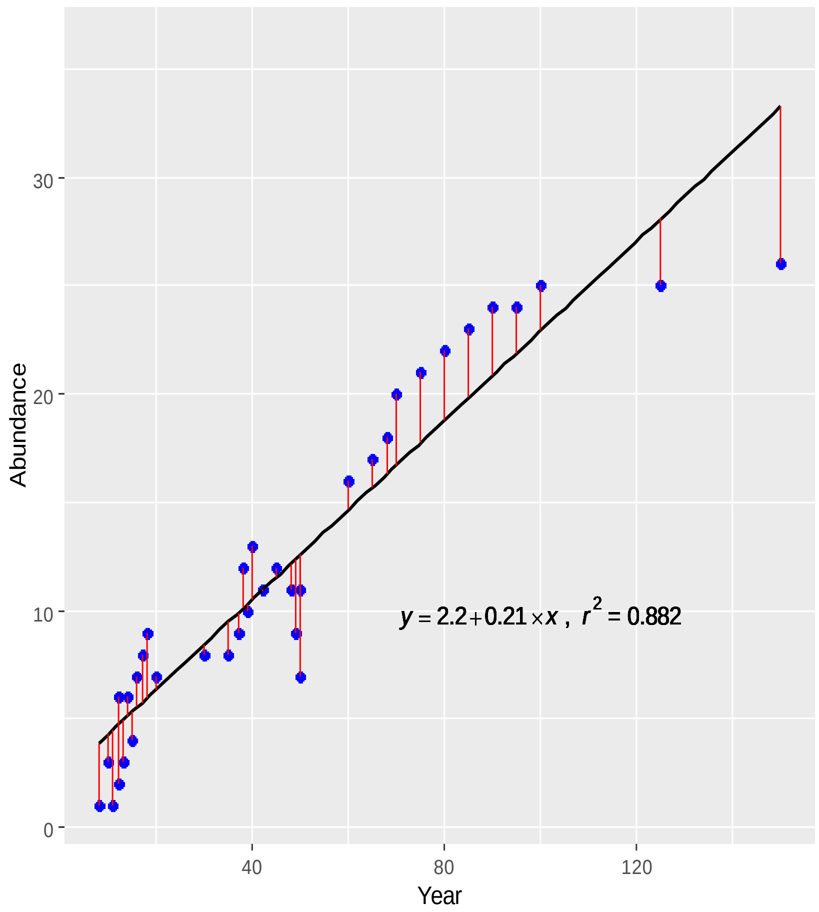
Table 9. The correlations of environmental variables

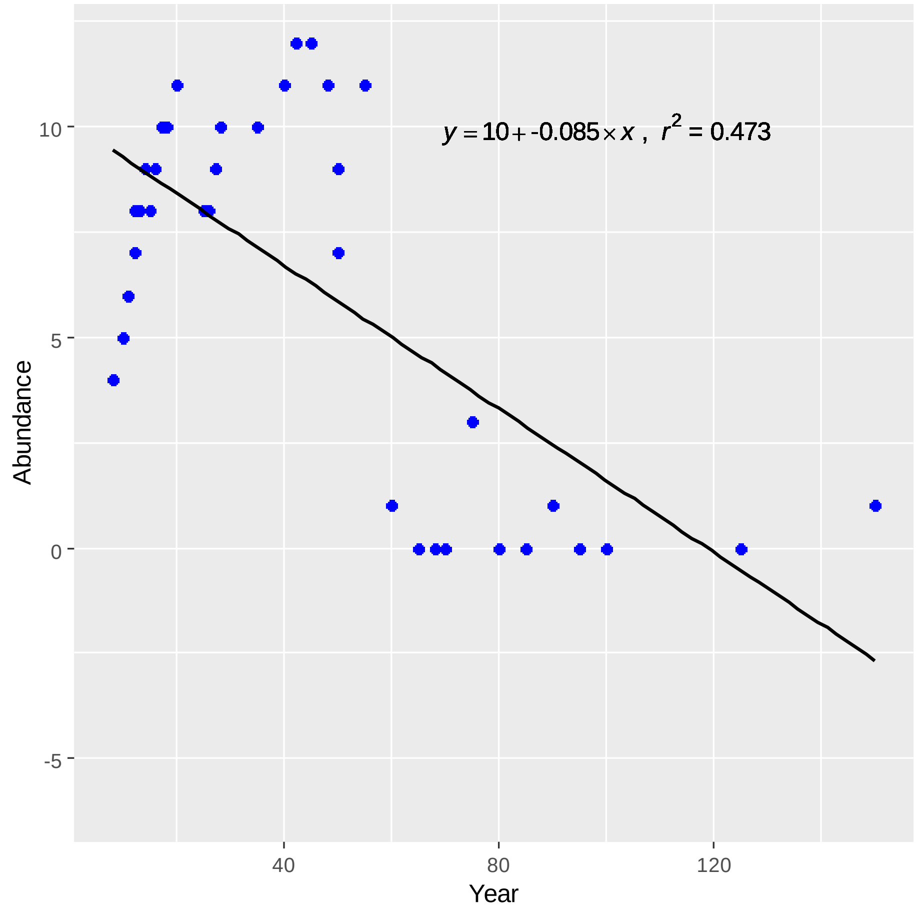
	Slope	Aspect	Grazing	Disturbance	Moisture	Age
Aspect	0.01					
Grazing	-0.15	-0.25				
Disturbance	-0.14	0.037	0.58			
Moisture	0.078	0.12	0.29	-0.31		
age	-0.057	0.38	0.32	-0.4	-0.13	
Altitude	-0.014	-0.15	-0.04	-0.05	-0.21	0.01





A species richness along age gradients B. Lower canopy trees along age gradients





C). Abundance of middle canopy trees along age gradients 10 D). Abundance upper canopy trees along age gradients

Figure 9. Graph A-D indicating species along age gradients

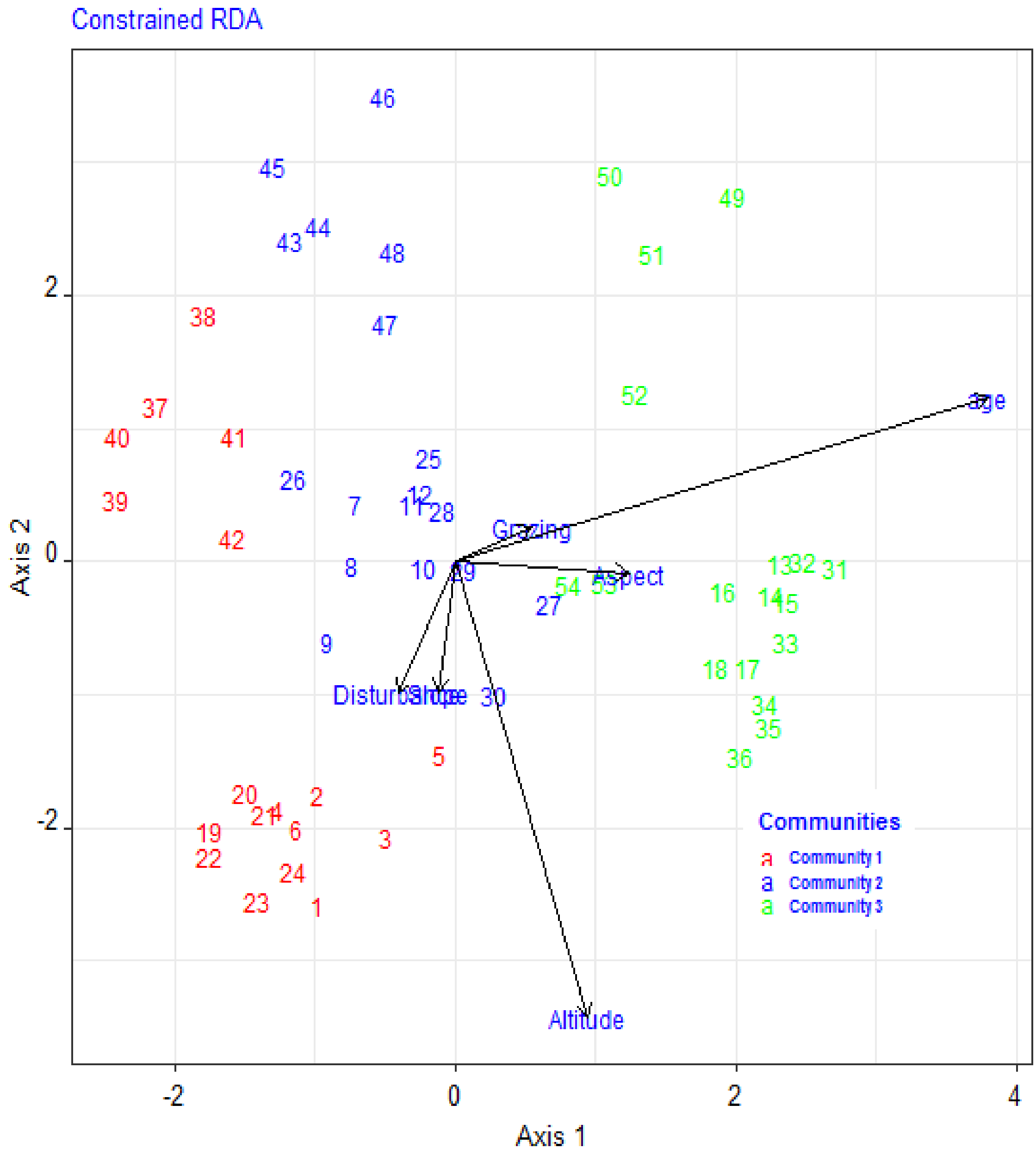


Figure 10. RDA display of environmental and geographic factors.

3.9. Diameter and height class in pioneer forests

In Pioneer forests, the lower-layer canopy trees had a J-shaped height and DBH classes of population structure. Middle and upper canopy trees had inverted J-type DBH and height distributions (Figures 11 and 12). Among the lower-layer canopy trees, *Acacia abyssinica and Nuxia congesta* had J-shaped DBH and height classes of population structure. *Maesa lanceolata* and *Maytenus arbutifola* had irregular DBH and height population patterns. Among middle-layer canopy trees, *Dombeya torrida* had a *U-shaped shape*; *Hagenia abyssinica* had an inverted U-shaped shape, and *Allophyllus abyssinicus had* a J-shaped population pattern. The dominant Upper canopy trees *Apodytes dimidiata*, *Ekebergia capensis*, and *Syzygium guineense* had Inverted-J type DBH and height classes. *Olea europaea* and *Prunus africana* had an inverted-U-shaped population pattern (Figure. 13).

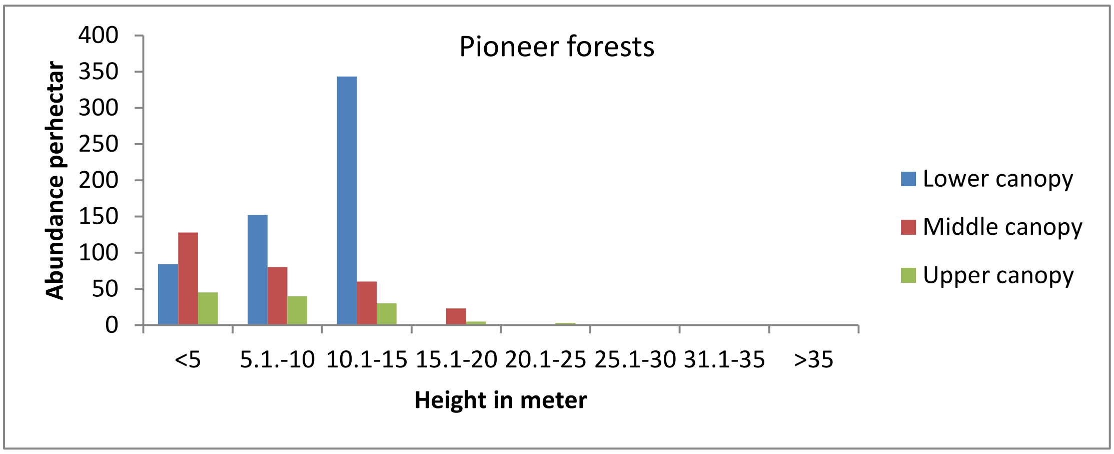


Figure 11. Height classes of woody trees in pioneer forests

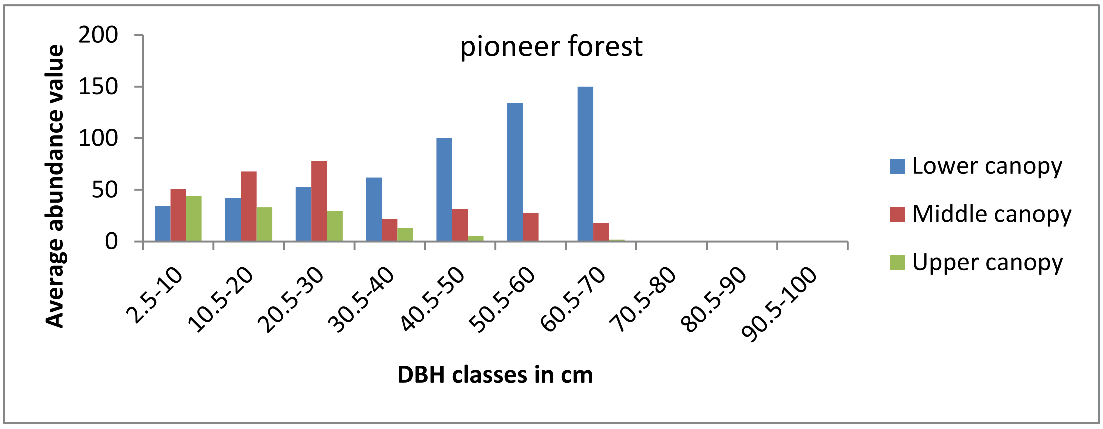


Figure 12. DBH classes of woody trees in pioneer forests

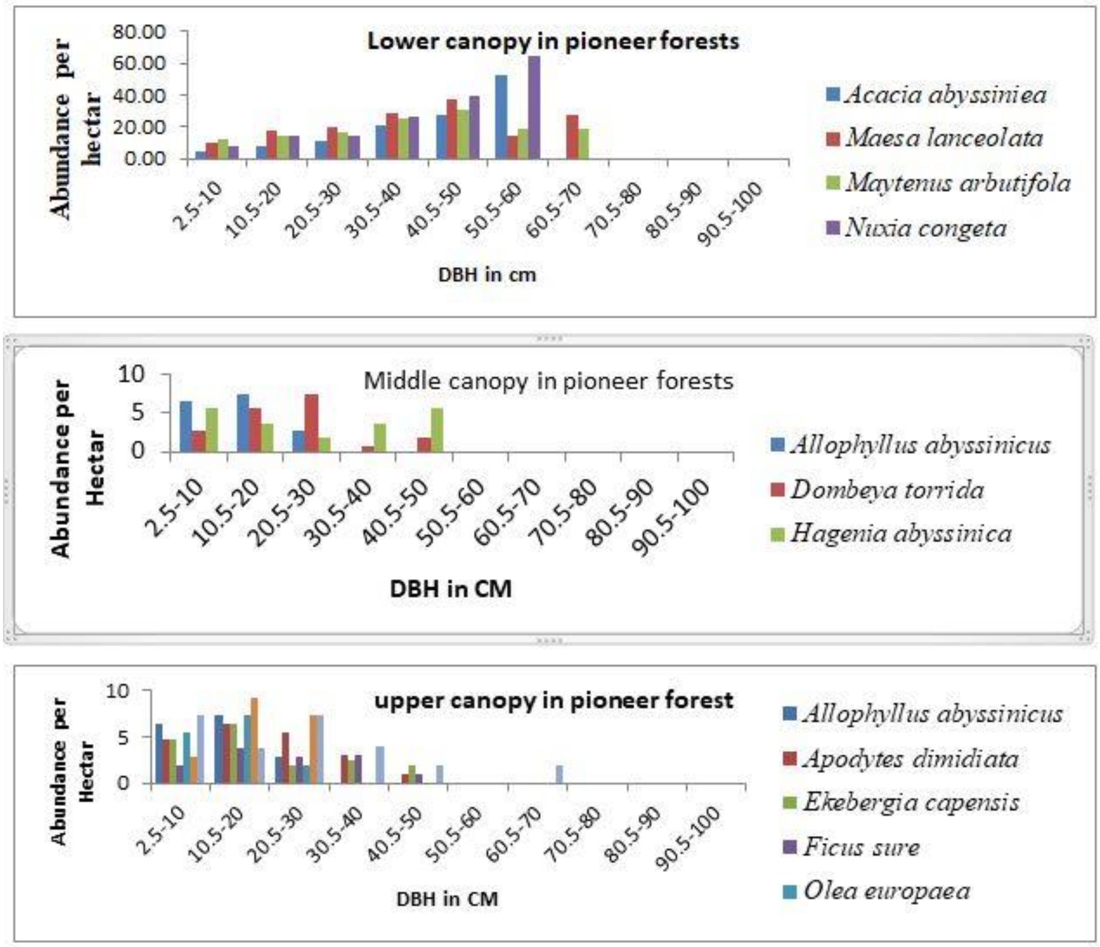


Figure 13. Woody species abundance per hectare in pioneer forests

3.10. Diameter and height class in intermediate forest

In an intermediate forest, lower and middle canopy trees had J-shaped structures, and the upper canopy trees had irregular-shaped DBH and height structures (Figures 14 and 15. *Maytenus arbutifola* and *Maesa lanceolata* had irregular DBH and height classes.Middle layer canopy trees: *Dombeya torrida*, *Hagenia abyssinica*, and *Allophyllus abyssinicus* had an inverted U-shaped DBH class of population structure. From the upper canopy tree species, *Apodytes dimidiate* and *Syzygium guineense* had irregular DBH and height classes. *Olea europaea* had a u-shaped population structure (Figure. 16).

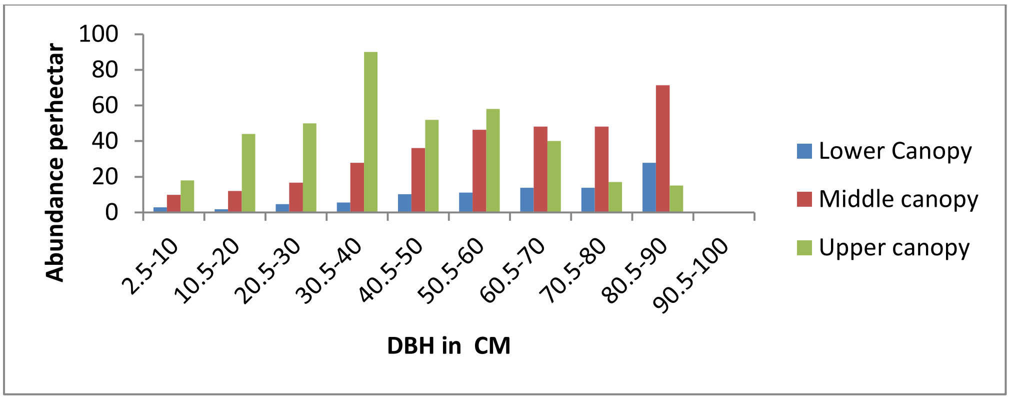


Figure 14 . DBH classes of woody trees in intermediate forests

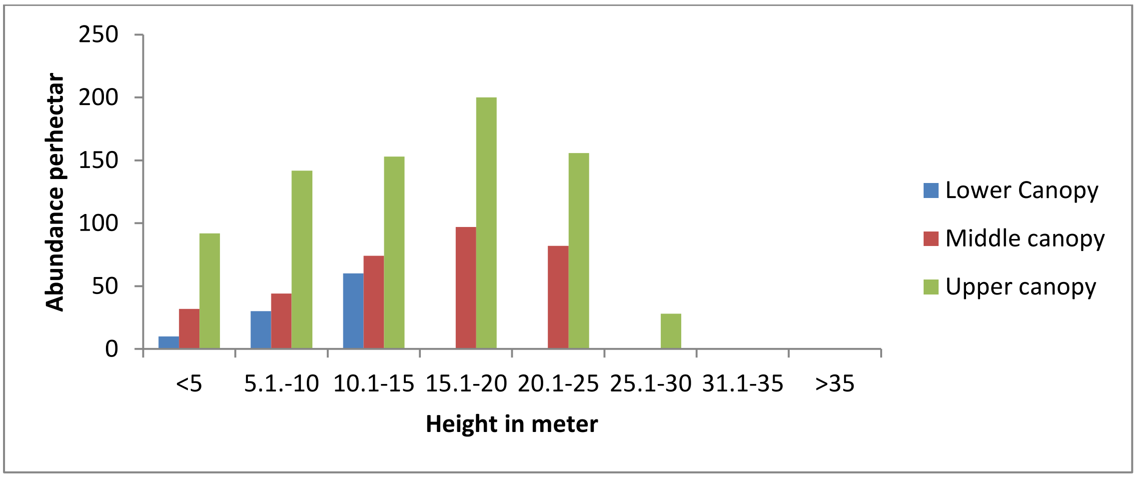


Figure 15. Height classes of woody trees in intermediate forests

3.11. Diameter and height class in Climax forest

In climax forests, the upper canopy trees, *Olea europaea, Apodytes dimidiate, Ekebergia capensis, and Prunus africana*, had J-shaped DBH and height classes (Figures 16 and 17). Middle and lower-layer canopy trees had a J-shaped population structure. However, shade-tolerant *Maytenus arbutifola* had irregular population patterns.

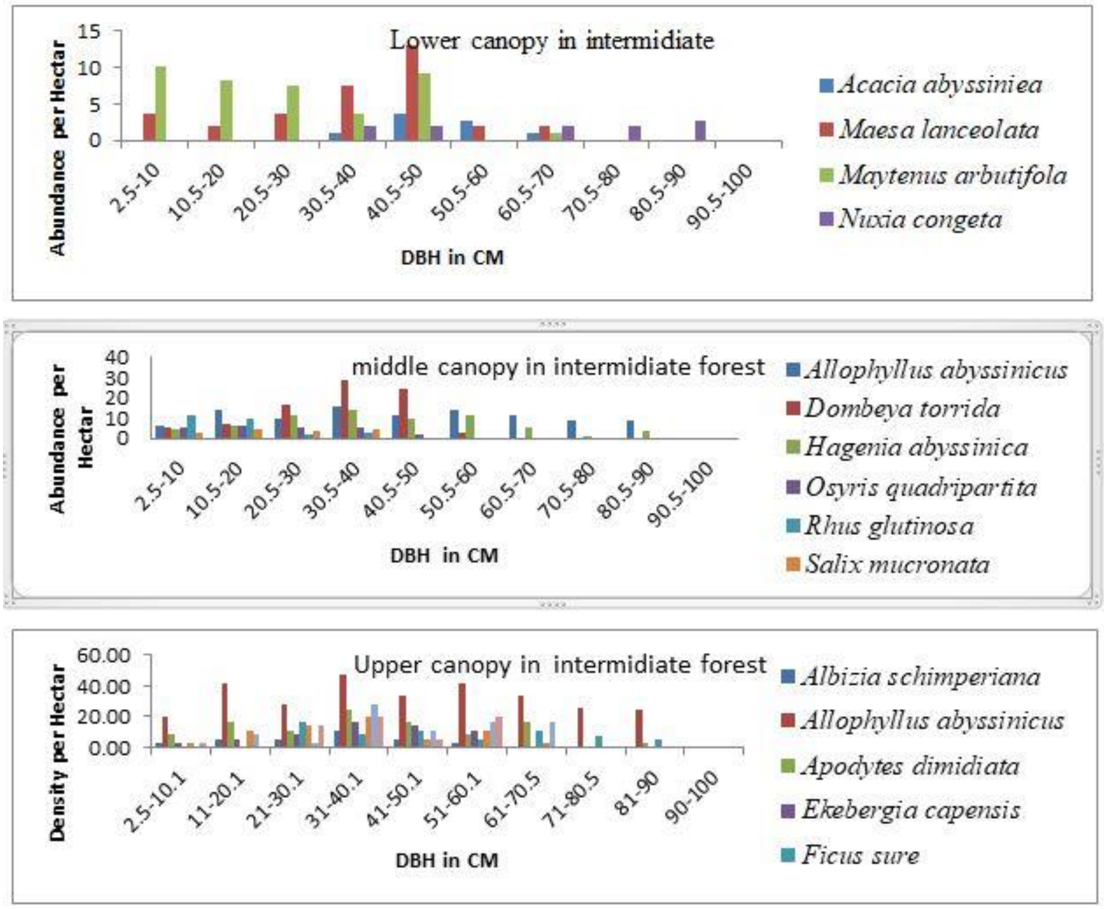


Figure 16. DBH of dominant woody species in three types of forests

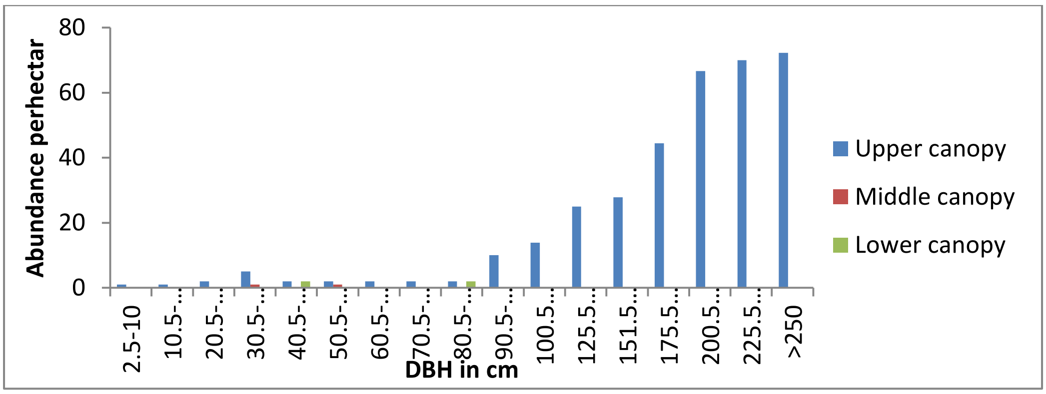


Figure 17. DBH classes of woody trees in Climax forests

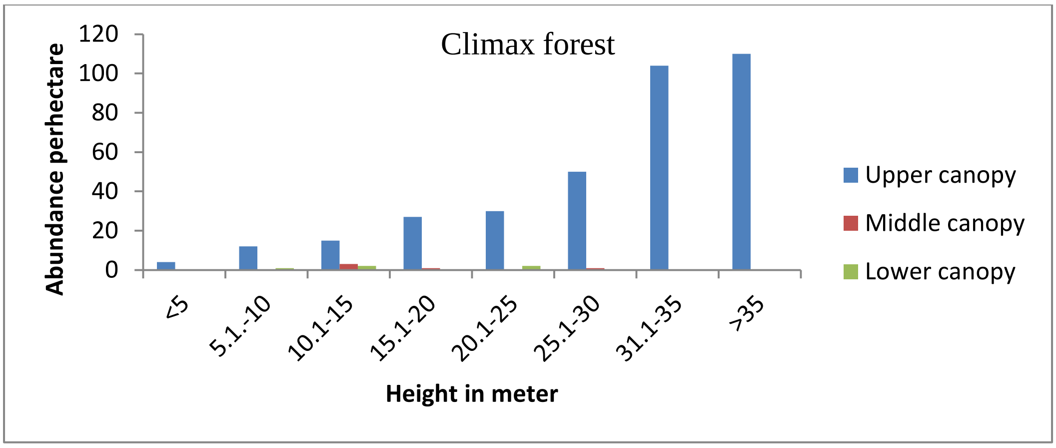


Figure 18.Height classes woody tree in Climax forests

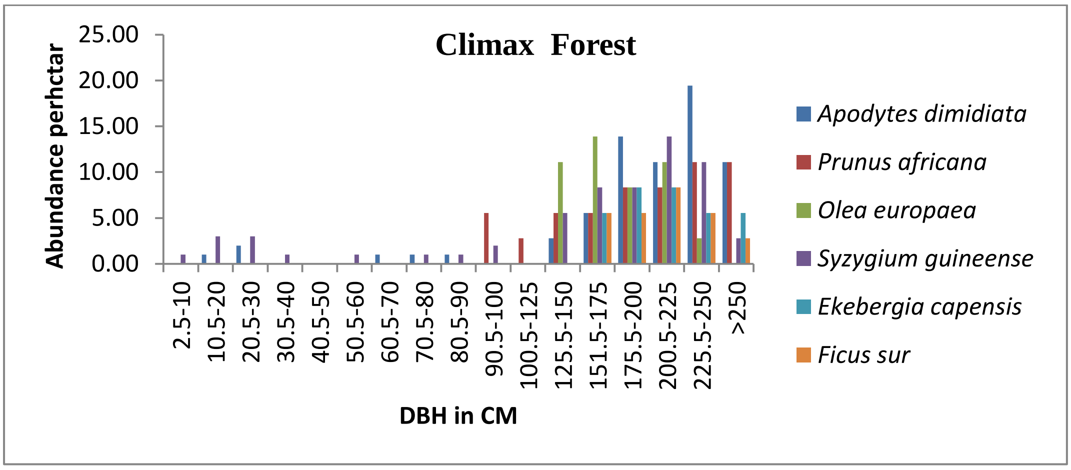


Figure 19. Dominant upper canopy trees in climax forests

3.12. Woody tree species Seedling and sapling Density

3.12.1. Statically tested of seedling and sapling per hectare

Seedling per plot varied significantly along age gradients among forest patches: in GTFP (P > 0.006.3), SLFP (P > 0.0025), and MBFP (P > 0.00297). More seedlings were recorded in pioneer, intermediate, and climax, respectively. Seedling per plot also varied significantly along disturbance in SLFP (P > 0.0065) and MBFP (P > 0.00298), but not in GTFP (P > 0.27). More seedlings were available in intermediately disturbed, intact, and highly disturbed forest patches, respectively. The interactions of age and disturbance did not vary significantly in the GTFP (P >.97), P > 0.077 in the SLFP, and P > 0.297 in the MBFP (Table 10).

Table 10. Seedling density in pioneer, intermediate and climax forest

GTFP						
	Df	Sum sq	Mean sq	F value	P(>F)	Sig
Age classes	2	25350.9	12675.4	11.409	0.0063	***
Disturbance	2	9842	4921	4.4293	0.0273	*
Age: disturbance	4	577.8	144.4	0.13	0.969	
Residual	18	19998	1111			
		SLFP				
Age classes	2	62222	31111.1	53.027	0.0029	***
Disturbance	2	20267	10133.3	17.2716	0.0065	***
Age: disturbance	4	5911	1477.8	2.5188	0.077	
Residual	18	10561	586.7			
		MBFP				
Age classes	2	28895.6	14447.8	28.0064	0.00298	***
Disturbance	2	20269.3	10134.7	19.6456	0.00299	***
Age: disturbance	4	2744.8	686.2	1.3302	0.297	
Residual	18	9285.7	515.9			
Signify. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1						

GTFP= Gesengesa –Tumi forest patch, SLFP= Sekora-Lopi forest patch and MBFP=Menesibu-babo forest patches

3.12.2 Sapling density in pioneer, intermediate, and climax forests

Sapling density was highest in intermediate forest patches, followed by pioneer forest patches in the three forest patches (Table 11), and significantly varied along age gradients among forest patches SLFP (P > 0.0093), MBFP (P > 0.00384), and GTFP (P> 0.00162). Many saplings were collected in intermediate, intact, and highly disturbed forest patch parts. Sapling per plot also varied significantly along disturbance at MBFP (P > 0.0056) and SLFP (P > 0.0088), but not significantly varied in GTFP (P > 0.066). The interactions of age and disturbance were not significantly varied in GTFP (F = 0.183, P > 0.944), SLFP (P > 0.0811), and MBFP (P > 0.348).

Table 11. Sapling density in pioneer, intermediate and climax fortes

	GTFP					
	Df	Sum Sq	Mean Sq	F value	P(>F)	Sig
Age	2	6180.1	3090.04	9.3743	0.0016	**
Disturbance	2	2088.1	1044.04	3.1673	0.066	
Age:Disturbance	4	241.7	60.43	0.1833	0.94	
Residuals	18	5933.3	329.63			
	MBFP					
Age	2	14798	7399	61.2425	0.0093	***
Disturbance	2	3963.6	1981.8	16.4034	0.0088	***
Age:Disturbance	4	1196.4	299.1	2.4758	0.0811	
Residuals	18	2174.7	120.8			
	MBFP					
Age	2	7437.9	3718.9	26.971	0.0038	***
Disturbance	2	4886.7	2443.4	17.72	0.00056	***
Age:Disturbance	4	656.4	164.1	1.19	0.35	
Residuals	18	2482	137.9			
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

GTFP = Gesengesa –Tumi forest patch, SLFP = Sekora-Lopi forest patch and MBFP = Menesibu-babo forest patches

3.12.3. Density per hectare of seedling, sapling and higher DBH of woody trees

In intact pioneer forests, seedling density per hectare was greater than sapling density (Table 12). In intact and highly disturbed intermediate forest patches, tree density per hectare was greater than that of seedlings and saplings. In highly intact, moderately disturbed, and highly disturbed forest patches of climax forests, tree density per hectare was higher than that of seedlings and saplings.

Table 12.Sapling and seedling per hectare

Forest patches	Forest patches age and disturbance gradients								
	Pioneer forests			Intermediate forest			Climax forest		
	INT	MDF	HDF	INT	MDF	HDF	INT	MDF	HDF
Seedling									
GTFP	439.90	614.20	475.59	290.50	398.40	282.20	182.60	332.00	99.60
SLFP	522.90	594.28	295.48	575.19	718.78	348.60	107.90	132.80	71.38
MBFP	442.39	572.70	268.09	536.18	680.60	307.10	187.58	251.49	112.88
Total	1405.19	1781.18	1039.16	1401.87	1797.78	937.90	478.08	716.29	283.86
Sapling									
GTFP	350	540	200	420	540	240	70	90	40
SLFP	380	1297.97	440.28	163.74	148.95	107.12	68	149.16	114.11
MBFP	315	405	180	385	495	220	140	180	80
Total	1045	2242.97	820.28	968.74	1183.95	567.12	278	419.16	234.11
woody trees(DBH>2.5cm)									
GTFP	283.91	292.78	346.02	487.97	505.72	275.04	159.70	221.81	204.06
SLFP	371.91	410.05	295.62	505.41	505.41	381.44	123.97	228.87	219.33
MBFP	433.48	390.14	268.76	450.82	476.83	303.44	199.40	225.41	138.71
Total	1089.30	1092.97	910.39	1444.20	1487.96	959.92	483.07	676.08	562.10

INT=intact natural forest, MDF= Medium disturbed forest and HDF= highly disturbed forest, GTFP= Gesegesa-Tumi forest patches, SLFP= Senkora-Lopi and MBFP= Menesibu-babo forest patches

4. Discussion

4.1 Population composition

The total numbers of woody species recorded from the three forest patches (GTFP, SLFP, and MBFP) were similar to the dry Afromontane and Awi Zone Forests (Berhanu *et al*. 2017). Wombera district and Awi zone share boundaries. The altitudinal ranges of wombera dry Afromontane forest patches range from 1765–2650 (current study) m.a.s.l, and Awi zone altitudes range from 1830–2660 m.a.s.l; this similarity contributes to vegetation similarity. The highest number of Asteraceae, Poaceae, and Fabaceae species recorded in wombera forest patches was similar to the flora of Ethiopia and Eritrea Volumes records. The result is also similar to other studies (Tadesse 2004, Lulekal *et al.* 2008, Yineger *et al*.2008, Gurmessa *et al*.2012). According to Gebrehiwot *et al*. (2019) Asteraceae and Poaceae families are the most widely distributed vascular plants standing first and the six in the world. Asteraceae, Fabaceae and others were among the top 10 species-rich families in many Neotropical forests (Gentry 1995). These are also widely distributed families, ranked third and second following Fabaceae, in Ethiopia (Kelbessa & Demissew 2014). Asteraceae inflorescence and the diverse pollination mechanism probably made the family widely distributed (Judd *et al*. 2008). These families are also the top species-rich families distributed worldwide (Stevens 2018).

Most plant communities were determined by altitude, aspect, slope, moisture, and soil type. There are different criteria and systems for classifying vegetation or plant communities (Mueller-Dombois & Ellenberg, 2002). However, other studies in Ethiopia studied plant communities based on topographic and soil physical and chemical characteristics (Yeshitela & Bekele 2002, Bekele 1994, Assefa *et al*. 2013). However, in the Wombera district, higher-altitude forest patches, age or maturity level, and disturbance gradients were also determinates of plant communities.

4.2. Communities

Community one (C1) is grown in pioneer forests mainly dominated by shrubs and lower-layer canopy trees: *Nuxia congesta* R.Br. ex Fresen, *Maesa lanceolata* Forssk., *and Acacia abyssiniea* Hochst. ex Benth. These species can invade grasslands, farmlands, bare land, abandon lands, and form pioneer forests. They are fast-growing and light-demanding, and seeds only germinate in full sunlight, with seedlings not surviving in the shade (Peters 1996).Pioneer bushes were also present in many of the enclosures on the damaged hillsides (Kidane et al. 2010). Thus, they are well-known soil layer builders for the coming species of middle and upper canopy trees. It is partly in line with the facilitation idea that "later species can become established and grow after earlier species have suitably modified the environment"(Connell & Slatyer 1977).

Community two (C2) is in the intermediate stage of the three forest patches. It developed from the ecology of community 1. In intermediate or transitional forests or community 2, middle-layer canopy trees are dominant. It exists on the same forest patches as communities one and three. It is more mature than Community (C1) and younger than Community3

Plant species are dependent on their environment, influence one another, and modify their environment (Connell & Slatyer 1977). Community three was a successor of plant community two, which was dominated by upper canopy trees: *Prunus africana (Hook. f.) Kalkam and Apodytes dimidiata E. Mey. ex Arn., Syzygium guineense (Wild.) DC., Ficus sur Forssk., and Olea europaea L. subsp. cuspidata, and Ekebergia capensis Sparrm*. The results of other researchers (Woldu *et al*. 1999, Bekel, 1993, Friis *et al*. 2010) are consistent with this one: elaborated upper canopy trees predominate in climax dry Afromontane forests. There were no lower-layer canopy trees, grasses, herbs, or middle-layer trees in intact climax forests. It is partly similar to the idea of inhibition (Mueller-Dombois & Ellenberg 1974), *i.e.*, “togetherness eliminates the role of tolerance”. However, where disturbances were high, lower layer strata were dominated by *Maytenus arbutifolia (A.Rich) Wilezek, Teclea nobilis Del., Brucea antidysenterica J.F. Mill., Bersama abyssinica Fresen.,* and saplings of upper canopy trees.

The similarity of lower canopy trees, middle canopy trees, and upper layer canopy trees in the three forest patches was in line with the community-unit theory, which states communities are highly structured, repeatable, and identifiable associations of species controlled by environmental gradients (Clements, 1936). On the other hand, the association and replacement of lower- and middle-layer canopy trees along age gradients in pioneer, intermediate, and climax forests in the three forest patches correspondingly support continuum theory, which stated that plant communities change gradually along complex environmental gradients such that no distinct associations of species can be identified (Curtis 1959, Whittaker 1953).

Compared to pioneer and climax forest patches, the soil layer and appropriateness of the shade in the intermediate forest contribute to its increased floral richness. The transitional forest patches consist of more herbs, climbers, seedlings, and saplings of upper canopy trees than climax forests. The highest species richness in moderately disturbed intermediate forests of GTFP (57), SLFP (53) and MBFP (55), followed by intermediately disturbed pioneer forests of GTFP (33), SLFP (43), and MBFP (45), was because open space encourages the growth of plant species. The species richness varied significantly along the disturbance gradients (intact, moderately disturbed, and highly disturbed) in three forest patches. Gebrehiwot *et al*. (2020) explained that anthropogenic disturbances, such as logging and livestock grazing, have altered an ecosystem's richness, variety, distribution pattern, and vegetation structure.

In moderately disturbed forest patches, the free space formed by disturbances allows the entry of other species and increase diversity. Moderate forest disturbances may increase the possibility for less adaptive species to coexist together (Connell & Slatyer 1977). These, in turn, may add to the high evenness and diversity of the community types. Relatively, the climax forest consists of a few understory trees. Following moderately disturbed forest patches, more species exist in intact forest patches of intermediate, pioneer, and climax forests. Highly disturbed forest patches had the lowest species composition because of over-extraction by humans, the dominance of a few invasive species, and overgrazing by animals.

The species diversity of moderately disturbed intermediate forests was higher than in moderately disturbed pioneer and climax forests. Diversity is generally lower in later successors; disturbances before the late successor can prevent species diversity (Mueller-Dombois & Ellenberg 1974). In moderately disturbed intermediate forest patches, plant species diversity (H) ranges from 3.85 to 3.87, followed by moderately disturbed Pioneer (H) ranges from 3.31 to 3.647, and in climax forests (H) ranges from 2.975 to 3.144. Variations in species diversity along age gradients (intermediate, pioneers and climax forest patches) were the related maturity level of the forest patches. Frequent disturbances that maintain early-succession conditions reduce diversity, leading to dominance by fast-growing species.

Constrained ordination or direct ordination refers to ordination techniques that use environmental variables to construct the ordination; this is because the environmental variables determine where the samples are positioned within the ordination (Van 1995). Species abundance and environmental matrices containing elevation (masl), slope, and aspect are used for ordinations (Kebede *et al*. 2013). All seven variables in the current study significantly affected the distribution of vegetation except moisture ($P<0.143$). Age ($P<0.001$), height ($P<0.001$), and aspect ($P<0.001$) all showed strong statistical significance. Moisture was not significant, while disturbance ($P<0.003$), grazing ($p<0.009$), and slope ($P<0.004$) varied moderately. The first RDA axis constrained the species of plants. Amongst the variables, age class or maturity level was highly correlated with axis one, thus maturity level was the major variable in explaining variations in plant species distribution and patterns of plant community formation in the higher altitude, dry Afromontane forest patches. Because of the highest severity and intensity of anthropogenic impact on vegetation at higher altitudes, age or maturity becomes the most important determinant of vegetation distribution. Administrative fluctuation and conservation cultures establish age gradients.

4.3. Population structure of wood tree species in pioneer forests patches

The J-shaped kind of DBH and the height classes of population structure indicate a poor regeneration growth pattern of a forest (Gebrehiwot and Hundera, 2014; Burju et al., 2013; Dibaba, 2014).In this study, the J-shaped population structure of lower canopy tree species in pioneer forests was a kind of poor regeneration status of plant population distributions. In pioneer forests, lower-canopy trees attain maximum growth. An inverted U-shaped population structure shows overexploitation of larger and smaller DBH, while the middle population has a good growth patterns (Burju *et al*., 2010). Similarly, in an inverted U-shaped population structure, *Maytenus arbutifola and Maesa lanceolata* (lower canopy), *Olea europaea (*upper canopy*)*, and *Hagenia abyssinica* (middle layer canopy) show exploitations of higher and lower DBH, while the middle population is in good growth patterns. *Maytenus* *arbutifola and Maesa lanceolata* are used mainly for firewood, fence construction, and'meskel' festival commemoration. However, inverted J-shaped patterns in DBH and height classes of middle and upper-layer canopy trees in pioneer forests show good regeneration (Hundera *et al.*, 2007; Yineger *et al.*, 2008; Zegeye *et al.*, 2011; Gurmessa *et al.*, 2012; Lulekal, 2014; Tilahun *et al*., 2015; Gedefa and Sormessa. 2014; Senbeta *et al*., 2014; Kidane, 2010).

The inverted J-shaped population structure of the middle and upper canopy trees was due to their lower use value at the immaturity level. However, *Dombeya torrida* has a J-shaped population structure as it has a higher use value at its immature level than others. The inverted U-shaped population patterns of Upper Canopy Trees, *Apodytes dimidiata,* and *Ekebergia capensis* are due to their lower use value for the community. In highly disturbed Pioneer forests, plant species with high use value had a J-shaped population pattern as mature and immature trees are overexploitation intensively; however, the population structure of upper canopy trees with less use value had an inverted J-shaped.

4.4. Population structure of wood tree species intermediate forest patches

The J-shaped population structure of lower and middle canopy trees in intermediate forest patches shows a poor regeneration pattern because they reach the highest maturity stage. However, a few shade-tolerant species, *Maytenus arbutifola,* have inverted J-shaped because of their multiple regeneration ways and disturbance adaptation potential. In disturbed forest patches, smaller DBH classes were grazed by animals and larger DBH classes were overexploited by local communities for timber production as result; they had irregular DBH patterns (Burju *et al*., 2010; Gurmesa, 2013). Similarly, some middle-layer canopy trees had irregular population patterns. The irregularity (inverted u-shaped or bell-shaped DBH) is due to selective overexploitation of mature trees such as *Hagenia abyssinica, which* have high use value; Overexploitation at an early stage resulted in such a pattern of species structure (Senbeta, 2006; Kelbessa & Soromessa, 2008). Few species of *Olea europaea* had unimodal or bell-shaped population patterns as the immature ones were over-extracted for farm tools at lower DBH classes and had poor regeneration status. The over exploitation of plant species at different DBH values and the dispersal ways form an irregular DBH pattern (Burju *et al*., 2010; Gebrehiwot and Hundera, 2014). Similarly, *Apodytes dimidiata* and *Syzygium guineense* had irregular DBH; this is due to interference of different disturbance types, degree of preference, and dispersal ways.

4.5. Population structure of wood tree species in Climax forest patches

The forest having good canopy cover might have affected the survival of seedlings under a good canopy (Pokhriyal *et al*., 2010), probably by reducing the penetration of sunlight reaching down to the forest floor (Sarkar, M., & Devi, A., 2014). A highly J-shaped population structure in climax forests has a poor regeneration status or has reached climax. In intact climax forests, the lower and middle canopy trees have no population structure patterns except a few species that exist as shade-tolerant and have irregular DBH classes of the population. However, in disturbed and highly disturbed climax forest patches, a few individual plant species had irregular population patterns because of disturbances. Syzygium guineense, which possesses a high dispesal probability due to its fruit edibility and a high capacity for seed bank germination, had an inverted J-shaped population in disturbed forest patch areas. *Prunus africana* had also irregular population growth structures as it had multiple regeneration ways.

4.6. Seedlings and sapling structure

The significant variation in seedling and sapling density in pioneer, intermediate, and climax forests of GTFP, SLFP, and MBFP is due to the maturity level and the suitability of forest ecology. Intermediate forests have more fertile soil than pioneer and climax forests; they recruit more seedlings and saplings. However, in pioneer forests, the grass hinders seed germination and the growth of seedlings. Seedlings of climax forest species may spend years under poor light conditions before a suitable gap appears; ample food reserves, coupled with shade tolerance and a low rate of growth, are necessary for survival (Whitmore, 1996).In climax forests, the thick upper canopy and shade-tolerant lower canopy trees block the sunlight entrance, hindering seed germination and the growth of seedlings and saplings. The accumulation of chemicals (allopathic) for a long time in climax forests also inhibited seed germination and seedling growth. Seedlings and sapling distribution can be affected by disturbances such as tree fall gaps, livestock grazing, and logging, which affect the abundance and composition of the seedlings in the forest understory (Wassie *et al*., 2009). The significant variation of seedlings and saplings along the disturbance gradient is due to the intensity and frequency of grazing animals and anthropogenic resource exploitation. In moderately disturbed forests, the open canopy of trees allows sunlight and enhances seedling germination and growth. However, in highly disturbed forests, the density of seedlings and saplings declines due to the massive suppression of intertwined herbs, the gazing of seedlings and saplings by animals, and the over-extraction of a seed-bearing mature tree. More shrubs and herbs grow in highly disturbed climax forests than the upper canopy tree seedlings and saplings. The seedlings of edible species as fodder, such as *Allophyllus abyssinicus, Prunus africana, and Ficus sur, are* not available in disturbed parts. The absence of the lower DBH, seedlings, and saplings in the highly disturbed area is because of over-extraction, consumption by herbivores, and the physical pressure exerted by some herbaceous climbers.

The greater density per hectare of the seedling, sapling, and higher DBH trees, respectively, in moderately disturbed forest patches shows good regeneration status in the forest. Similar findings were reported by Dibaba *et al*. (2014). On the contrary, the greater density per hectare of higher DBH than seedlings and saplings in intact and highly disturbed intermediate forest patches shows a poor regeneration status of the forest patches. The poor regeneration status of upper canopy trees in climax forest tree species such as *Ekebergia capensis, Ficus sur,* and *Olea europaea in* highly disturbed forest patches is related to poor seed dispersal mechanisms. The dispersal rate depends on the wealth of the forest ecology, specifically the availability of fruit-eating animals. *Prunus africana* and *Syzygium guineense* had better regeneration in disturbed parts of climax forests. .

CONCLUSION

There are variations in the species composition of plants along vegetation age classes and disturbance gradients.All plant species were present in the intermediate forest patches.The maximum species diversity was found in intermediate, pioneer, and climax forest sections along age gradients, respectively. Along disturbance gradients, parts of moderately disturbed forests had the highest species diversity, followed by intact and highly disturbed forest patches. Lower-layer canopy trees have a better chance of surviving and rejuvenating in low-nutrient soil than middle- and upper-layer canopy trees. Plant species composition varies along with vegetation age classes and disturbance gradients.In Pioneer forests, the lower-layer canopy trees had a J-shaped height and DBH classes of population structure. Middle and upper canopy trees had an inverted J-type DBH and height distribution. Middle-layer canopy trees dominate the intermediate forest patches more than upper and lower-canopy trees. Lower and middle canopy trees had J-shaped structures, and the upper canopy trees had irregular-shaped DBH and height structures in intermediate forest patches. In Climax forests, the upper canopy trees, Olea europaea, *Allophyllus abyssinicus*, *Apodytes dimidiata*, *Ekebergia capensis*, and *Prunus africana,* had J-shaped DBH and height classes.

CHAPTER FOUR

Land use land cover change and driving force in Wombera district, Benshangul Gumuz regional state, Ethiopia.

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Abstract

Land use Land cover change (LULCC) were analyzed for wombera district along agro-ecological gradients (lower, middle & higher) using a Satellite image of Landsat Mss, Landsat TM, Landsat ETM+, and Landsat OLI/TIRS of 1973, 1986, 2000 and 2016 respectively. After reconnaissance survey and field observations 402 individuals were selected. Six groups of Key informants interview (KII) and six groups Focus Group Discussion (FGD) were selected for structural and open ended questions. One hundred thirty two GPS data were collected using handheld GPS Garmin Global Positioning System for confirmations of accuracy assessment. Five direct and six indirect driving forces of LULCC were identified for each corresponding agro-ecology gradients for each year. ERDAS version 15, excel, and ArcGIS 10.3.1 used for satellite image calibration and analysis. Maps of Forest, woodland, scrubland, grassland, farmland, water body, and settlement were created. The finding reveals that croplands, settlements, and grasslands are increasing. However, woodland and forest are decreasing from 1973 and 2016. Among the indirect driving forces, Socio-cultural practice and demographics imposed a higher impact in 1970; conversely, institutional setup and technological advancements contribute the highest effect in 2000 &2016. Among the direct or proximate causes, farming and fire contribute the highest impact in 1970 in the lower and middle altitude. Farming activities and logging had the highest impact on the higher altitudes during 1970s. To improve accuracy, the LuLCC of the district should be analyzed in greater detail using images from satellites with high resolution smaller, more visible pixels.

Keywords: LULCC, Landsat and driving force, Image

1. Introduction

Land use and land cover are described as the distribution of vegetation, water, desert, ice, and the immediate subsurface, including biota, soil, topography, surface, and groundwater (Chrysoulakis, 2004). It also includes those structures created by human activities (FAO, 2000). Oyinloye and Oloukoi (2013) suggest that non-vegetation parts were covered with vegetation in early times. It is not uniformly distributed globally (WIREs Climate Change, 2014). The impact of LULCC on global and local environmental changes varies across space and time (Bryan, 2013; Costanza *et al., 2014)*. LULCC varies in place time (Fisseha *et al*., 2011), time (Weng, 2002), geographical location (Poyatos *et al*., 2003) slope, and altitude (Kindu *et al*., 2013, Tegene, 2002). According to Jamal (2012) certain land-use and land-cover changes are local and place-specific Many authors indicated that the area under natural forest, shrub, and grazing lands was declining continuously while cultivation and settlement were expanding dramatically (Geist and Lambin, 2002; Tekle and Hedlund, 2000; Mekuria *et al*., 2011). Thus LULCC is space and time dependent.

LULCC is driven by multiple factors (Gong *et al.*, 2015). It is the result of actors and factors of interactions (Bakker MM and van Doorn, 2009). Causes of LULCC were classified as proximate and underlying forces (Geist and Lambin, 2002). The underlying causes of LULCC originate from a complex interaction of social, policy, institutional, economic, demographic, technological, cultural, and biophysical factors (Geist and Lambin, 2002; De Sherbinin, 2002). The proximate causes of LULCC are immediate actions of local communities and directly exerted on land resources (Geist and Lambin, 2002, Shiferaw, 2011). It is a complex process that triggers biotic and abiotic factors spatiotemporally (Valbuena *et al.*, 2008; Rindfuss *et al*, 2004). It is caused by the expansion of agriculture, urbanization, and deforestation (Rawat & Kumar, 2015). It might be caused by climate and physiographic conditions (Bewket, 2002). It is also aggravated by rapid population growth and resettlement, agricultural expansion, and deforestation (Tsegaye, 2010).Thus, LULCC are caused by direct and indirect driving forces independently or in synchronized way.

It would be necessary to conduct studies that explicitly reveal the variations in LULCC characteristics. The data needed to develop mitigation strategies that protect LULCCS for specific intervals into the future could not be generated and refined for use in land use classification. The impact of the socio-economic structure, population pressure, infrastructure development, administrative role, and cultural practice on LULCC was not assessed in the district. This study was carried out to obtain information on LULCC and socio-economic factors that triggered the changes. No research addressed relevant issues on LULCC concerning the socio-economy and provides recommendations that may contribute to the sustainability of natural forests and the conservation of biodiversity and wildlife habitat in the study area. The objective was to classify land use and land cover changes and evaluate driving forces that intensified patterns. This specific objective addressed: (1) the rate and patterns of LULCC; (2) the historical and contemporary LULCCS; and (3) the factors that drive LULCC.

2. Materials and Methods

2.1. Descriptions of the Study Area

Study area, Wombera district is 658km from the capital city, Addis Ababa. It is found in the Metekel administrative zone of Benishangul Gumuz national regional state in the northwestern part of Ethiopia. Wombera is one of the largest districts in the Metekel administrative zone (see Figure 1).

2.1.1. Topography

The topography is undulating and with few plain. The altitudes of wombera district extend from 576 to 2615 (Figure 20). The aspects vary in all of the three agro-ecological zones. The general agro-ecology of wombera district was classified into three agro-ecologies: higher, Middle, and lower altitudes. The classifications of agroecology were based on the vegetation strata, crop productivity, and altitudes range.

2.1.2. Vegetation

The lower altitudes are in *combretum-Terminalia* woodland vegetations (Berhanu *et al*., 2017). The altitudes range from 576- 1200masl. The majority of the study area lay in the lower altitudes (576-1200) followed by the higher altitudes which ranges form 2001-2616m. The Vegetation of higher altitudes is related to dry Afromontane which is part of the Gojam region vegetation type (NMSA, 2019). The middle altitudes range from 1201-2000. The middle altitude is mainly known for the productivity and abundance of coffee, fruits, spices, and vegetables. The vegetation layers mainly dominated by: *Albizia schimperiana, Albizia gummifera, Millettia ferruginea, Cordia africana*, and *Ficus. Sp*

2.1.3. Climate and Temperature

Climate data were obtained from the Ethiopian National metrological agency.Twenty years of data (1999-2016) were taken from three districts record (See Figure 2).

2.2. Data Source and Analysis

The aim of this study was to analyze LULCC along an altitudinal gradient relating to driving force in wombera district during periods of 1973, 1986, 2000, and 2016. The driving forces of land use and land cover were identified and categorized into indirect and direct following the methods of different authors (Geist, and Lambin, 2002; Mezgebu and Workneh, 2017) with some modifications respective to the study area. Five direct or proximate causes and six indirect driving forces were identified. The driving forces were computed for each year along each agro-ecology independently. Four satellite images Landsat-mss 1973, Landsat-5 TM 1986; Landsat-7 ETM+2000, and Landsat-8 OLI- 2016 were used to analyze the LULCC change of the study area (Table 13). The images with a spatial resolution of 30 m were downloaded from the United States Geological Survey (USGS) Earth Explorer (http://earthexplorer.usgs.gov.). The images with high resolution and Minimum or less than 10% cloud covers were selected from several images for each period. The image in the summer season was not suitable as the ground is covered by extra green. On the other hand, the winter season image was not suitable as fire is released in the lower and middle altitude and smoke covers the lower atmospheres. Thus the images taken in January and February were found to have no cloud and fire smoke cover. The selection of appropriate image acquisition dates is a precondition for clear identification of the LULCC types from satellite imageries (Othow *et al*., 2017). Digital elevation data of the SRTM DEM was also obtained (http://earthexplorer.usgs.gov) with a spatial resolution of 30m and was used for the classification of geomorphologic terrain features: elevation, slope, river basin, altitude, contour, and aspect variables of wombera district (Figure 20).

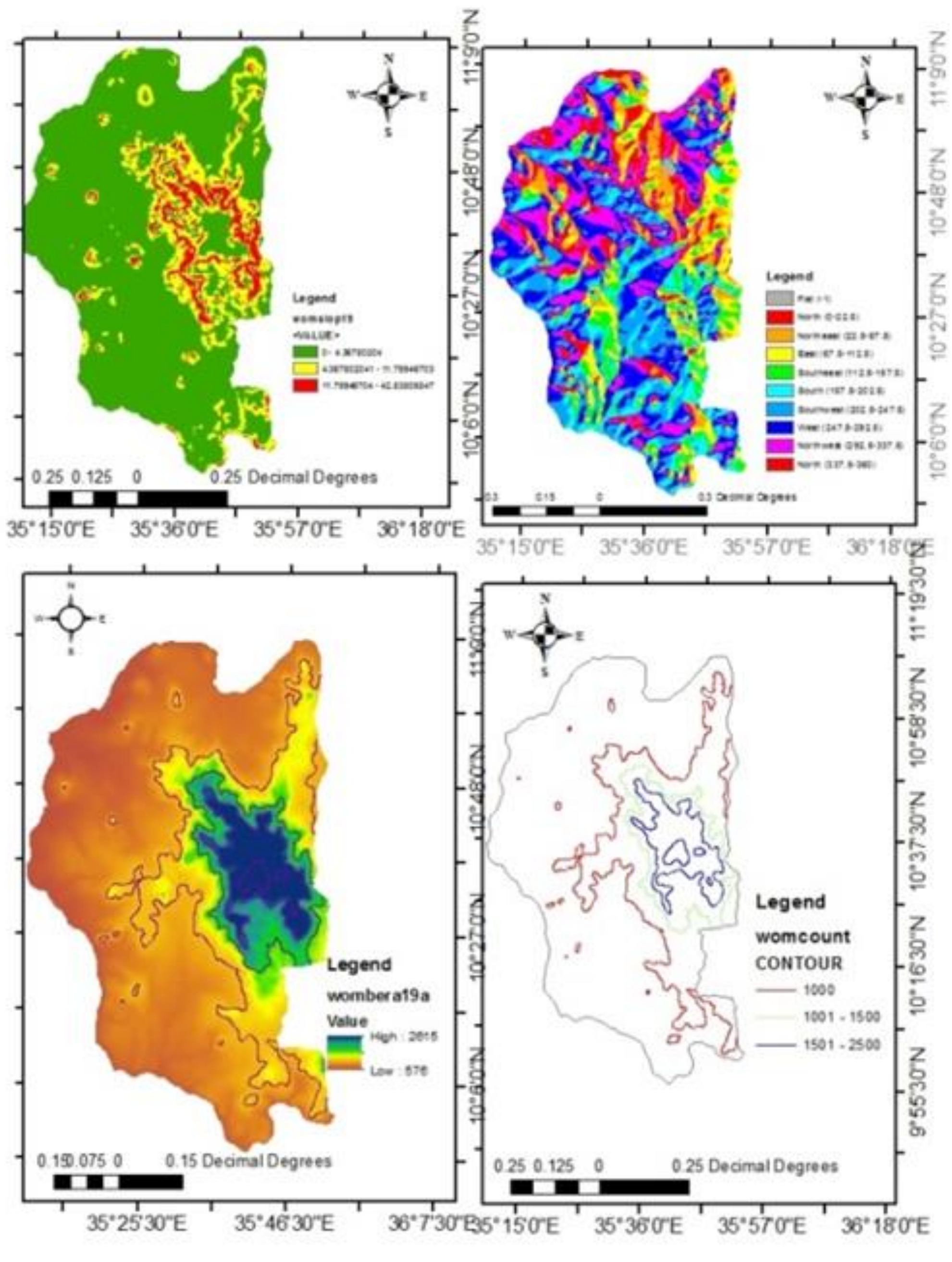

Figure 20. Altitude, aspect, contour of study area

Table 13. Satellite data accessed from USGS

Data set Type	Acquisition	Pixel Resolution	Path / Row
Landsat Mss	1973-01-01	30	183/053 and 183/052
Landsat TM	1985-01-14	30	170/052,170/053,171/052,171/053
Landsat ETM+	2000-01-15	30	170/052,170/053,171/052,171/053
Landsat OLI/TIRS	2016-01-15	30	170/052,170/053,171/052,171/053
Sentinel	2016	15	general
Google earth		general	general
DEM	2016	30	General

2.2.1. Population selection

The data were collected from primary and secondary sources. The primary data was obtained from households living around to forest patches. Target populations were selected based on the distance of the village from the forest boundary.At the end of the preliminary survey 3155 households were identified as the total population and 450 were purposely selected(Appendix-Table 4).The informants were purposefully selected based on age and knowledge from selected samples. An informant between the ages of 45 and 70 were chosen in order to collect data.The selection of this age group was based on their familiarity with current affairs and past history of the district.

2.2.2. Focus group and Key informant (KII) selection

From the total of 450 individuals sampled, six focused group discussions (FGD) were formed, one for each forest patch. They were formed based on the local customs of each community in each agroecology. The groups consist of 5–10 individual residents age 45–70. Six groups of key informants were also formed, one at each forest patch (GTFP, SLFP, MBFP, BMFP, ABFP and PMFP), to check the reliability and validity of the data. The key informant groups consist of community leaders, senior agricultural experts, and senior administrative officers.

2.2.3. LULCC Drivig force identification

Field trips were conducted with the help of local communities and field guiders. The results of the reconnaissance survey were used to choose Kebeles and organize focus group discussions (FGD) and KIIs (key informant interviews). In collaboration with the local community, FGD, KII, the elderly, and agricultural experts, five direct or proximate causes (Appendix-Table 6) and six indirect driving forces (Appendix-Table 5 were identified following the methods of various authors (Geist and Lambi, 2002; Nesanet, Deneke, 2007; Mezgebu and Workneh, 2017) With modification respective to the district.

2.2.4. Focus group Discussion

Focus group discussions were held with selected groups of community members in the respective agroecology zones of the study area. The groups were given the questions (Appendix 9) for free discussion, and their responses were noted and compiled for comparison. For each group, questions such as how long they have lived in the area, what types of LULCC have been changed in their local area, what types of natural resources are available in the forest patches, and whether and how they have been extracting resources were administered**.**

2.2. 5. Field Survey and Data Collection

Following the identification of the driving force of LULCC, data were collected through questionnaires and interviews with selected informants (Appendices 10). The informants were requested to select which one of the following direct causative agents: farming (crop cultivations), logging, temporary disasters (fire, wind, and flood), grazing (by livestock), and on LULCC. They were asked to select one of the following indirect driving forces: demographic, economic, technological, and infrastructure advancement; institutional policy change; socio-cultural factors, and permanent disasters on the direct driving forces during 1973 to 1985, 1986 to 2000 and 2000 to 2016.

The field survey was conducted in three agro-ecological zones independently. During the field survey, eighteen types of LULCC were identified (Appendix-Table 8). However, only seven are visible in satellite images (Table 12 and Figure 12). In the district 132 Ground Points (GTPs) were collected using handheld GPS Garmin (Global Positioning System). Ground truth points were used for confirmation accuracy assessment (Congalton *et al*., 1999; Lillesand *et al*., 2008). Photos of existing LULCC types were taken to aid different steps of image processing, classification, and accuracy assessments.

2.2.5 Key Informant interview (KII)

The selected KII was interviewed and discussed to confirm the reliability and honesty of the data collected from informants. Assessments were made on the coverage of forests, land degradation, and recent and past natural disasters and integrated into a GPS.To completely comprehend the possible causes of LULCC; the historical socioeconomic state of the area was assessed using primary and secondary data sources. The direct and indirect forces that caused changes in land use and land cover in the past and present were evaluated (Appendix 9).

2.3. Image pre- processing

Images acquired by Landsat sensors are subjected to distortion due to sensor, solar, atmospheric, and topographic effects (Young, 2017). Before image analysis, pre-processing of image is crucial (Campbell, 2007).The digital images were corrected geometrically, i.e., linked to a GIS coordinate system and a projection of the earth's globe (UTM, Zone 37 North, Datum Adindan). Following georeferencing, the raw image data was clipped to the research area's boundary to get ready for further processing. Preprocessing of images also involves the initial processing of raw image data to correct radiometric and atmospheric corrections to minimize geometric distortions (Bedru, 2006). It is crucial to enhance images for better image interpretability (Bakker *et al*., 2001). Layer stacking, resampling, image enhancement of the image dataset, and subsetting are of utmost importance for LULCC analyses (ILWIS, 2001).Thus, The standard image processing techniques of extraction, layer stacking, geometric correction/geo referencing, image enhancement and change detection were performed on the four Landsat images. The study area is covered by four satellite scenes. Some of the four scenes were downloaded from USGS-EROS using the path and rows and some are accessed from EMA indicated in (Table 12).

2.4. Image composition identification and analysis

The panchromatic bands in each scene were stacked together so as to produce a multispectral image for each scene (Mezgebu and Workneh, 2017).In land use and land cover analysis, the first step was the recognition of the real object. In the context of this study, the remote sensing of land surface could include forests, woodlands, scrublands, croplands, settlements, water bodies, and grasslands (Table 14). The second stage in the classification process is the labeling of the entities (normally pixels) to be classified. The process of classification often requires to (1) determine the number and nature of the categories in terms of which the land cover is to be described and (2) assign numerical levels to the pixels on the basis of their properties using a decision-making procedure, usually termed a decision rule or classification rule.

Table 14. LULCC descriptions

LULCCs	Descriptions
Forests	A land covers by intermediate forests and climax forests. The forest portion of LULCC includes High land forests, Mountain forests, riverside forests and plantations. The forest covers are dense tree with thick canopy.
Shrub	Small tree, shrubs, bushes and pioneer forests on abandon lands
Grass land	The land covered by grass and herbaceous. Bamboo vegetation in middle attitude and short grasses on higher altitude. Abandoned lands were included in the grass land.
Settlement	It includes urban centers, villages and camps.
Water bodies	It includes rivers,dams and swamps and wet lands
Wood lands	The land covered with both open and closed (high) woodland with dominant species of *Combretum-Terminalia* wood land vegetation. It also includes acacia wood land and recovery forests from fire.
Farm lands	all cultivated land which includes crops (teff ,barley, wheat); vegetable (cabbage, fruits) ,cash crops(sesame)

2.5. Supervised classification of the image into LULCCS classes

Image classification is the process of sorting pixels into a finite number of individual classes or categories of data based on their data file values. A pixel is classified into the appropriate class when it meets a specific set of requirements. Assigning training sites, classifying data, and producing outputs were the three phases of a supervised classification scheme using a maximum likelihood classifier decision rule (Campbell and Wynne, 2011). The LULCC classification was done on the basis of reflectance characteristics of the different land cover types using false-color composites. This was supplemented by field visits that made it possible to establish the land use and land cover types.

2.6. Accuracy Assessment

After classification was performed, the results were evaluated by accuracy assessment. It gives evidence of how the results reflect reality on the ground (Othow *et al.*, 2017). It was performed to confirm to what extent the produced classifications of LULCC were compatible with what actually exists on the ground (Mezgebu and Workneh, 2017). Accordingly, an error matrix was produced for all images in this study. The reference data used for accuracy assessment were obtained from GPS points during fieldwork and the original mosaic image. More than 132 Ground Truth Points (GTPs) were collected by handheld GPS Garmin (Global Positioning System). Ground truth points are important for confirmation accuracy assessment. Google Earth, a sentinel image, and the original mosaic image were also used as references. An error matrix is a square array of rows and columns and presents the relationship between the classes in the classified and reference data (Lillesand *et al.*, 2008). Based on the error matrix, overall accuracy and kappa statistics were used to illustrate the classification accuracy (Congalton *et al.*, 1999).

Error matrix was calculated by the following formula:

$$\text{Over all accuracy} = \frac{\text{Total number of correctly classified pixel}}{\text{total number of reference}} * 100$$

$$\text{User accuracy} = \frac{\text{Number of correctly classified in each category}}{\text{Total number of classified pixel(row)}} * 100$$

$$\text{Producer accuracy} = \frac{\text{Number of correctly classified pixel}}{\text{Total number of correctly classified pixel(column)}} * 100$$

$$kappa\ cofficient. = \frac{Total\ sample * total\ corrected\ sampled - \sum Columen * row}{(Total\ sample)2 - \sum Column * row}$$

2.7. LULCC Conversion Matrix

Conversion matrix was analyzed to show which Land cover type is converted into another Land cover type or Land use type. The conversion matrix shows the destination and source of land use land cover types (Adam, 2011; Ali, 2009). Analysis of conversion matrix was computed by overlaying classified images of two study years on ArcGIS 10.3. In all change matrixes, the row of the table stand for the initial year and the column of the table symbolize the final year of the change.

2.8. LULCC Detection analysis

LU/LCC statistics were computed in three different ways:

Total LU/LCC in hectare calculated by:

1. $LULCCs\ = \ Area\ of\ Final\ year - \ Area\ of\ Initial\ Year$

2) Percentage LU/LCC calculated using the following equation:

$$Percentage\ LULCCs = \frac{Area\ of\ Final\ year - Area\ of\ \text{Initial year}}{Area\ of\ Initial\ Year} * 100$$

3. Rate of LU/LCC: computed using the following simple formula:

$$Rate\ = \frac{Area\ of\ Final\ year - Area\ of\ initial}{Year\ of\ Final\ year - Year\ of\ Initial\ year}$$

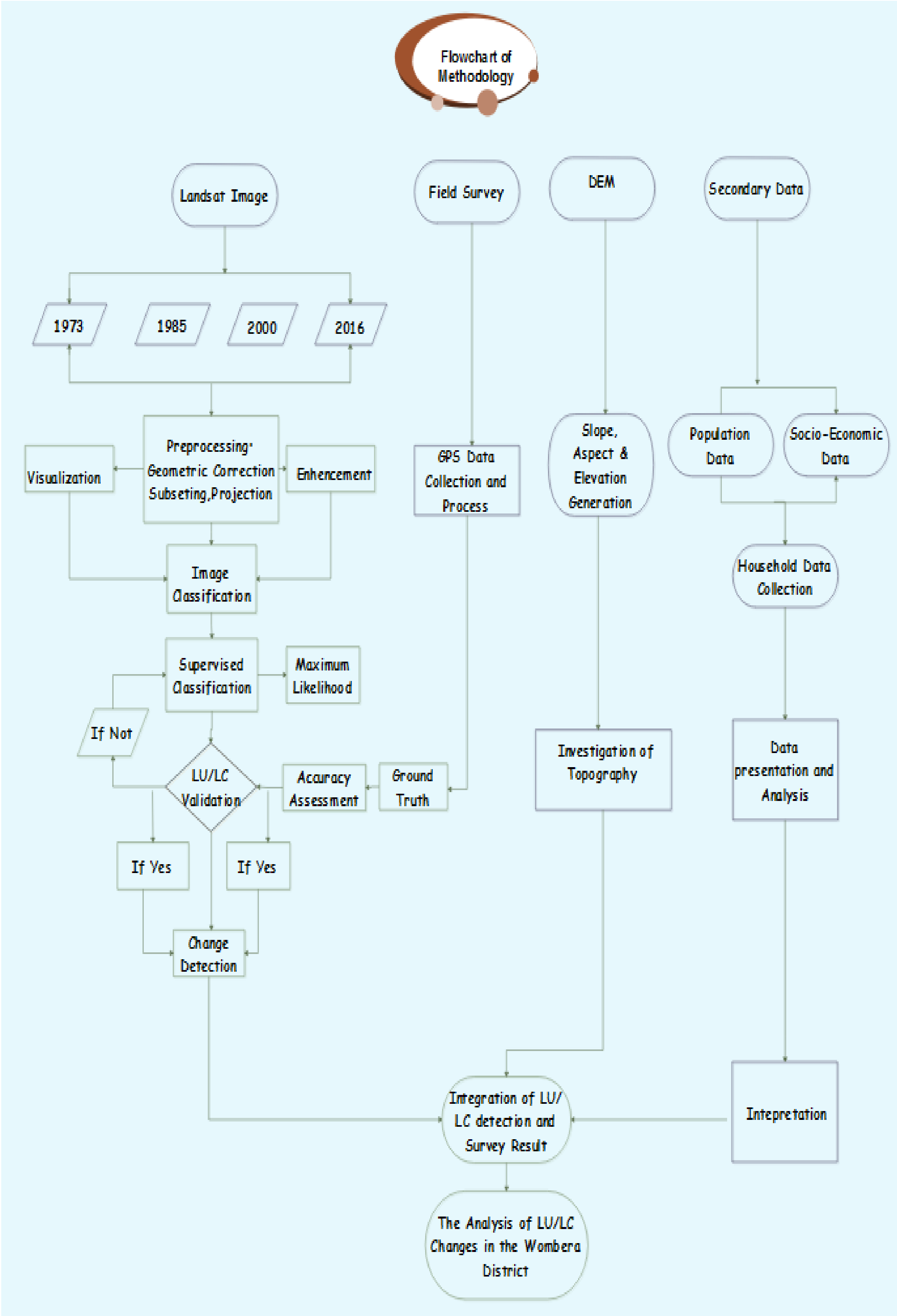

Figure 21. Chart of methodology

3. Results

3.1 Characteristics of LULCC

Seven major LULCC types: Woodland, Forest, scrubland, grassland, Cropland or farmland, settlement, and water bodies were created by using the field data and satellite images of Landsat MSS 1973, Landsat TM 1985, Landsat ETM+ 2000, and Landsat OLI/TIRS 2016 (Figure 22 A-D).

3.2. Land use/Land Covers in 1973-2016

Wombera district has a total of 723246 hectares of land. Woodlands have the largest coverage (503251, 69.6%), followed by farmlands (102092, 14.11%) and shrubland (59829, 8.27%) in 1973. The woodland declined from 503252 to 430076 ha from 1973 to 2016. The forest coverage also highly declined, from 49019 to 16692 ha. Shrubland moderately declined from 59825 to 46623 ha. Waterbody increased from 2103 to 2169 ha during 1973-2016. Settlements increased from 1814 to 4530 ha. The grasslands highly increased from 5142 to 13558 ha, and farmlands double from 102092 to 209598 ha during 1973- 2016 (Table 12).

3.3. The rate of land use land covers change

Among the increasing LULCC, farmland had the highest annual rate change, followed by grassland from 1973–2016. For the declining LULCC, shrublands had the highest annual rate change, followed by forests from 1973–2016. The net change for increasing LULCC, grassland were highest (163.67%), followed by settlement (149.72%) and farmlands (105.30%). Forest had percentage the highest among declining net changes (-65.94%), followed by shrub bland (-22.07%) and woodland (-14.54%). Farmlands were the highest from 1985–1973 (49036, 48.03%), and settlements were the highest from 1985–2000 (1119, 52.78%). Forests had the highest declining changes (-18598, -37.94% to -10392, -34.16%) from 1973–1985 and 1985–2000, respectively, followed by shrubs (-22195, 4.41% to -31610, -6.85%) from 1973–1985 and from 2000–2016, respectively. The vegetation covers (forests, woodland, and scrubland) were declining, whereas the farmland and settlements were increasing, while the water body rarely changes (Table 15).

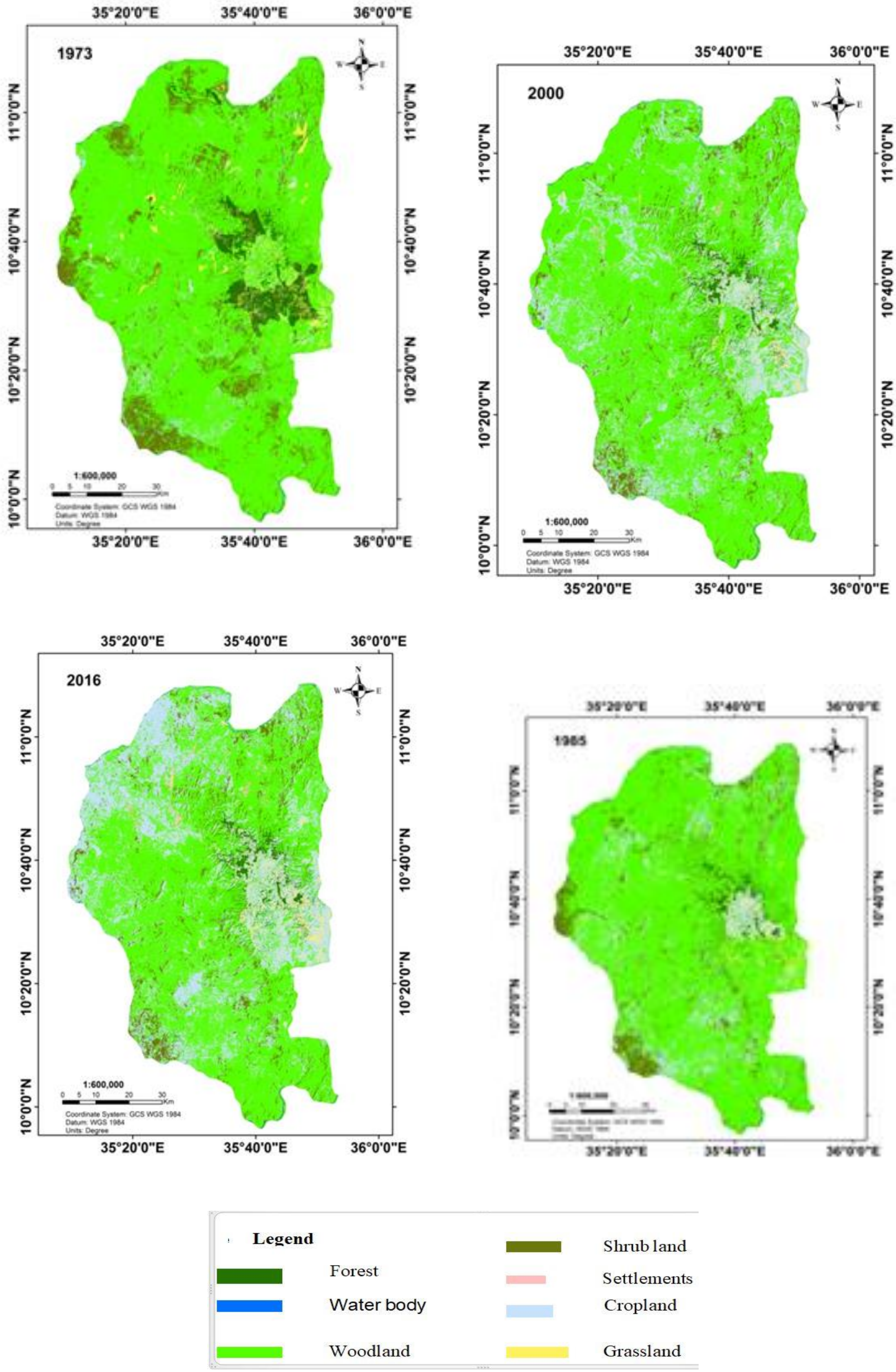

Figure 22. LULCC from 1973, 1986, 2000 and 2016

Table 15.LULCCs proportions and percentages of LULCC from 1973-2016

LULCCs	1973		1985		2000		2016	
	Area(Ha)	Area (%)	Area(Ha)	Area (%)	Area(Ha)	Area (%)	Area(Ha)	Area (%)
Forest	49019	6.77	30421	4.2	20029	2.76	16692	2.3
Waterbody	2103	0.29	2133	0.29	2028	0.3	2169	0.3
Shrub	59825	8.27	50026	6.91	48219	6.67	46623	6.44
Woodland	503251	69.6	481056	66.51	461686	63.83	430076	59.48
Farmland	102092	14.11	151128	20.9	180208	24.91	209598	28.99
Settlement	1814	0.25	2161	0.29	3280	0.46	4530	0.62
Grassland	5142	0.71	6321	0.9	7796	1.07	13558	1.87
Total	723246	100	723246	100	723246	100	723246	100

3.4 The comparative LULCC rates

Farmlands were the first in an average rate change per year from 1973–2016, 1973–1985, and 1985–2000. Grasslands were increasing in land-use type from 1973 to 2016. Among the decreasing land cover changes, Woodlands was the first in rate change per year from 2000–2016, 1973–1985, 1985–2000, and 1985–2000.The average rate of change for forests decreased between 1973 and 2016, 1985 and 2000, and 1973 and 1987. Shrub lands were the third in an average rate of change from 1973–1985 and 1985–2000. Settlements and water bodies have a steady rate of change (Figure 23).

Table 16. Land use land cover change and rate change

LULCC	1985-1973			2000-1985			2016-2000			Net(2016-1973)	
	Change(ha)	%	ha/year	Change(ha)	%	ha/year	Change(ha)	%	ha/year	Change(ha)	percent
Forest	-18598	37.94	1430.62	-10392	34.16	-692.80	-3337	16.66	-208.56	-32327	-65.95
Waterbody	30	1.43	2.31	-105	-4.92	-7.00	141	6.95	8.81	66	3.14
Shrub	-9799	16.38	-753.77	-1807	-3.61	-120.47	-1596	-3.31	-99.75	-13202	-22.07
Farmland	49036	48.03	3772.00	29080	19.24	1938.67	29390	16.31	1836.88	107506	105.30
Settlement	347	19.13	26.69	1119	51.78	74.60	1250	38.11	78.13	2716	149.72
Grassland	1179	22.93	90.69	1475	23.33	98.33	5762	73.91	360.13	8416	163.67
Farmland	49036	48.03	3772.00	29080	19.24	1938.67	29390	16.31	1836.88	107506	105.30

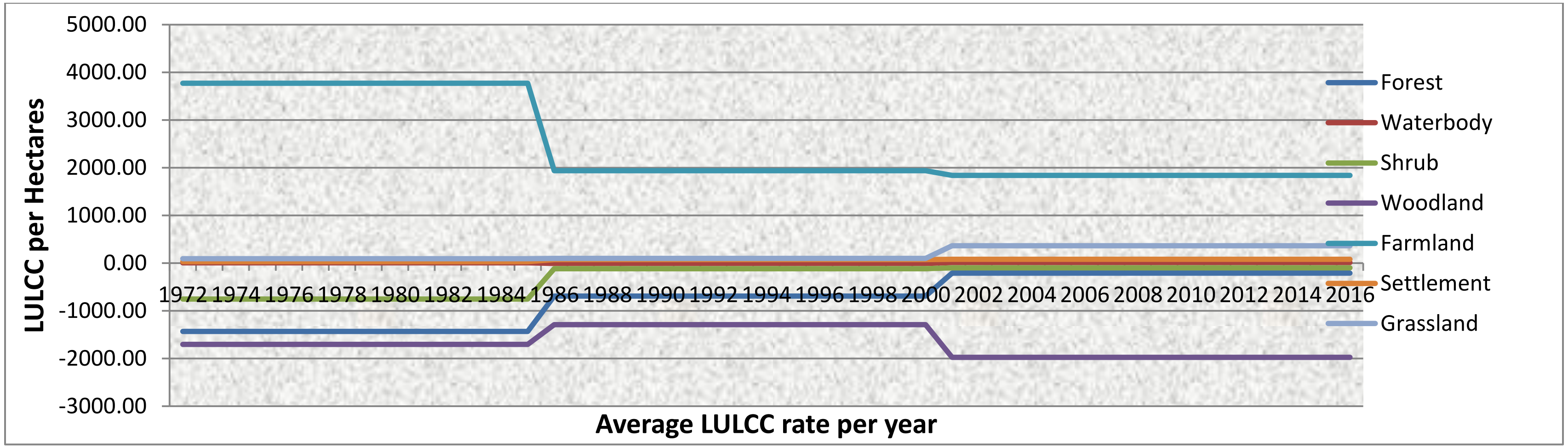

Figure 23. Average LULCC rate per year

3.5 Land Use/Land Cover Change Matrix

The change detection matrices for the periods 1973–1985, 1985–2000, and 1973–2016 were classified separately. In the change matrix analysis, some land use/cover types gain and some other loss. The diagonal Bolden numbers indicate the unchanged matrix (Tables17-20). The maximum stagnant landuse type recorded in 2000-2016 (596,788ha), followed by the year 1973-1985 (576,495 ha) and 1985-2000 (544,966 ha).

Table 17.LULCCs matrix between 1973 and 1985

LULC Class	Forest	Water Body	Woodland	Shrub	Settlement	Farmland	Grassland	Class Total
Forest	**12447**	1	3648	5	10	423	24	16558
Water Body	1	**1776**	259	86	16	228	48	2414
Woodland	3605	183	**463340**	9949	14	18603	1348	497042
Shrub	1	55	6419	**39959**	12	1051	3	47500
Settlement	3	4	2321	20	**848**	84	28	3308
Farmland	1493	158	79655	8869	100	**50102**	4564	144941
Grassland	28	43	2515	6	15	853	**8023**	11483
Class Total	17578	2220	558157	58894	1015	71344	14038	**723246**

Table 18.LULCCs matrix between 1985 and 2000

LULCC Classes	Forest	Water body	Woodland	Shrub	Settlement	Cropland	Grassland	Class Total
Forest	**8447**	1	3648	5	210	423	24	12758
Water Body	1	**676**	259	86	516	1008	48	2594
shrub	3105	183	**413340**	4149	214	26703	1348	449042
Woodland	1	395	6419	**26925**	112	8141	3	41996
Settlement	3	204	2321	20	**1715**	10384	28	14675
Cropland	4973	672	68507	16309	226	**86295**	2464	179446
Grassland	28	283	2548	6	315	11987	**7568**	22735
Class Total	16558	2414	497042	47500	3308	144941	11483	**723246**

Table 19.LULCCs matrix between 2000 and 2016

LULC Classes	Forest	Water Body	woodland	Shrub	Settlement	Farmland	Grassland	Class Total
Forest	**6447**	1	3648	5	510	1623	24	12258
Water Body	1	**676**	259	86	523	908	48	2501
Woodland	2805	193	**403340**	2549	414	1703	1301	412305
shrub	1	395	6419	**20947**	332	2046	2	30142

Settlement	3	244	2321	94	**11715**	15384	1028	30789
Farmland	3473	792	30507	15309	526	**137795**	4464	192866
Grassland	28	293	2548	3006	655	19987	**15868**	42385
Class Total	12758	2594	449042	41996	14675	179446	22735	**723246**

Table 20.LULCCs matrix between 1973 and 2016

LULC Classes	Forest	Water Body	Woodland	Shrub	Settlement	Farmland	Grassland	Class Total	Loss
Forest	**8267**	1	3328	205	410	23	24	12258	3991
Water Body	101	**406**	259	86	123	908	618	2501	2095
Woodland	2805	193	**403240**	2549	314	1703	1501	412305	9065
Shrub	1	391	6419	**20947**	136	2246	2	30142	9195
Settlement	3	244	22221	2094	**15**	5384	828	30789	30774
Farmland	6373	692	120107	30007	16	**35093**	578	192866	157773
Grassland	28	293	2583	3006	1	25987	**10487**	42385	31898
Class Total(2016)	17578	2220	558157	58894	1015	71344	14038	**723246**	
Gain	9311	1814	154917	37947	1000	36251	3551		
Net gain	5320	-281	145852	28752	-29774	-121522	-28347		
Net persistence	0.643	-0.69	0.3617	1.373	-1.985	-3.46285	-2.70306		

3.6. LULCCS Accuracy Assessment

Overall accuracy assessments were: 85.40% (1973), 85.88% (1985), 86.82% (2000) and 87.67% (2016). It was achieved by the Landsat mss 1973, TM of 1985, Landsat ETM+ of 2000, and Landsat OLI/TIRS of 2016 correspondingly (Tables 21-24).

Table 21. LULCC accuracy for 1973

LULC Classes	Forest	Water Body	woodland	Shrub	Settlement	Farmland	Grassland	Classified total	User accuracy
Forest	16	0	1	0	0	0	0	17	94.12
Water Body	0	13	0	0	1	0	0	14	92.86
Woodland	1	0	21	2	0	0	0	24	87.50
shrub	0	0	0	20	0	1	0	21	95.24
Settlement	0	1	0	0	15	0	2	18	83.33
Farmland	0	0	0	0	0	19	1	20	95.00
Grassland	0	0	0	1	1	0	14	16	87.50
Reference(T)	17	14	22	23	17	20	17	130	
Producer accurecy	94.12	92.86	95.45	86.96	88.24	95.00	82.35		
Over all classification accuracy =85.40% ; Over all kappa statistics = 0.8022									

Table 22. LULCC accuracy for of 1986

LULC Classes	Forest	Water Body	woodland	Shrub	Settlement	Farmland	Grassland	Classified total	User accuracy
Forest	15	0	1	0	0	0	0	16	93.75
Water Body	0	14	0	0	1	1	0	16	87.50
Woodland	1	0	24	0	0	0	1	26	92.31
shrub	0	0	0	21	0	1	0	22	95.45
Settlement	0	1	1	0	17	0	0	19	89.47

Farmland	0	0	0	2	0	16	0	18	88.89
Grassland	0	0	0	0	1	0	14	15	93.33
Reference(T)	16	15	26	23	19	18	15	132	
Producer accuracy	93.75	93.33	92.31	91.30	89.47	88.89	93.33		
Over all classification accuracy =85.88% ; Over all kappa statistics = 0.8022									

Table 23.LULCC error matrix of 2000

LULC Classes	Forest	Water Body	woodland	Shrub	Settlement	Farmland	Grassland	Classified total	User accuracy
Forest	15	0	1	1	0	0	0	17	88.24
Water Body	0	16	0	0	1	0	0	17	94.12
Woodland	1	0	22	0	0	1	1	25	88.00
shrub	0	1	0	21	0	0	0	22	95.45
Settlement	0	0	0	0	17	1	0	18	94.44
Farmland	0	0	1	0	0	17	0	18	94.44
Grassland	0	1	0	0	0	0	14	15	93.33
Reference(T)	16	18	24	22	18	19	15	132	
Producer accuracy	93.75	88.89	91.67	95.45	94.44	89.47	93.33		
Over all classification accuracy =85.88% ; Over all kappa statistics = 0.808									

Table 24. LULCC accuracy for 2016

LULC Classes	Forest	Water Body	woodland	Shrub	Settlement	Farmland	Grassland	Classified total	User accuracy
Forest	14	0	1	1	0	0	0	16	87.50
Water Body	0	15	1	0	1	0	1	17	88.24
Woodland	2	0	25	2	0	0	1	30	83.33
shrub	0	0	1	19	0	0	1	21	90.48
Settlement	0	0	0	0	18	1	0	19	94.74
Farmland	0	0	0	0	1	17	0	18	94.44
Grassland	0	0	0	1	1	0	14	16	87.5
Reference(T)	16	16	28	23	21	18	17	137	
Producer accuracy	87.50	93.75	89.29	82.61	85.71	94.44	82.35		
Over all classification accuracy =87.67% ; Over all classification accuracy =87.67									

3.7. Indirect driving force of land use land covers changes

The percentage of indirect driving forces on LULCC was computed in three agroecologies during 1973–1985, 1982–2000, and 2001–2016. They directly trigger the direct driving forces. The demographic factor was the highest trigger of direct driving from 1973–1985, 1986–2000, and 2001–2016 in the three agroecological zones. The socio-cultural activities were the highest during 1973–1985 but declined between 1986–2000 and 2001–2016. Economic activities, institutional setup, and technological advancement increased during 1973–1985, 1982–2000, and 2001–2016 in the three agroecologies.Natural disaster has the least impact (Table 25).

Table 25.Percentage of respondants of indirect driving forces of LULCC

Driving Forces	1973-1985			1985-2000			2000-2016		
	HAL	MAL	LAL	HAL	MAL	LAL	HAL	MAL	LAL
Demographic	40.00	35.50	30.60	40.50	40.00	35.00	45.00	39.50	37.00
Economic	25.00	26.67	23.33	27.00	32.00	25.00	26.00	34.00	30.00
Institutional	8.00	8.33	5.33	9.33	9.88	5.33	12.00	10.00	10.00
Technology	5.33	5.83	5.33	5.33	7.50	5.33	12.00	9.00	9.50
Socio-Culture	21.00	16.67	33.00	17.00	10.00	28.00	5.00	5.83	12.00
Natural disaster	1.33	6.67	2.66	1.33	2.40	2.00	0.67	2.50	1.50

HAL= Higher altitude. MAL= Middle altitude and LAL = Lower altitude

3.8. Direct cause of LULCC

The percentage of direct driving forces on LULCC was computed in three agroecologies during 1973–1985, 1982–2000, and 2001–2016. They directly cause LULCC changes or act on the land cover and change into another land use type. Farming activity contributes the highest among the proximate causes of LULCC from 1973-1985, 1986-2000, and 2001-2016 in higher altitude and middle altitude agro-ecological zones. The vegetation changed to croplands annually. Among the direct driving forces, fire contributed the highest impact on LULCC in the lower altitude from 1973-1985 and declined from 1986-2000 and 2001-2016. It has the lowest impact in higher altitudes. Logging and firewood collection had second and third values at higher altitudes in 2001- 2016 (Table 26).

Table 26. Percentage of respondants for direct driving forces of LULCC

Direct driving	1973-1985			1985-2000			2000-2016		
	HA	MA	LA	HA	MA	LA	HA	MA	LA
Farm	36.00	36.67	30.00	40.00	38.00	35.00	41.00	40.00	38.30
Fire	20.00	23.00	47.00	6.67	15.00	42.00	3.33	10.00	30.00
Logging	10.00	9.80	8.92	20.00	16.00	13.33	20.00	15.00	13.33
Fire wood	13.60	13.67	6.67	12.00	13.33	8.00	13.00	16.00	10.00
Grazing	20.50	16.33	8.00	22.00	18.00	7.00	23.00	19.00	8.67

HAL= Higher altitude. MAL= Middle altitude and LAL = Lower altitude

4. Discussion

4.1. Characteristics of LULCC Units

Seven main LULCC types were visible under satellite image analysis. Other authors in similar agroecology identified similar LULCC types (Tegene, 2002; Fisseha *et al*., 2011; Kidane *et al*., 2012). However, according to Kidane *et al.* (2012), who accessed aerial photographs and recent satellite images, identified more distinguished LULCC types. The forest includes dry Afromontane, riverside forest, eucalyptus plantations, coffee forests, and mountain forests. In the same manner, Mesgebu and Workineh (2017) classify human-made plantation forests, riverside forests, dry evergreen forests, and moist mountain forests as forests.

The dominance of woodland forest is because 65% of the study is in lower altitudes. It might be related to the change in climate and the expansion of woodlands along altitudinal gradients. The woodland forest is expanding to mid-altitude. The first and most dominant characteristic of woodlands in the lower altitudes is their ecological range. According to FGD and KII, lower altitudes have high temperatures and low humidity, so, people preferred to live at middle and higher altitudes as result the impact of population pressure were low before 1985. In addition, the environmental conditions of lower altitudes are most suitable for malaria consequently, it was not occupied by highland movers; i.e, during and before 1973 and early 1985, the impact of most indirect and direct driving of LULCC was lower than dring 2000 and 2016. The second most important reason for woodland dominancy is the dependency of inhabitants on shifting cultivation and hunting that maintains the woodland agroecology at equilibrium.

4.1.1. Higher Altitude LULCC

Population growth pressures are expanding the area of land uses such as agriculture and settlement into natural habitats in all parts of the world to meet the demand for food and housing (Kabba and Li 2011; Lambin *et al*. 2003). The decline of forest from 49019 hectares in 1973 to 16692 hectares in 2016 confirms deforestation and forest resource over exploitation. As a result, biodiversity has been diminishing considerably due to land change; while lands change from primarily forested land to a farming type, the loss of forest species within deforested areas is immediate and very large (Ellis and Pontius, 2006).

The maximum forest coverage changed during 1973–1985 (-1430.62 per year, -18598 ha (-37%)), and the minimum during 2000–2016 (-208 per year, -3337 ha (-16.66%)) was evidence of the impact of indirect driving forces on the proximate cause of LULCC. Drivers and causes of LULCC changes can come from biophysical, demographic, economic, infrastructural, and technological factors (Elias *et al*., 2018). Most people prefer to live at higher altitudes (Woldu, 1988). The demographic change was the most direct driving force in the district. Cultural factors such as habits of logging vegetation cover, exposure of soil for erosion, and degrading land may also trigger LULCC (Lambin et al., 2003). In 1973–1985 and 1986–2000, population growth synchronized with socio-cultural practices and aggravated the proximate driving forces. During this period, the lower development of technology and infrastructure and weak administrative practices aggravated the LULCC. The minimum forest coverage changed during 2000–2016 (-208.56 ha per year, -3337 ha (-16.66%)) due to the better-organized law enforcements, administration and infrastructure developments; as a result the rate change of vegetation cover had decreased.

Institutional causes like political, legal, economic, and traditional factors and their interaction with individual decisionmaking are important for LULCC and management (Lambin et al., 2003). According to FGD and KII, during the 1970s, the feudal collapse and the emergence of the military force created an administrative gap that made it impossible to control forest resource overexploitation. The political transitions fail to establish strong institutions, infrastructure, and administrative bodies. The failed law enforcement, the lower infrastructure developments, and the high cultural practices that synchronized population growth aggravated the effect of the direct agents of LULCC. Forestlands have been deforested to increase agricultural output in order to feed the growing population (Lemlem *et al*., 2017; Ariti *et al*., 2015; Daniel *et al*., 2012; and Assefa and Bork, 2016).The administrative gap was also in line with the findings of the authors (Nune *et al.*, 2017). Thus, the expansion of farmlands at the expense of other LULCC types in the study area, especially forests, bushlands, and woodland, is an effect of the weak or inappropriate institutional arrangements.The impact of indirect driving forces: Demographic, Socio-cultural, Economic, or income-generating imposed high impact on direct driving forces. It is also in line with the report of different scholars (Nune *et. al*. 2016; Ettema ***et al***., 2007).

4.1.2. Middle Attitude LULC

In the middle altitudes, the LULCC was caused by indirect driving forces on direct driving forces in a similar way to lower attitudes at higher altitudes. The impacts of population, cultural influence, and economy were similar at higher altitudes to some extent. The development of infrastructure and institutional policy was lower in the middle latitudes during 1973–1985. The sloppy nature of the landscape hinders the supply infrastructure. Among direct causative agents, fire burns were also the highest in the area, similar to lower altitudes. Illegal logging was more severe as the area is in the vicinity of timber trees such as *Cordia africana*. According to Mesgebu (2016), economic transformation is the leading agent of LULCC. Thus, in middle-altitude timber, poles, and posts, production was high, which triggered LULCC.

4.1.3. Lower Altitude LULCC

Land-use systems are dynamic in response to population and economic growth, public and private investments, and market and government actions (Berke and Kaiser 2006).The fundamental causes of LULCC originate from a complex interaction of social, policy, institutional, economic, demographic, technological, cultural, and biophysical factors (Geist and Lambin, 2002; De Sherbinin, 2002). Similarly, in this study, at lower altitudes, the impacts of indirect driving on direct driving forces were more serious during 2001–2016 than during 1973-200.The direct driving forces of LULCC were caused by demographic change, economic, technological, and institutional or policy, socio-cultural and disasters; these underlying forces facilitate

LULCC independently or in a synchronized way. During 1973–1985, the same way as to upper and middle altitude dwellers among indirect forces LULCC, the demographic and cultural values imposed change on the direct agents, mainly farming. The vegetation coverage change was slower than the upper and middle altitude agro-ecologies. The changed woodland coverage was minimum during 1986–2000 (-19370ha, -4.03%, -1291.33 ha/year). The impacts of indirect driving forces were lower than during 2000–2016. During 1973–1985, the main factors of LULCC in the lower altitude were agricultural expansion and fire burns. These factors induced LULCC independently or in a synchronized way. However, according to FGD and KII, shifting cultivation balanced the change. It is an agricultural activity in which forests are slashed, burned, and used for crop cultivation (Mekonnen, 2004). After two to three years of crop cultivation, the lands were abandoned so that the trees can regenerate within three to five years. This type of agricultural practice changes the forest coverage at equilibrium. The second factor was the deliberate and unintentional release of fire. The fires burn many hectares of wood and shrubs annually. However, the fire also initiates the seed to germinate and regenerate the forest. The regeneration of the forest again balances the rate of LULCC. Thus, woodland changes were the least from 1985–1973 and 1986–2000.

During 2001–2016, economic activity, institutional arrangements, and infrastructure developments changed the LULCC. They revolutionized economic activity by integrating institutional structure and technological advancement. As a result, the LULCC in the lower altitudes increased alarmingly because all the indirect driving except socio-cultural impacts tends to increase. Investment (economic growth) and population movements had increased and aggravated direct driving forces, mainly on farming. The technology-aided mechanized and manually intensified farming had an imbalanced equilibrium impact on the proximate driving forces of LULCC. Investors and non-indigenous higher-altitude dwellers changed the shifting cultivation custom and intensified the rate of LULCC.

According to FGD and KII, before 2000, the population growth of the GUMUZ ethnic group was at equilibrium.They had an uncontrolled birth rate and a polygamous marriage society, yet both natural and cultural factors limited population expansion. Naturally, diseases like malaria prevalence and natural calamities like drought control population growth. The prevalence of malaria was high due to low infrastructure development, such as education and health services. Population regulation was also controlled by human-induced problems such as mini-conflicts (wars) with clans of Gumuz and other ethnic groups. However, from 2001–2016, building more advanced infrastructure (roads, health centres, and schools) and institutional buildup (organized administration) changed the social structure. Thus, more people moved to lower altitudes and triggered LULCC.

4.2. Land Use Land Cover and Rate Change

There was a direct correlation between the substantial changes in agriculture inside the LULCC and the need for food and other necessities.Patterns of land use, land cover change, and land management are shaped by the interaction of economic, environmental, social, political, and technological forces on local and global scales (Adam, 2011). Thus, the increasing population numbers from year to year that demand food primarily cause farmland expansion at an alarming rate. Secondly, global trade (globalization) across continents encourages investment, which seeks farmland expansion. It is similar to the finding of Nune *et al*. (2016), as the main drivers of LULCC are related to farmland expansion and population growth.

4.3. Accuracy Assessment of LULCC

Among the accuracy assessments, the highest result was recorded from Landsat OLI/TIRS 2016, followed by Landsat ETM+ of 2000, Landsat TM of 1985, and Landsat mss-1973, respectively. These were related to the quality of the image acquired. The better the quality of the image, the better the visibility of the land cover will be on the ground and on the map.

4.4. Matrix of LULCC

The change in land cover type to other land cover types declined from 1973 to 2016. The unchanged land cover types were maximum during 2000–2016 (596788 ha, 82.52%) and least during 1985–2000 (544966 ha, 75.35%). Thus, these indicate that the impact of indirect driving forces on direct driving declined more in 2000–2016 than in 1985–2000. The law enforcement and administrative bodies had control over the illegal exploitation of forest resources, such as logging, fire collection, forest firing, and illegal land grabbing for farming.

5. Conclusion

A satellite image analysis indicates that land cover and land use have been changing at an alarming rate in the Wombera district since 1973. Woodland, forest cover, and scrublands were the dominant land cover types. The vegetation cover has declined, whereas the cropland and settlements were increasing. The demographic, cultural, and economic systems have been imposing direct driving forces, mainly farming, since the early times. The demographic driving force was the leading cause of LULCC from 1973 to 2016 in the three agro-ecological zones. In 1970, the lower development of technology and infrastructure and weak administrative practices aggravated the LULCC. Among direct causative agents, fire was also the highest in the middle and lower altitudes.

CHAPTER FIVE

Wood plants Rejuvenation, Use value and distribution along successional gadients selected patches of wombera district, Benshangul, Gumuz regional state, Ethiopia

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Abstract

Three forest patches: GTFP, SLFP and MBFP were selected, to study patch dynamics in species composition and structures along disturbance gradients and succession gradients (pioneer, intermediate, and climax) in Wombera district, Benshangul, and Gumuz regional state, Ethiopia. Along altitudinal gradients, transect lines were laid 300 meters apart; plots were laid every 150 meters along the transects. DBH of woody plant species, and landscape variables were recorded in 54 (20× 20) main quadrants. In five (5 m × 5m) quadrants, nested in the larger quadrantes, shrubs, seedlings, and saplings were collected. In 1 m × 1 m quadrants nested in the 5 m × 5m quadrants, herb and grass species were recorded. Use value and regeneration potentioal of selected woody plants were ranked by informants and further confirmed by key informant discussion. Frequency, density, and abundance were calculated using Excel lower, middle and upper canopy trees have the highest frequenct, density and IVI values in pioneer, intermidite and climax forest patches respectively. Along with the vertical structure, the vegetation was stratified into lower, medium, and upper canopy layers. Pioneer trees can grow and survive in poor soil. Reforestation of degraded lands should be established in pioneer, intermediate, and climax forest growth patterns.

Keywords: vegetation structure, frequency, important value index, density, abundance, pioneer

1. Introduction

The Dry Evergreen Montane Forest (DAF) is an Afromontane vegetation type characterized by a complex vegetation type and successional system relating widespread legume-rich grasslands on heavy black clay soils that are periodically flooded areas, shrubs, and small to large trees to a closed forest with a canopy of several strata on slopes (Friis *et al*., 2011). The vegetation comprises *Juniperus procera* and *Olea europaea* subsp. *cuspidata*, *Podocarpus falcatus*, and *Prunus africana* dominate the DAF vegetation. *Hyparrhenia, Eragrostis, Panicum, Sporobolus,* and *Pennisetum* are grasses, while *Trifolium*, Indigofera, Tephrosia, and *Crotalaria* are legumes (Gebre Egziabher, 1988; Friis *et al*., 2011). *Urera hypselodendron, Embelia schimperi*, and *Jasminum abyssinicum* are examples of lianas (IBC, 2009). The Ethiopian highlands cover more than half of all African land covered by Afromontnae vegetation (Bekele, 1993), with dry Afromontane forests accounting for the majority of this (Teketay, 2005). At an altitude of 1350 - 3550 m a.s.l., with an average annual temperature and rainfall of 14 - 25^{o}C and 700 - 1100 mm, respectively, this vegetation exhibits a complex system of successions involving broad grasslands rich in legumes, shrubs, and small to large trees to closed forests (Friis, 1992; Woldu, 1999). Depending on the location and severity of disturbance, the DBH and height structure of trees varies greatly among DAF forests. The DBH of mature trees in undisturbed forests can reach 270 cm, while their height can reaches 45 meters (Yineger *et al*., 2008; Zegeye *et al*., 2011; Tadele *et al*., 2013).

The vegetation structure of the forest was characterized using height, DBH size class distribution, density, frequency, and basal area (Bekele, 1994). Frequency is the number of sampling plots in which a given species occurred in the study area. It gives an indication of the homogeneity and heterogeneity of given vegetation (Lamprecht, 1989). Frequency classes show floristic homogeneity or similarity and heterogeneity in species composition (Aye *et al*., 2014). According to Gentry (1988), the density of woody plants in the montane forests of Africa is relatively high as compared to other tropical montane forests. The results of a basal area analysis provide a better measure of the relative dominance of woody species in a forest (Cain and Castro, 1959). The importance value index (IVI) is an important parameter that reveals the ecological significance of species in a given ecosystem (Lamprecht, 1989). It combines data from three parameters, i.e., relative frequency, relative density, and relative dominance (Kent and Coker, 1992), and hence many ecologists consider it the most realistic aspect of vegetation study (Curtis and McIntosh, 1950).

The Ethiopian highlands are the areas of the country with the oldest settlements (Woldu, 1999; Friis *et al*., 2011). Crop cultivation or farming, in general, began thousands of years ago in areas covered by the Afromontane vegetation complex, and in particular, the northern part of the Dry Evergreen Afromontane forest and grassland complex (DAF) has been heavily used by man ever since; as a result, the forests have shrunk in size, and bushland has taken over the majority of the area (Schmitt *et al*., 2010). Due to overexploitation for fuelwood, building materials, and agricultural uses, the amount of forest cover in the Ethiopian highlands has significantly decreased (Yirdaw, 2001). In dry Afromontane forest patches, woody trees are used for different purposes. In addition, these natural resources are under increased pressure due to the needs of growing human populations (FAO, 2010). However, tropical forest plants regenerate from one or more pathways: seed rain, dispersed soil seed bank, coppice: root or shoot sprouts of damaged individuals (Garwood 1989). This study investigated the vegetation structure, use value, and regeneration potential of woody plants in three selected forest patches along age or succession gradients (pioneer, intermediate, and climax).

2. Materials and methods

2.1. Descriptions of the study area

Wombera ditrict is 658km from Addis Ababa, the capital city. It is found in the Metekel administrative zone of Benishangul Gumuz national regional state in the northwestern part of Ethiopia. The district is one of the largest districts in the Metekel administrative zone. It is bounded by the districts of Guba and Dangur in the north, Bullen in the east, Agallometi, and Yaso in the south, and Serba Abbay and Sherkole in the west. The latitudinal and longitudinal position of the district are from 9^0 57' 30'' to 11^0 08' 45'' N and 35^0 09' 09” to 35^0 50' 25'' E respectively (Figure.1).

2.1.1. Climate and temperature

Nineteen years of climate data were taken from Ethiopian metrological station.Annual temperatures range between a minimum of 7.2^{o}C and maximum of 26^{o}C with average 15.9^{o}C. The average annual rainfall was 1942mm (Figure. 2).

2.2. Methods

2.2.1 Forest patch selection

Three forest patches: GTFP, SLFP and MBFP, were selected to study patches dynamics in species composition and structure along disturbance and forest maturity gradients. In the early times, to conserve a forest, the local communities use traditional cultural practices; the forests patches were named after prominent clan members or leaders to honor them. A forest named after a person was not freely accessed. They also conserve forest for keeping honey bee hives, farming, hunting, and shelter for cattle during the long rainy season, harvesting the medicinal plant, and making house utensils and farm tools. However, due to an administrative change in the last two to three decades, most of the traditions and customs have been declined. These situations aggravated the unwise use the forest resources. However, the abandonment of farmland due to administrative change in recent years has created a favourable condition for the rehabilitation of forest vegetation; As a result, the Classifications of forests were mainly based on the age of the forest and disturbance level following Ayenekulu (2011) identified disturbance levels based on their intensity, frequency, severity, and extent (With the guidance of focused group discussions with residents living nearby the forest area, an age-based classification was accomplished. The forests were classified: into three age classes. Each age class of forest was reclassified based on anthropogenic and natural disturbance levels.

2.2.2. Data collection

Vegetation data were collected in three forest patches of different age classes (pioneer, intermediate and climax) at the end of rainy season, from November to December 20018 at three forest patches (GTFP, SLFP, MBFP A series of nested quadrates following Stohlgren *et al.*(1995) were established at 150 m intervals along parallel transect which were 300m apart along altitudinal gradient. The following quadrates sizes were used: (1) in 20 m × 20 m was trees with stem diameter at breast height (DBH) >2.5 cm were collected; (2) in 5 m × 5 m quadrates nested in the larger quadrates shrubs, seedlings, saplings and in (3) 1 m × 1 m quadrates nested in the 5 m × 5 m quadrates herbs and grass were collected.

2.2.3. Population sampling and survey

Three forest patches were selected in order to evaluate the woody plants' multiple-use values (see 2.2.1). Informants were sampled from the total population (Appendix-Table 7) for data collection. Focus group discussions and key informants were selected to collect, discuss, and confirm the validity of the data (section 2.2.1, chapter 4). A total of eighteen woody plants were selected to assess their potential use and ways of regeneration.The woody species' use value and rejuvenation status were ranked. The use value and regeneration state of eighteen woody species were ranked. Key informants verified the results after discussing them with the focus group.

2.2.3. Species survival and regeneration

Anthropogenic disturbances or levels of overexploitation: grazing, forest fires, charcoal production, fuel wood collection, timber collection for construction, and farming tool production were gathered from three forest patches to rank the factors that affect plant species, composition, and regeneration status. Field observations, interviews, and discussions were held with residents to evaluate the potential regeneration of specific plant species. Interviews and questions were administered to respondents (Appendix 13). Woody plant regeneration ways, such as seed germination (SG), seed edibility (SE), sprouting (stem regeneration) (SP), root proliferation (RP), bee forage/beekeeping (BK), and traditional rituals (TR), were used to evaluate the species regeneration potential (SRP). The respondents were requested to give their testimony and preference for each species. The respondent response percentage was converted into rank as: 100 - 75% = 4, 75.5% - 50% = 3, 50.5% - 25% = 2, 1 - 25% = 1 and 0% = 0. Species regeneration potential (SRP**)** was computed as SRP = SG + SE + SP + RP + BK + TR. Finally, SRP was used to rank the regeneration potential of each woody tree species, and each regeneration ways ranked.

2.2.4. Multiple use vales or anntropogenic disturbance

Potential effects of human disturbance or overuse of vegetation degrade the diversity of vegetation, its structure, and its stage of regeneration. It also includes disturbance by livestock. According to the index developed by Goris et al. (2002), it incorporates the impact of many parameters indicating positive and negative disturbance; however, the scale and parameters have changed for this study. Multipurpose use values were assessed as disturbance factors that degraded vegetation diversity and abundance. Use values for charcoal (CH), firewood (FW), timber/furniture (TF), poles/posts (PP), farm tools/handles (FT), carvings/utensils (CU), animal feed (FA), medicine/stimulant (MS), house fence (HF), and traditional ceremonial (TC) were added together to determine the overall use values. Total use value, or negative regeneration, was calculated as TUV = CH + FW + TF + PP + FT + CU + FA + MS + HF + TC. The informants' responses regarding the total use value of woody plants were ranked as 100-75.5% = 4, 75-50.5% = 3, 50%-25.5% = 2, <25% = 1, and 0% = 0. Finaly woody tree species were raked based on their total use value (TUV) and the highet use value were ranked based on the percentage ranking.

2.2.5. Species Identification

All plant specimens were collected, temporarily tagged with plot numbers and temporary labels assigned to species (fast method), pressed and brought to the National Herbarium (ETH) for identification and storage. Species were identified at the National Herbarium (ETH) of Addis Ababa University by using the taxonomic keys in the various volumes of the Flora of Ethiopia and Eritrea (Hedberg & Edwards, 1989; Edwards *et al*., 1995; Phillips, 1995; Edwards *et al*., 1997; Hedberg *et al*., 2003; Tadesse, 2004; Hedberg *et al*., 2006, 2009a, 2009b). The specimens were also compared with authenticated specimens. Botanical names and authorities were verified using the species and family lists in Volume 8 of the Flora of Ethiopia and Eritrea (Hedberg *et al*., 2009).

2.3. Data analysis

2.3.1. Frequency and Relative Frequency of species

Frequency is defined as the probability or chance of finding a species in a given sample area or plots. Relative frequency in this study is expressed as a percentage of

the total number of plots in which individuals of a given species were recorded divided by the sum total number of the plots taken in the study area.
The following formulas were used in Microsoft Excel spreadsheet programme.

Frequency (F) = $\frac{\textbf{Number of plots in which species occure}}{\textbf{Total plots laid}}$

Relative frequency (R_{fr}) = $\frac{\boldsymbol{Frequencyofspecies}}{\boldsymbol{Total\ frequencies}} * \mathbf{100}$

2.3.2. Population structure (DBH and height class distributions)

The study on the population structure, which is defined as the frequency and distribution of individuals defined by DBH or height classes, was carried out for woody species based on most widely used DBH and height classes in Ethiopia (Dalle, 2015; Berhanu *et al*., 2017).The population structure is important indicator of forest reproduction and recruitment (Schulz *et al*., 2009).

2.3.3. Woody species density, basal area and dominance

Density (De) - is the number of individuals per unit area. It is calculated from the count of all the individuals from the study area on hectares basis (Mueller-Dombois and Ellenberg, 1974). Woody species density was expressed as number of individuals of a species per hectare. The density and relative density of woody species were computed in Microsoft Excel Spreadsheet program. The total species density, which is expressed as the sum total of all Individuals of all species in a hectare was also computed to calculate the relative density. Density was calculated using the following formula:

Density (De) = Density (De) = $\frac{\boldsymbol{Numberofspeciescounted}}{\boldsymbol{Sampled\ area\ in\ hectar}}$

The relative density was calculated using the following formula:

$R_{de} = \frac{\boldsymbol{De}}{\sum_{\boldsymbol{i=1}}^{\boldsymbol{s}} \boldsymbol{De}}*100$

Where, R_{de} is the relative density of a species and De is density of the i^{th} species (s); Basal area (m2 ha-1) measured as the cross-section area of a tree at breast height, is computed from the measurement of DBH as follows in Microsoft Excel spreadsheet programme: $Ba = \pi d^2/4$, where $\pi = 3.14$, Ba is basal area, and d is DBH (m). However, since DBH was measured in centimeters, the formula was converted to square meters. Thus, $Ba = \pi d^2/40{,}000$ or $0.0000785d^2$, where d is DBH in centimeters. The mean basal area of all investigated plots was converted to mean basal area per hectare. Basal area provides a better measure of the relative importance of tree species than Simple stem counts (Bekele, 1993).

The dominance and relative dominance were calculated as follows:

$$Do = Bi \times Ni,$$

Where Do is dominance of a species, Bi is mean basal area per species and Ni - number of

Individuals in the ith species

$$R_{do} = \frac{\boldsymbol{Doi}}{\sum_{\boldsymbol{i=1}}^{\boldsymbol{S}} \boldsymbol{doi}} * 100$$

Where, Rdo is relative dominance and Doi is dominance of the ith species (s).

The variations of structure (density, basal area and dominance) among the forest patches was

2.3.4. Important value index (IVI)

Importance Value Index (IVI), besides its use in indicating the relative ecological importance of a given woody species in a particular site, is one of the important tools used to identify threatened woody plants in a specific site or area (Kent and Coker, 1992). The IVI of a species signifies the sum of its relative density (RDE), relative Frequency (RFR) and relative dominance (RDO). That is, IVI = RDE + RFR + RDO. The IVI was computed in Microsoft Excel spreadsheet program. Consequently, woody species having the least IVI values were prioritized for the purpose of conservation and management interventions.

4. Results

4.1 Frequency of woody plants in pioneer forests

In Pioneer forests, lower-layer canopy trees such as *Acacia abyssinica*, *Maesa lanceolata, Nuxia congesta, and Maytenus arbutifola* in GTFP, SLFP, and MBFP were the most frequent, followed by shrubs and climbers, *Vernonia amygdalin, and Brucea antidysenterica. Hagenia abyssinica*, *Dombeya torrida*, and *Allophyllus abyssinicus* were the most common intermediate-layer canopy trees. The upper canopy trees were the least abundant (Tables 27–29 and Figure 24).

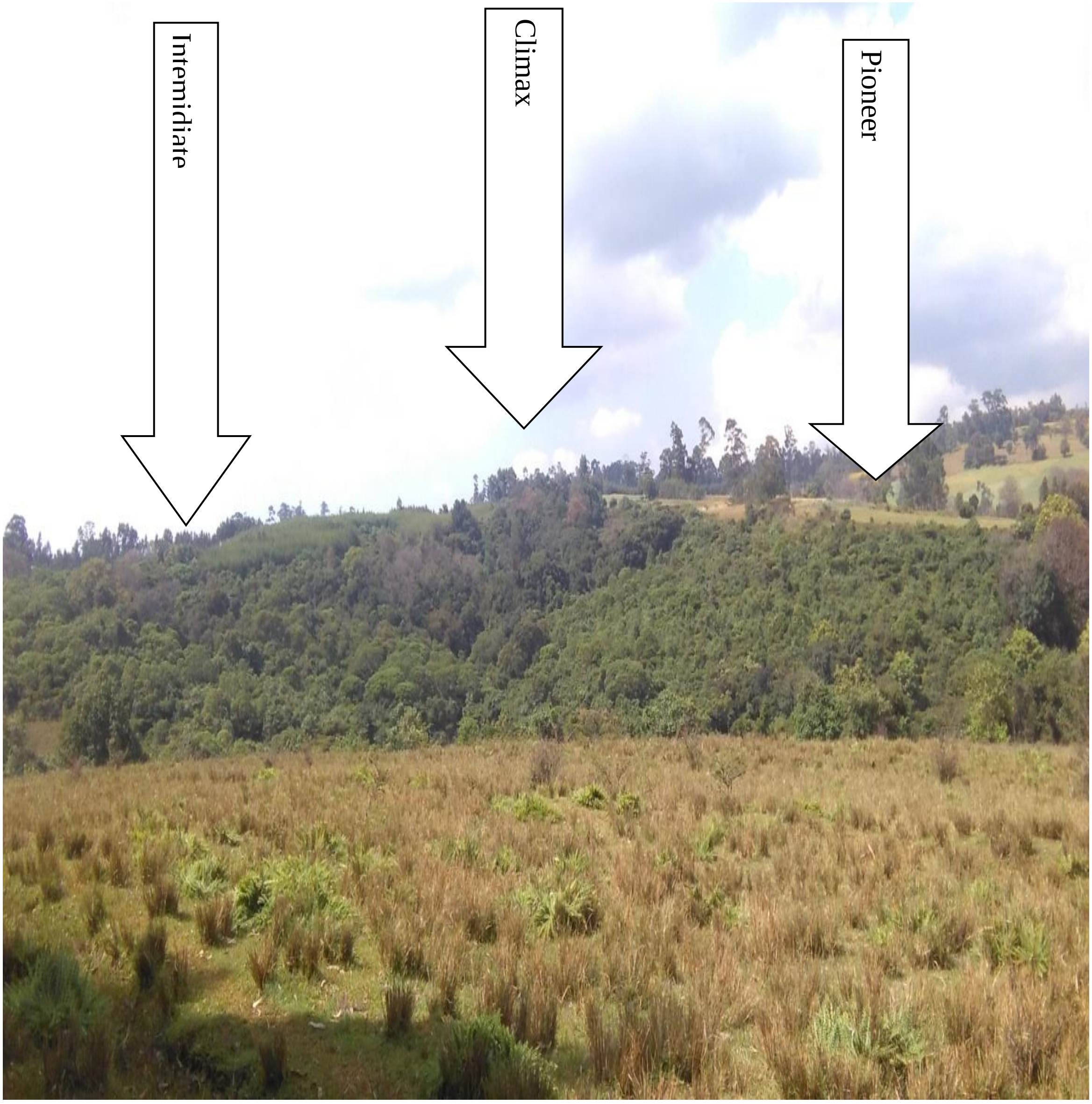

Photo forest age classes taken by Girma Gudesho

Figure 24. Forest patches of pioneer, intermidiate and climax

4.2. Frequency of woody plant species in intermediate forests

In intermediate forests, lianas such as *Stephania abyssinica*, *Premna schimperi*, *Jusminum abyssinicum*, and *Rubus steudneri* were the most frequent in SLFP, GTFP, and MBFP.The shrub layer species *Myrsine africana* and *Brucea antidysenterica* were the second most frequent species in the three forest patches. The middle-layer canopy trees were represented by *Hagenia abyssinica* and *Dombeya torrida*, and, (Figure 25). Among the upper-layer canopy trees, *Apodytes dimidiata*, *Ekebergia capensis*, and *Olea europaea* had a higher frequency than the lower-layer canopy trees: *Acacia abyssinica*, *Maesa lanceolata*, *Nuxia congesta*, and *Maytenus arbutifola* in intermidite forest patches (Tables 30–32).

Figure 25. Intermediates forest patches

4.3. Frequency of woody plants in Climax forests

In Climax forests, upper canopy trees such as *Apodytes dimidiata*, *Ekebergia capensis,* and *Olea europaea* were the most frequent in sampling plots, whereas the lower layer and middle layer canopy trees were the least abundant or even absent (Figure 26). The frequencies of *Syzygium guineense*, *Ficus sur*, and *Olea europaea* were highest along river banks. The frequencies of *Croton macrostachyus* and *Schefflera abyssinica* increased along disturbance gradients. Among the shade-tolerant species, *Brucea antidysenterica* had the highest frequency (Tables 33–35).

Figure 26. Climax forest patches

4.4. Density of woody species pioneer forests

The dominant species among lower canopy trees, *Acacia abyssinica* in GTFP, SLFP, and MBFP; *Maesa lanceolata* in MBFP; *Nuxia congesta* in SLFP; and *Maytenus* *arbutifola* in MBFP, had the highest density. Among the middle-layer canopy trees, *Hagenia abyssinica* had the highest density in SLFP and GTFP. *Dombeya torrida* has the second-highest density per hectare in SLFP. In the upper-layer canopy tree, *Syzygium guineense in* GTFP and MBFP, *Apodytes dimidiata* in GTFP and SLFP, and *Ekebergia capensis* in GTFP and MBFP had the highest density per hectare (Tables 27–29 and appendices 15-17).

4.5. Density of woody species intermediate forests

Allophyllus abyssinicus was the most abundant in SLFP and GTFP in intermediate forest patches; *Hagenia abyssinica* was second to the middle-layer canopy tree in GTFP and SLFP. *Dombeya torrida* was the third from GTFP and SLFP. *Apodytes dimidiata* from SLFP, *Albizia schimperiana* from MBFP, and *Prunus africana* from SLFP had the highest density among the upper canopy trees. Lower canopy trees, such as *Nuxia congesta* from SLFP and GTFP, had the highest density per hectare. Thirdly, *Mease lanceolanta* had a high density in the MBFP and GTFP of the intermediate forest patches.In intermediate forest patches, the most common shrubs were *Vernonia amygdalina* and *Vernonia auriculifera* from MBFP, *Myrsine africana* from SLFP, and *Premna schimperi* from GTFP (Tables 30–32 and appendices 18-20).

4.6. Density of woody tree species Climax forests

In the Climax forest, the upper canopy tree species such as *Apodytes dimidiata*, *Prunus africana*, *Ekebergia capensis, Albizia schimperiana*, *Allophyllus abyssinicus*, *Olea europaea*, and *Ficus sur* have the highest density per hectare. *Apodytes dimidiata* has the highest density per hectare in SLFP and MBFP. In SLFP and GTFP, *Prunus africana* was the most abundant, followed by *Albizia schimperiana* from MBFP and *Syzygium guineense* from GTFP, *Ekebergia capensis* from SLFP, and *Syzygium guineense* from MBFP. Middle canopy trees were few in climax forest trees except *Allophyllus abyssinicus*. There were few bushes and climbers in areas where there was a disturbance. *Teclea nobilis* and *Maytenus arbutifola* were the dominant species in the lower layer as shade-tolerant trees (Tables 33-35) and appendices (21-23).

4.7. Basal area and dominance of woody species in pioneer forests

Acacia abyssinica, Nuxia congesta, Maytenus arbutifola, and *Maesa lanceolata* in GTFP; *Nuxia congesta, Acacia abyssinica,* and *Maesa lanceolata* in SLFP; and *Maesa lanceolata, Nuxia congesta,* and *Maytenus arbutifola* in MBFP have the highest basal area per hectare, respectively, in the pioneer forests. *Allophyllus abyssinicus* had the highest basal area per hectare among the middle-layer canopy trees in three forest patches, followed by *Hagenia abyssinica* in SLFP and *Dombeya torrida* in MBFP. *Apodytes dimidiata, Ekebergia capensis, Prunus africana* in MBFP, and *Apodytes* dimidiata in GTFP had the highest basal area per hectare among upper canopy trees (Tables 27–29 and Appendices 13–15).

4.8. Basal area and dominance of woody species in intermediate forests

In intermediate forest patches, middle-layer canopy trees *Allophyllus abyssinicus, Hagenia abyssinica, and Dombeya torrida* in GTFP and SLFP had the highest basal area and dominance. *Allophyllus abyssinicus* in MBFP had the highest basal per hectare. Upper canopy trees: *Olea europaea and Apodytes dimidiata from GTFP; Prunus africana and Ficus sure from SLFP; and Albizia schimperiana* from MBFP were second in basal area and dominancy. Lower canopy trees were the least (Tables 30–32 and Appendix–Table 16–18).

4.9. Basal area and dominance of woody species in climax forests

The upper canopy trees had the highest dominance and basal area per hectare in the climax forest. *Apodytes dimidiata* had the highest basal area and dominance in the three forest patches. *Prunus africana* in SLFP and GTFP, Albizia schimperiana, and *Syzygium guineense in* MBFP were next to *Apodytes dimidiata. Maytenus arbutifola* and *Teclea nobilis* were the only lower canopy trees in the three forest patches. *Brucea antidysenterica* were also the dominant shrubs as shade-tolerant in three climax forests (Tables 33–35 and Appendices 21–23).

4.10. Importance value index of woody species in pioneer forests

Among the lower-layer canopy trees, *Acacia abyssinica, Nuxia congesta, Maesa lanceolata, and Maytenus arbutifola* in GTFP; *Nuxia congesta*, *Acacia abyssinica*, *Maesa lanceolata*, and *Maytenus arbutifola* in SLFP; *Maesa lanceolata,* *Maytenus arbutifola,* and *Nuxia congesta i*n MBFP had the highest IVI value. Allophyllus abyssinicus from GTFP and MBFP and Dombeya torrida from SLFP had the highest IVI among the middle-layer canopy trees. *Syzygium guineense* from GTFP and MBFP and *Apodytes dimidiata* from SLFP had the highest IVI values among the upper canopy trees (Tables 27–29 and Appendix–Tables 15–17).

Table 27. Dominant woody species structural value in GTFP

no	Species	F	Ab	RF	BA	Dom	Rdom	De	RD	IVI
1	*Acacia abyssinica*	9	62	6.66	1.75	108.63	31.14	172.22	14.6	52.39
2	*Nuxia congesta*	7	55	5.18	1.55	85.49	24.5	152.78	12.95	42.63
3	*Maytenus arbutifola*	5	40	3.7	1.13	45.22	12.96	111.11	9.42	26.08
4	*Maesa lanceolata*	8	45	5.92	1.41	63.59	18.23	125	10.59	34.74
5	*Bersama abyssinica*	6	19	4.44	0.04	0.71	0.2	52.78	4.47	9.12
6	*Syzygium guineense*	4	17	2.96	0.8	13.61	3.9	47.22	4	10.86
7	*V. amygdalina*	6	16	4.44	0.5	8.04	2.3	44.44	3.77	10.51
8	*B. antidysenterica*	7	11	5.18	0.26	2.9	0.83	30.56	2.59	8.6
9	*Apodytes dimidiata*	4	9	2.96	0.28	2.54	0.73	25	2.12	5.81
10	*P.linearifolia*	6	14	4.44	0.02	0.31	0.09	38.89	3.3	7.82
11	*A. abyssinicus*	6	7	4.44	0.33	2.31	0.66	19.44	1.65	6.75
12	*Ekebergia capensis*	3	8	2.22	0.31	2.51	0.72	22.22	1.88	4.82

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

Table 28. Dominant woody species structural value in SLFP

No	*Species*	**F**	**AB**	**RF**	**BA**	**Dom**	**Rdom**	**De**	**RD**	**IVI**
1	*Nuxia congesta*	9	58	8.25	1.64	95.07	30.96	161.11	14.54	53.75
2	*Acacia abyssinica*	9	50	8.25	1.57	78.5	25.56	138.89	12.54	46.35
3	*Maesa lanceolata*	9	40	8.25	1.13	45.22	14.72	111.11	10.03	33.00
4	*Maytenus arbutifola*	7	35	6.42	1.37	48.08	15.66	97.22	8.77	30.85
5	*Dombeya torrida*	8	15	7.34	0.71	10.6	3.45	41.67	3.76	14.55
6	*Hagenia abyssinica*	5	15	4.59	1.06	15.9	5.18	41.67	3.76	13.52
7	*Rosa abyssinica*	5	18	4.59	0.02	0.41	0.13	50	4.51	9.23
8	*Apodytes dimidiata*	4	9	3.67	0.71	6.36	2.07	25	2.26	7.99
9	*V.amygdalina*	4	12	3.67	0.09	1.13	0.37	33.33	3.01	7.04
10	*B. antidysenterica*	3	14	2.75	0.02	0.25	0.08	38.89	3.51	6.34
11	*Bersama abyssinica*	3	13	2.75	0.02	0.21	0.07	36.11	3.26	6.08
12	*A. abyssinicus*	3	7	2.75	0.49	3.46	1.13	19.44	1.75	5.63

13	*Ficus sure*	2	6	1.83	0.57	3.39	1.1	16.67	1.5	4.44
14	*Prunus africana*	2	6	1.83	0.42	2.54	0.83	16.67	1.5	4.17
15	*Ekebergia capensis*	2	4	1.83	0.28	1.13	0.37	11.11	1	3.2

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

Table 29. Dominant woody species structural value in MBFP pioneer

No	Speciies	F	Ab	Rf	BA	Dom	Rdom	De	Rde	IVI
1	*Maesa lanceolata*	9	60	6.12	1.7	101.74	33.79	166.67	13.52	53.43
2	*Maytenus arbutifola*	8	62	5.44	1.46	90.53	30.06	172.22	13.97	49.47
3	*Nuxia congesta*	9	45	6.12	1.06	47.69	15.84	125	10.14	32.1
4	*Bersama abyssinica*	9	25	6.12	0.03	0.79	0.26	69.44	5.63	12.02
5	*Maytenus undata*	8	22	5.44	0.17	3.8	1.26	61.11	4.96	11.66
6	*V. auriculifera*	4	15	2.72	0.5	7.51	2.49	41.67	3.38	8.59
7	*B. antidysenterica*	8	13	5.44	0.02	0.2	0.07	36.11	2.93	8.44
8	*Syzygium guineense*	5	10	3.4	0.71	7.07	2.35	27.78	2.25	8.2
9	*V. amygdalina*	4	15	2.72	0.35	5.3	1.76	41.67	3.38	7.86
10	*Dombia torrida*	5	12	3.4	0.34	4.07	1.35	33.33	2.7	7.46
11	*A. abyssinicus*	4	9	2.72	0.49	4.45	1.48	25	2.03	6.23
12	*Rhamnus staddo*	3	12	2.04	0.28	3.39	1.13	33.33	2.7	5.87
13	*Ekebergia capensis*	4	7	2.72	0.38	2.69	0.89	19.44	1.58	5.19
14	*Prunus africana*	3	8	2.04	0.44	3.52	1.17	22.22	1.8	5.01
15	*Vernonia ruppellii*	5	5	3.4	0.21	1.03	0.34	13.89	1.13	4.87
16	*Teclea nobilis*	2	8	1.36	0.59	4.7	1.56	22.22	1.8	4.72

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

4.11. Importance value index of woody species in intermediate forests

In the intermediate forest patches, middle layer canopy trees: *Dombeya torrida*, *Allophyllus abyssinicus, and Hagenia abyssinica* in the GTFP; *Allophyllus abyssinicus*, *Hagenia abyssinica*, and *Dombeya torrida* in SLFP; and *Allophyllus abyssinicus*, *Dombeya torrida in* the MBFP had the highest IVI value. Among the upper canopy trees, *Olea europaea* and *Apodytes dimidiata* from GTFP; *Prunus* *africana* and *Ficus sure* in SLFP; and *Albizia schimperiana* in BMFP had the highest IVI (Tables 30-32) and appendices-Tables 18–20).

Table 30. Woody species structural value in intermediate of GTFP

NO	Species	Fre	Ab	Rf	Ba	Dom	Rdom	De	Rde	IVI
1	*Dombeya torrida*	7	4.61	35	4.8	167.97	35.47	97.22	9.28	49.36
2	*A.abyssinicus*	8	5.26	30	4.11	123.41	26.06	83.33	7.96	39.28
3	*Hagenia abyssinica*	6	3.95	20	2.57	51.42	10.86	55.56	5.31	20.11
4	*Myrsine africana*	8	5.26	45	0.03	1.56	0.33	125	11.94	17.53
5	*Apodytes dimidiata*	5	3.29	12	1.85	22.21	4.69	33.33	3.18	11.16
6	*Olea europaea*	4	2.63	12	1.75	20.98	4.43	33.33	3.18	10.24
7	*S. guineense*	4	2.63	10	1.54	15.43	3.26	27.78	2.65	8.54
8	*P.viridiflorum*	4	2.63	15	0.51	7.71	1.63	41.67	3.98	8.24
10	*Premna schimperi*	8	5.26	10	0.01	0.13	0.03	27.78	2.65	7.94
11	*Ekebergia capensis*	5	3.29	8	1.26	10.08	2.13	22.22	2.12	7.54
12	*Salix mucronata*	3	1.97	12	0.93	11.11	2.35	33.33	3.18	7.5
13	*Teclea nobilis*	6	3.95	9	0.31	2.78	0.59	25	2.39	6.92
14	*M.arbutifola*	8	5.26	4	0.31	1.23	0.26	11.11	1.06	6.58
15	*O. quadripartita*	4	2.63	10	0.6	6	1.27	27.78	2.65	6.55
16	*B.antidysenterica*	6	3.95	9	0.08	0.69	0.15	25	2.39	6.48

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

Table 31. Woody species structural value in intermediate of SLFP

no	Species	Fr	Ab	Rf	BA	Dom	Rdom	De	Rde	IVI
1	*A. abyssinicus*	9	6.57	35	4.5	157.47	32.81	97.22	8.82	48.2
2	*Hagenia abyssinica*	8	5.84	30	3.6	107.98	22.5	83.33	7.56	35.9
3	*Dombeya torrida*	7	5.11	20	3.09	61.7	12.86	55.56	5.04	23
4	*Myrsine africana*	9	6.57	60	0.08	4.63	0.96	166.67	15.11	22.65
5	*Maytenus arbutifola*	6	4.38	25	1.29	32.14	6.7	69.44	6.3	17.37
6	*Prunus africana*	5	3.65	16	2.19	35.1	7.31	44.44	4.03	14.99
7	*Bersama abyssinica*	6	4.38	20	0.25	4.94	1.03	55.56	5.04	10.45
8	*Apodytes dimidiata*	4	2.92	12	1.65	19.75	4.11	33.33	3.02	10.06
9	*Ficus sure*	4	2.92	11	1.51	16.59	3.46	30.56	2.77	9.15

10	*B. antidysenterica*	7	5.11	11	0.01	0.16	0.03	30.56	2.77	7.91
11	*Ekebergia capensis*	3	2.19	10	1.29	12.86	2.68	27.78	2.52	7.39
12	*Osyris arborea*	5	3.65	8	0.27	2.19	0.46	22.22	2.02	6.12

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

Table 32. Woody species structural value in intermediate of MBFP

	Species	Fr	Ab	Rf	BA	Dom	Rdom	De	Rde	IVI
1	*Allophyllus abyssinicus*	8	4.97	31	3.19	98.83	27.02	86.11	8.16	40.15
2	*Dombeya torrida*	5	3.11	28	2.64	73.91	20.21	77.78	7.37	30.68
3	*Maytenus arbutifola*	8	4.97	25	1.93	48.21	13.18	69.44	6.58	24.73
4	*Albizia schimperiana*	6	3.73	12	1.65	19.75	5.4	33.33	3.16	12.28
5	*Apodytes dimidiata*	6	3.73	12	1.03	12.34	3.37	33.33	3.16	10.26
6	*Vernonia amygdalina*	4	2.48	14	0.76	10.7	2.93	38.89	3.68	9.09
7	*Hagenia abyssinica*	3	1.86	13	1	13.03	3.56	36.11	3.42	8.85
8	*Vernonia auriculifera*	4	2.48	13	0.71	9.23	2.52	36.11	3.42	8.43
9	*Bersama abyssinica*	9	5.59	6	0.33	1.97	0.54	16.67	1.58	7.71
10	*Rhus glutinosa*	3	1.86	12	0.72	8.64	2.36	33.33	3.16	7.38
12	*Prunus africana*	5	3.11	8	0.69	5.48	1.5	22.22	2.11	6.71
13	*Schefflera abyssinica*	3	1.86	9	0.95	8.59	2.35	25.00	2.37	6.58
14	*Maesa lanceolata*	3	1.86	9	0.94	8.5	2.32	25.00	2.37	6.55
15	*Ebelia schimperi*	6	3.73	7	0.02	0.16	0.04	19.44	1.84	5.61
16	*Syzygium guineense*	2	1.24	9	0.77	6.94	1.9	25	2.37	5.51
17	*Maytenus undata*	6	3.73	4	0.31	1.23	0.34	11.11	1.05	5.12
18	*Brucea antidysenterica*	6	3.73	4	0.01	0.05	0.01	11.11	1.05	4.79

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

4.12. Importance value index of woody species in Climax forests

In climax forest patches, the upper canopy trees such as *Apodytes dimidiata*, *Prunus africana*, *Syzygium guineense,* and *Olea europaea* in GTFP; *Apodytes dimidiata, Prunus africana,* and *Ekebergia capensis* in SLFP; and *Prunus africana*, *Apodytes dimidiata*, Albizia schimperiana, and *Syzygium guineense in* MBFP had the highest

IVI. *Maytenus arbutifola* and *Teclea nobilis* had the highest IVI among the lower canopy trees in the three forest patches (Tables 33–35 and Appendices-Table 21–23).

Table 33. Woody species structural value in Climax of GTFP

no	Species	F	RF	AB	De	RD	BA	Dom	RD	IVI
1	*Apodytes dimidiata*	6	9.09	22	61.11	11.11	26.95	592.9	22.69	42.9
2	*Prunus africana*	4	6.06	21	58.33	10.61	18.38	385.88	14.77	31.44
3	*M.arbutifola*	7	10.61	17	47.22	8.59	18.78	319.25	12.22	31.41
4	*Olea europaea*	5	7.58	17	47.22	8.59	16.36	278.16	10.65	26.81
5	*S.guineense*	3	4.55	19	52.78	9.6	23.28	442.23	16.93	31.07
6	*S. abyssinica*	5	7.58	12	33.33	6.06	0.11	1.26	0.05	13.68
7	*B.antidysenterica*	8	12.12	17	47.22	8.59	0.04	0.63	0.02	20.73
8	*B.abyssinica*	9	13.64	14	38.89	7.07	0.03	0.43	0.02	20.72
9	*A.abyssinicus*	3	4.55	14	38.89	7.07	12.25	171.5	6.56	18.18
10	*Ekebergia capensis*	4	6.06	12	33.33	6.06	12.6	151.2	5.79	17.91
11	*Teclea nobilis*	3	4.55	9	25	4.55	7.88	70.88	2.71	11.8
12	*Ficus sur*	3	4.55	9	25	4.55	12.3	110.74	4.24	13.33
13	*P.falcatus*	2	3.03	8	22.22	4.04	10.94	87.5	3.35	10.42

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

Table 34 Woody species structural value in Climax of SLFP

no	Species	Fr	RF	AB	De	RD	BA	Dom	RD	IVI
1	*A.dimidiata*	8	8.7	35	97.22	11.91	33.69	1179.06	26.57	47.18
2	*Prunus africana*	7	7.61	34	94.44	11.57	26.78	910.35	20.52	39.7
3	*E. capensis*	6	6.52	33	91.67	11.23	31.76	1048.16	23.62	41.38
4	*Olea europaea*	6	6.52	29	80.56	9.87	22.84	662.29	14.93	31.32
5	*S.guineense*	3	3.26	18	50	6.13	14.18	255.15	5.75	15.14
6	*B. antidysenterica*	9	9.78	20	55.56	6.81	0.06	1.26	0.03	16.62
7	*B.abyssinica*	9	9.78	17	47.22	5.79	0.6	10.12	0.23	15.80
8	*M. arbutifola*	9	9.78	15	41.67	5.11	1.18	17.72	0.4	15.29
9	*Ficus sur*	3	3.26	13	36.11	4.43	13.65	177.45	4,00	11.69
10	*Teclea nobilis*	6	6.52	14	38.89	4.77	0.77	10.72	0.24	11.53

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

Table 35. Woody species structural value in Climax of MBFP

no	Species	Fr	Rf	AB	De	RD	BA	Do	RDO	IVI
1	*Prunus africana*	7	9.21	27	75	12.62	33.08	893.03	31.03	52.86
2	*Apodytes dimidiata*	5	6.58	23	63.89	10.75	31.45	723.24	25.13	42.46
3	*A.schimperiana*	6	7.89	17	47.22	7.94	17.85	303.45	10.54	26.38
4	*S. guineense*	4	5.26	17	47.22	7.94	17.85	303.45	10.54	23.75
5	*C.macrostachyus*	3	3.95	16	44.44	7.48	14	224	7.78	19.21
6	*Ekebergia capensis*	3	3.95	15	41.67	7.01	15.75	236.25	8.21	19.17
7	*M.arbutifola*	5	6.58	24	66.67	11.22	0.05	1.26	0.04	17.84
8	*B. antidysenterica*	7	9.21	15	41.67	7.01	0.03	0.49	0.02	16.24
9	*B. abyssinica*	7	9.21	10	27.78	4.67	0.13	1.26	0.04	13.93
10	*Teclea nobilis*	6	7.89	10	27.78	4.67	0.79	7.88	0.27	12.84
11	*A. abyssinicus*	4	5.26	6	16.67	2.8	6.3	37.8	1.31	9.38
12	*Olea europaea*	4	5.26	6	16.67	2.8	5.78	34.65	1.2	9.27
13	*Myrsine africana*	4	5.26	8	22.22	3.74	0.02	0.14	0	9.01
14	*Ficus sur*	3	3.95	6	16.67	2.8	8.2	49.22	1.71	8.46

F=frequency, Ab=abundance, RF=Relative frequency, BA=Basal area, Dom=Domnance, Rdom=relative dominance, De=density RD=Relative Density and IVI= importance value index

4.13. Use value or anthropogenic disturbance

The woody plants are used for charcoal, firewood, timber/furniture, poles/posts, farm tools/handles, carvings/utensils, fodder/forage animal feeding, medicine, and house fence. Among lower canopy trees, *Acacia abyssinica, Nuxia congeta, and Maesa lanceolata have the highest TUV* in pioneer forests (Table 36). *Hagenia abyssinica, Dombeya torrida,* and *Allophyllus abyssinicus* have the highest Tuv among middle-layer canopy trees. They were highly over exploited in the middle-layer canopy trees. *Prunus africana* has the highest TUV, followed by *Ekebergia capensis* and *Olea europaea from the* Upper Canopy Tree in the Climax Forest Patches. They were highly over exploited from the upper canopy trees. The residents use woody plants for fire wood, House fence, animal fodder (open grazing) respectively.

Table 36. Species Use value or disturbance factor

	Use value of woody plants											
Species	CH	Fw	TF	PP	FT	CU	FA	MS	HF	Tc	Tuv	Rank
Acacia abyssinica	4	5	0	3	3	2	5	0	5	5	32	4
A.abyssinicus	0	3	0	2	2	2	4	0	5	2	20	13
Apodytes dimidiata	0	3	3	3	3	3	1	1	5	1	23	8
Dombeya torrida	0	3	0	2	2	2	5	0	5	5	24	7
Ekebergia capensis	2	5	4	5	4	5	5	3	5	2	40	2
Ficus sur	0	2	3	3	3	5	5	2	2	1	26	6
Hagenia abyssinica	0	2	5	5	2	5	4	4	3	0	30	5
Maesa lanceolata	1	5	0	2	1	1	1	1	4	5	21	11
Maytenus arbutifola	3	5	0	1	0	0	5	0	5	2	21	12
Nuxia congesta	1	5	0	2	0	0	5	0	5	5	23	9
Olea europaea	2	5	2	5	5	5	2	2	5	5	38	3
Osyris quadripartita	5	2	0	0	0	0	0	0	0	0	7	18
Prunus africana	2	5	3	5	2	4	5	5	5	5	41	1
Rhus glutinosa	5	4	0	0	2	1	4	1	3	0	20	14
Salix mucronata	0	4	0	2	0	1	0	1	3	0	11	17
Syzygium guineense	0	4	0	4	0	2	0	0	5	0	15	16
Teclea nobilis	3	5	0	4	4	2	0	2	3	0	22	10
V.amygdalina	0	4	0	0	2	1	5	5	2	0	19	15
Total	28	71	20	48	35	41	56	27	70	38		
Rank	8	1	10	4	7	5	3	9	2	6		

Charcoal = CH, FW= Firewood, TF Timber/Furniture, PP = Poles/posts, FT = Farm Tools/handles, CU = Carvings/Utensils, FA = Fodder/Forage animal feeding, MS = Medicine/Stimulant, HF = House Fence and TC = Traditional Ceremony/ritual, and TUV = Total use value or negative regeneration.

4.14. Species regeneration

Woody plants can regenerate in multiple ways, such as seed germination, fruit edibility, stem sprouting, root proliferation, bee forage and beekeeping, and traditional rituals. All of these regeneration ways give species survival or regeneration potential. *Prunus africana, Ficus sur, and Syzygium guineense from the upper canopy tree in climax forests; Acacia abyssinica, Maytenus arbutifola,* and *Nuxia congesta* from the lower layer canopy trees; and *Allophyllus abyssinicus, Dombeya torrida,* and *Hagenia abysinica from the middle layer had the* highest survival potential, as shown in Table 37. The majority of species are regenerated through the processes of seed germination, sprouting, and fruit or seed edibility.

Table 37.Species regeneration potential

	Woody plant regeneration							
Species	SG	RP	SP	BK	FE	TR	SEP	Rank
Acacia abyssinica	5	5	5	1	1	0	17	4
Allophyllus abyssinicus	3	1	3	3	5	0	15	7
Apodytes dimidiata	3	0	3	3	3	0	12	9
Dombeya torrida	3	0	3	2	0	0	8	13
Ekebergia capensis	3	0	2	5	5	2	17	5
Ficus sur	1	4	4	4	5	5	23	2
Hagenia abyssinica	5	1	1	3	1	0	11	10
Maesa lanceolata	3	0	3	0	2	0	8	14
Maytenus arbutifola	5	5	5	1	0	0	16	6
Nuxia congeta	3	0	4	1	1	0	9	12
Olea europaea	4	1	5	2	3	0	15	8
Osyris quadripartita	1	0	3	0	0	0	4	18
Prunus africana	4	5	5	3	5	5	27	1
Rhus glutinosa	2	1	1	0	1	0	5	17
Salix mucronata	2	2	2	1	0	0	7	15
Syzygium guineense	5	2	2	5	5	0	19	3
Teclea nobilis	4	1	2	0	0	0	7	16
Vernonia amygdalina	2	2	4	0	0	2	10	11
Total	58	30	57	34	37	14		
Rank	1	5	2	4	3	6		

SG=Seed Germination, Fruit edibility = FE, SP= Stem sprouting, RT=Root proliferation, BK = Bee forage/bee keeping, TR = Traditional rituals, SSP = species survival potential

5. Discussion

5.1 Frequency of species in pioneer, intermidiate and climax forest

The homogeneity and heterogeneity of specific vegetation are shown by its frequency (Lamprecht, 1989). Thus the highest frequency of lower canopy trees: *Acacia abyssinica*, *Nuxia congesta*, *Maytenus arbutifola*, *Maesa lanceolata*, and *Brucea antidysenterica* is related to their fast growth rate, ease of dispersal, and ability to grow and mature under poor soil conditions.Rey *et al*. (2000) stated that a species' highest frequency is always influenced by variables related to habitat preferences, adaptation, level of exploitation, and accessibility of favourable environmental circumstances for regeneration. Similarly, because of the better soil conditions, the frequency of middle-layer canopy trees like *Allophylus absynicus, Hagenia abyssinica*, and *Dombeya torrida* was highest in moderately disturbed intermediate forest patches; similar to moderately disturbed pioneer forests, the frequencies of most species in moderately disturbed intermediate forest patches were higher than intact or undisturbed forest patches. The Over-exploitation of multiple-use plants among middle-layer canopy trees (*Hagenia abyssinica and Dombeya torrida*) resulted in lower frequencies. In intermediate forest patches, the frequency of lower-layer canopy trees was decreasing except for a few shade-intolerant lower canopy trees. Thus, the soil fertility and canopy layer of intermediate forest favors middle and upper canopy trees to alive and succeed.

The frequency of upper canopy trees species was higher in moderately disturbed forests than in intact and highly disturbed forest patches. In intermediate forest Patches; upper canopy trees such as *Apodytes dimidiata and Prunus africana* had the highest frequency. The frequency of highly edible plants (leaves and stems) by domestic animals (*Prunus africana and Ficus sure*) declined along disturbance gradients similar in pioneer forests. The frequency of species that have high use value decline along disturbance gradients; However, the frequency of less use value species increases or remains the same along the disturbance gradients.

In climax forests, the frequencies of upper canopy trees were higher than the middle layer and lower layer canopy trees. Near the riverbank, the frequency of *Syzygium guineense and Ficus sur* were highest in the three forest patches. However, faraway from the riverbanks, the frequency of *Apodytes dimidiata* and *Prunus africana* were highest. The frequencies of species with high use values, such as *Olea europaea* and *Ficus sur* decreased along disturbance gradients.

The frequency of Shrubs such as *Brucea antidysenterica* was high in the climax forest as shade tolerant and even higher along the disturbance gradient since they have a lower Use value. *Maytenus arbutifolia* and *B. abyssinica* was most common among lower canopy trees in Climax forests, which ranged from intact to extensively disturbed forest. This is similar to Tesfaye & Berhanu (2006) and Berhanu *et al*. (2017), who found that *B. abyssinica* and *Maytenus arbutifolia* are common species in disturbed and secondary forests.

5.2. Density of woody trees in the pioneer forests

Many pioneer species may establish and grow in high density during early succession development until they reach the climax stage, where competition eliminates many individuals (Ewel, 1983; Girma, 2011). Similarly, the higher density of lower canopy trees in pioneer forests than in the middle layer and upper canopy trees is attributed to the growth pattern and regeneration potential of trees. Compared to other dry Afromontane forests, the density of total woody trees in pioneer forest patches: GTFP, SLFP, and MBFP were also higher than in Bore-Anferara (woldemariam, 2017), Komto (Gurmessa *et al*., 2012), Jibat (Burju *et al*., 2013), and Gedo (Kebede *et al*., 2014) forest patches. However, the density of woody trees in pioneer forests was lower than in Belete (Hundera and Gadissa, 2008), Masha-Anderacha (Yeshitila and Bekele, 2003) and Tara (Zegeye *et al*., 2011) forests. Lower canopy trees had a smaller size than middle and upper layer canopy trees; as a result, the density of shrubs and lower canopy layer species was higher than that of middle and upper layer canopy trees in pioneer forests. Lower canopy trees and shrubs have different adaptations; these species can regenerate in different ways under poor soil conditions. They regenerate under high disturbance. The soil seed banks and rain seeds germinated in mass (especially *Acacia abyssinica*) and had the highest growth rate among the others. It can grow into a mature tree in a few years (short life span). When the woody stem above the ground is damaged or slashed, the root proliferates into mature seedlings and saplings (*Maytenus arbutifola and Acacia abyssinica*).

5.3. Density species in the intermediate forests

Because of their abundance, middle-layer canopy trees had the highest cumulative density in intermediate forests, followed by climbers (lianas) and understory shrub trees. Intermediate forest patches favour middle-layer canopy tree species. Middle canopy trees had a higher percentage in the three forest patches. In particular, *Allophyllus abyssinicus was* highest in GTFP, SLFP, and MBFP, respectively. *Allophyllus abyssinicus* has edible fruits dispersed by wild animals. Following, *Allophyllus abyssinicus Dombeya torrida* in GTFP, SLFP, and MBFP had the highest density per hectare. Intermediate forests are the optimum environment for middle-layer canopies like *Dombeya torrida* and *Hagenia abyssinica* as they require ready access to resources and are not shaded by the higher canopy trees. However, similar to disturbed pioneer forests, the density of *Dombeya torrida and Hagenia abyssinica* declines along disturbance gradients.

The densities of species with high use values were highest in intact intermediate forests under natural competition. Their density, on the other hand, decreases as disturbance gradients increase. Disturbance-seeking species such as *Croton macrostachyus and Schefflera abyssinica*, on the other hand, are increasing in number in disturbed parts of forests. The density of the ground layer species such *as Brucea antidysenterica* remained the same in the three forest patches along the disturbance gradient and intact in intact forests as they are shade tolerant. They also had less useful value. Their density remained the same in disturbed and highly disturbed forest patches.

5.4. Density species in the Climax forests

Except for shade-tolerant plants, upper canopy trees are more densely crowded than middle and lower canopy trees due to their longer lifespans, heights, and capacity to expand over all woody trees. Few understory shrubs exist as shade-tolerant under upper canopy trees. Due to the physical and chemical effects of upper canopy trees, lower and medium canopy trees are rare in climax forests.

The density of woody species variation within the forest thus appears to be influenced by topographic variation, the habitat preferences of species comprising the forest, and the intensity of anthropogenic disturbances (Whittaker *et al*., 2003). Climax forests favour upper canopy trees such as *Apodytes dimidiata, Prunus africana, Syzygium guineense, Olea europaea, Ekebergia capensis, and* Syzygium *guineense.* The species with the lowest density were *Olea europaea* and *Ficus sur*, which had a high use value and few regeneration ways. The density of lower and middle-layer canopy trees was lowest in intact Climax forests. Shade-tolerant, economically less valuable species like *Brucea antidysenterica*, *Bersama abyssinica*, *Maytenus* arbutifola, and *Teclea nobilis* had high density.

5.5. Basal area and dominance of woody tree types in pioneer forests

According to earlier studies (examples: Bekele, 1993; Senbeta, 2006; Tadele *et al*., 2013; Lulekal, 2014), the lower and upper DBH classes determine the overall basal area. Among woody tree types, in pioneer forests, the higher basal area and dominance of lower canopy trees were related to their abundances, followed by the upper canopy trees because of their higher diameters than the middle canopy tree species. Lower canopy trees had the highest proportion in SLFP, GTFP, and MBFP, respectively.The highest basal area per hectare of lower canopy tree species: *Acacia abyssinica*, *Nuxia congesta, Maytenus arbutifola*, and *Maesa lanceolata* in GTFP, *Nuxia congesta*, *Acacia abyssinica,* and *Maesa lanceolata* in SLFP, and *Maesa lanceolata*, *Nuxia congesta* and *Maytenus arbutifola* in MBFP were related to their high frequency and abundance in pioneer forest patches. Following lower layer canopy trees, the basal area per hectare of middle layer canopies such as Dombeya *torrida* and *Hagenia abyssinica* in SLFP had a high basal area per hectare. Thirdly, upper-layer canopy trees, *Apodytes dimidiata* in GTFP and SLFP, and *Syzygium guineense* in MBFP, had a higher basal area. The basal area per hectare of species with high use value is less than that of species with low use value, such as *Syzygium guineense* and *Apodytes dimidiata*.

5.6. Basal area and dominance of woody species in intermediate forests

The higher basal area of middle layer canopy trees in intermediate forest patches was related to their abundance, followed by the upper canopy trees because of their higher diameters than the middle-layer canopy tree species. The basal areas of the middle canopy trees were highest in GTFP and significantly higher in SLFP and MBFP. Following middle-layer canopy trees, the upper canopy trees were greater than lower, understory, and non-canopy trees or climbers. Because of their abundance and DBH, middle layer canopy trees such as *Allophyllus abyssinicus*, *Hagenia abyssinica*, and *Dombeya torrida* from SLFP, *Osyris arborea* from SLFP, and *Salix mucronata* from GTFP have the highest basal area per hectare in intermediate forests. Secondly, the higher basal area per hectare of upper canopy trees of *Apodytes dimidiata* in GTFP and SLFP and *Syzygium guineense* in MBFP is related to abundance and frequency following middle layer canopy trees.

5.7. Basal area and dominance of woody species in Climax forests

The highest basal area per hectare of *Apodytes dimidiata* in three forest patches is because of abundance, DBH, and less use value (less preferable for grazing animals and rarely extracted by the local community).In intact climax forests, the middle and lower layer canopy trees had a smaller basal area per hectare due to their lower tolerance to the shading effect. However, due to their shade tolerance, only a few species of lower-layer canopy trees exist, such as *Teclea nobilis* and *Maytenus* *arbutifola*. The basal area per hectare of species with a high use value is less than that of species with a lower use value, such as *Olea europaea* and *Apodytes dimidiata*, respectively. The basal areas of woody trees in climax forests and wombera Afromontane forests are higher than in other forests such: Denkoro (Ayalew *et al*., 2006), Komto (Gurmessa *et al*., 2012), and lower than in Wof Washa (Bekele, 1993), Masha-Anderacha (Yeshitila and Bekele, 2003), Dodola (Hundera *et al*., 2007), and Mana Angetu (Lulekal *et al*., 2008). However, the basal area of woody trees in pioneer and intermediate forest patches wasless than other Afromontane forests cited above. In climax forests DBH contributes the most to the basal area per hectare, rather than frequency or abundance. Similarly, different scholars stated that DBH contributes the highest value in Afromontane forests in Ethiopia: Masha-Anderacha (Yeshitila and Bekele, 2003), Dodola (Hundera *et al.*, 2007), and Komto (Fekadu Gurmessa *et al.*, 2012). Large DBH classes provided more than 74 per cent of the total basal area (Woldearegay, 2017).

The higher frequency, abundance, and DBH of *Albizia schimperiana*, *Albizia gummifera,* and *Millettia ferruginea* contributed to a higher basal area per hectare in BMFP. Among shrubs, *Vernonia amygdalina* had a higher basal area per hectare. Their higher frequency and abundance are related to ecological adaptation to the altitude of the middle layer. .

5.8. Importance value index of woody species in Pioneer forests

Among the vegetation evaluating parameters, the Importance Value Index (IVI) is the main factor of the ecological significance of species (Lamprecht, 1989). The importance value index is the combination of three parameters, i.e., relative frequency, relative density, and relative dominance (Kent and Coker, 1992); hence, many scholars believe that the IVI value is the most important indicator of the ecological significance of species (Curtis and McIntosh, 1950). Similarly, in the pioneer forests, the highest IVI values of lower canopy trees: GTFP, SLFP, and MBFP, indicated high ecological importance. The IVI values of *Acacia abyssinica* were highest in GTFP and second SLFP. Among lower canopy trees, *Acacia abyssinica* is the most well-known pioneer species with the highest use-value in the GTFP and SLFP and multiple ways of regeneration; The roots grow into the stem when the stem part is removed or damaged; The soil seed bank and seed rain germinate massively, and the stem regenerate when its part is damaged or cut. It is a known fast-growing species. *Nuxia congesta* has the highest IVI in SLFP and GTFP but has a lower Use Value and ranks second in regeneration potential following *Acacia abyssinica*, indicating its ecological importance. The higher IVI of *Maesa lanceolata*, *Maytenus arbutifola,* and *Nuxia congesta* in MBFP also showed their ecological significance. Thus, in the pioneer forest patches: *Maesa lanceolata, Maytenus arbutifola, Nuxia Congesta,* and *Acacia abyssinica* were the most useful lower canopy trees that build up the pioneer forests.

5.9. Importance value index of woody species in intermediate forests

The highest IVI Middle Layer canopy trees, such as *Allophyllus abyssinicus, Hagenia abyssinica, and Dombeya torrida* from SLFP; *Dombeya torrida, Allophyllus abyssinicus,* and *Hagenia abyssinica f*rom GTFP; and *Dombeya torrida, Allophyllus abyssinicus*, and *Rhus glutinosa* from MBFP, respectively, were an indication of their higher ecological importance in intermediate forest patches. Middle-canopy trees were the dominant successors of the lower-layer canopy trees. They succeeded the pioneer species and established the environment for the successor species.

5.10. Importance value index of woody species in Climax forests

Upper-canopy trees had a higher IVI than middle and lower-layer canopy trees, indicating that they had the highest ecological importance in climax forest patches. In addition to their ecological importance, the higher IVI of upper canopy trees such as *Apodytes dimidiata* and *Prunus africana* was related to their less use value compared to other upper canopy trees; however, species with lower IVI had the highest use value, such as *Olea europaea* and *Ficus sur*. According to Mueller-Dombois and Ellenberg (1974) and Curtis and McIntosh (1950), IVI analysis could be used to determine the relative ecological relevance and/or dominance of a tree species in forest ecology. Similarly, in pioneer forests, frequency and density have the highest contribution to IVI, whereas, in climax forests, DBH has the highest contribution to IVI; the three population characteristics were equally relevant for determining IVI in intermediate forest patches, making them the most relevant parameters to indicate ecological significance. The IVI of pioneer forests were lower than other related forest patches whereas the IVI value of climax forest patch species was higher than other forests of Tara Gedam and Abebaye (Zegeye *et al*., 2011); Zengena (Tadele *et* *al*., 2013), Ankober (Lulekal, 2014), Awi (Berhanu *et al*., 2017), Denkoro (Ayalew *et al.*, 2006), Komto (Gurmessa *et al.*, 2012) and lower than Wof Washa (Bekele, 1993), Masha-Anderacha (Yeshitila and Bekele, 2003), Dodola (Hundera *et al.*, 2007) and Mana Angetu (Lulekal *et al*., 2008). On the other hand, the IVI of woody trees in intermediate forest patches is between the pioneer and climax forests.

5.11. Mutiple use value of plants

Various plant species have different use values depending on the socio-economic conditions of a given community. Forests are important sources of non-timber forest products such as fruits, fodder, honey, and herbal medicine, as well as tools and construction materials, timber, and food for local communities (Tona, 2016). Disturbance, such as intensive removal of trees for timber, construction, and forest grazing have placed significant pressure on forest regeneration (Tesfaye *et al*., 2010). Similarly the evaluation of this study shows that woody plants have different use values, such as charcoal, firewood, timber/furniture, poles/posts, farm tools/handles, carvings/utensils, fodder/forage animal feeding, medicine, and house fence. In the ecology of forests, species survival is declining due to the excessive exploitation of woody plants due to their high use value. Upper canopy trees, such as *Olea europaea, Prunus africana, Ekebergia capensis, and Syzygium guineense,* are heavily removed used for poles and posts. *Teclea nobilis, Ficus sur, Olea europaea, and Ekebergia capensis* are overexploited in the production of agricultural tools. *Ekebergia capensis, Prunus Africana, Hagenia abyssinica, Ficus sur, and Olea europaea* are used to make carvings and house material. The manufacturing of charcoal diminishes the quantity of lawer canopy trees, specifically Acacia abyssinica and Osyris quadripartite.

All types of plants are used to make fences for homes. Woody plants, such as *Prunus africana*, *Olea europea*, *Vernonia amygdalina, Dombia torrida*, and *Hagenia abyssinica*, are used in traditional medicine and ceremonial rituals. They do have a lower number and density due to overexploitation, but some species, like *Prunus africana and Syzygium guineense*, have multiple ways of regeneration that enable them to survive and regenerate. The highest use value of *Acacia abyssinica and Osyris quadripartite* in the production of charcoal reduces their abundance; however, *Acacia abyssinica* can regenerate itself in several ways and is abundant in pioneer forest patches. For the purpose of producing lumber and furniture, *Hagenia abyssinica* and *Ekebergia capensis are overextracted.*

5.12. Regeneration woody plants

Tropical forest plants regenerate from one or more pathways, i.e., (i) seed rain: recently dispersed seeds; (ii) soil seed bank: dormant seeds in the soil; (iii) seedling bank or advance regeneration: established, suppressed seedlings in the understorey; and (IV) coppice: root or shoot sprouts of damaged individuals (Garwood, 1989; Tesfaye *et al*., 2002). In this study, even though woody plants were over-extracted due to their high use values, they have several means of regenerating and surviving: Seed germination, fruit edibility, stem sprouting, root proliferation, Bee forage and beekeeping, and traditional rituals. Upper canopy trees such as *Prunus africana and Ekebergia capensis have* high regeneration or survival potential due to their high seed germination, fruit or seed edibility, cutting regeneration (sprouting), and root proliferation. *Prunus africana* has the highest seed germination potential compared to other upper-canopy trees. Similarly, Tektay (2005) stated that plants can regenerate through sprouting when their roots or stems are damaged.

Climax species typically have larger seeds than pioneer species that germinate immediately or within a few days after dispersal under the forest canopy (Swaine & Whitmore, 1988; Whitmore, 1989). According to Tektay (2005), the seeds of several woody species are large and contain high moisture, indicative of adaptations to immediate germination, seedling establishment, and survival under the canopy of forests. In this study the seeds of upper and middle canopy trees, *Allophyllus abyssinicus*, *Syzygium guineense*, and *Prunus africana*, have the highest seed germination capacity under the canopy of trees. However, the seeds of pioneer plants such as *Acacia abyssinica and Maytenus arbutifola* germinate more than other plant seeds. These plants have a greater advantage in colonizing bare lands than other plants. Plant species have a higher chance of surviving in abandon and grass land when their seeds germinate into seedlings and grow into saplings and mature trees. Thus, through immediate germination and establishment, many trees and shrubs form large populations of seedlings in the forest.Seed edibility increases species dispersal and survival ability in the forest ecosystem. The seeds of Syzygium *guineense, Ekebergia capensis,* and *Ficus sur* are highly edible by wild animals; as a result, they have a higher dispersed probability throughout the forest ecosystems and can survive. *Ekebergia capensis is also the* most edible upper canopy tree in the forest. Thus, the edibility of seeds by wildlife animals increases the dispersal mechanism and its survival probability.

According to Mersha Ashagre *et al*. (2016), keeping remnants of trees, shrubs, and herbs in and around agricultural fields due to their use as forage, fuelwood, timber, construction, spiritual, and ritual needs is a traditional conservation practice. Specifically, Hundera (2007) stated that Ficus *vasta, Ficus sychomour, Podocarpus falcatus, and Ekebergia capensis are* respected as scare trees in the Jimma zone in western Ethiopia. Similarly, in this study, the high-land dwellers have historically conserved some trees, such as *Prunus africana*; subsequently, they think it has miraculous properties. To preserve water, some trees, such as *Ficus sur*, is planted near streams and river mouths. Thus, social and traditional activities increase the conservation of plants. In addition to tall trees where beehives are hang, mountains, hills, valleys, and rivers have been used as a boundary between one Jang and the other (Mesfin, 2015). Similarly, in the study area, upper canopy trees, mainly Syzygium *guineense, Ekebergia capensis,* Ficus *sur, Allophyllus abyssinicus, and Prunus africana are used for beehive hanging as well as forage.*

Conclusion

Pioner trees such as lower canopy trees can survive and established on bare and degraded land under poor soil nutrients. Middle and upper canopy trees can survive and established in pioneer forest under the influence of heavy shade and form intermediate and climax forests respectively. The middle canopy trees dominate the lower canopy trees and form intermidite forest and finaly the upper canopy trees dominate the middle canopy trees and form climax forests. Woody plants have different use values that minimize their abundance however; they have different regeneration ways to rejuvenate.

CHAPTER SIX

Wood plants structure and regeneration status in Lower and middle altitude forests forest patches of wombera district, Benshangul, Gumuz regional state, Ethiopia

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Abstracts

Wood plant structure and regeneration status were assessed in lower and middle-altitude forest patches of Wombera district, Benshangul, Gumuz regional state, Ethiopia. Vegetation data were collected in PMFP, ABFP, and BMFP from September to October, respectively, in a series of nested quadrates. The frequency, density, abundance, and IVI were computed in a Microsoft Excel spreadsheet. In PMFP, Combretum collinum and Combretum hartmannianum were dominant, followed by Anogeissus leiocarpa and Pterocarpus lucens. In ABFP, Terminalia macroptera, Ficus sycomorus, and Breonadia salicina had the highest frequencies and densities. In BMFP, Albizia schimperiana, Albizia gummifera, and Millettia ferruginea had the highest frequency, density, and abundance. The density of seedlings was higher than saplings per hectare in three forest patches. Seedling and sapling per hectare were highest in PMFP, BAFP, and BMFP, respectively. The high DBH value of dominating species in woodland agroecology indicates that they are ecologically compatible and long-term adaptable to fire, low precipitation, and soil nutrient deficiencies. *Most species regenerate by sprouting from the ruminants of slash woods; some species regenerate from roots that remain alive in the soil, and all species regenerate from soil seed banks or seed dispersal by wild animals. Shifting cultivation and semi-agroforestry are unique means of a conservation strategy in PMFP and ABFP. Conservation methods in BMFP are primarily related to agro-forestry farming, traditional belief practices, and beekeeping. Agro-forestry*

agriculture is the source of income for those living in the middle latitudes. Modern conservation methods should recognize and include the traditional conservation practices of shifting agriculture and agro-forestry farming.

Key words: woody plants, agro-forestry, Species, regeneration

1. Introduction

Ethiopia is one of the regional centers of biological diversity and genetic resources in the world (Zerihun Woldu, 1999; IBC, 2009). However, the rapid population growth and the demand for natural resources have put great pressure on the biodiversity of the country (Aukema *et al.*, 2017). The present trends of population growth and deforestation need to be abated through family planning and appropriate land use practices, respectively, to reverse the deterioration of natural resources and prevent the decline or loss of biodiversity (Teshome Soromessa *et al.,* 2004).In Ethiopia, dry lands cover approximately 71.5% of the landmass (Lemenih and Teketay, 2004). *Combretum-Terminalia* woodlands and wooded grasslands are one of the major natural vegetation types in Ethiopia, mainly occurring along the western escarpments of the Ethiopian highlands (Friis et al. 2010). However, the loss of dry forests in Ethiopia is occurring through the destruction of habitat owing to extensive deforestation and the conversion of forests to agricultural lands (Mekuria et al., 1999). The Combretum-Terminalia dry lowland of Ethiopia destroyed 650,000 ha between 2000 and 2013 (Franks, 2017). Competition for other land uses, climate change, ecosystem modification, overharvesting and the spread of invasive species are causes of forest loss (FAO, 2014).

Combretum–Terminalia vegetation type is found in the western escarpment of the Ethiopian plateau from the Eritrea border to western Kefa and Omo Zone, also in Benshangul-Gumuz and Gambela, the Didesa valley, and in northern, eastern, central and southwestern and parts of the country(Ib *et al*., 2010; Addi *et al*., 2016).The woodland Vegetation in Bensangul gumuz region was classified into five plant communities: (1) *Hyphaene thebaica-Pterocarpus lucens*, (2) *Boswellia Papyrifera-Pterocarpus lucens*, (3) *Securidaca longepedunculata-Albizia malacophylla*, (4) *Croton macrostachyus- Albizia malacophylla* and *Breonadia salicina-Phoenix reclinata* (Tesfaye Awas *et al.,* 2007).

The middle altitude vegetation is dominated by *Albizia schimperiana*. This type of vegetation is associated with the coffee growing area. FAO (2006) defined a forest as a minimum land area of 0.05–1 ha with tree crown cover more than 10–30% and tree height of 2–5 m at maturity; FAO (2001) defined a forest as “land with a tree crown cover (or equivalent stocking level) of more than 10% and an area of more than 0.5 hectare; the trees should be able to reach a minimum height of 5 m at maturity in situ”. In addition to forests that meet FAO definitions, a considerable number of trees are grown in agroforestry forms. Agroforestry is a farming system that integrates trees into the farmland (Alemayehu Wassie, 2017). Thus the coffee plantations under shade tree species are considered as middle altitude forest patches.

2. Material and Method

2.1. Description of study area

Wombera ditrict is located 658km from Addis Ababa, capital city of the country. it is found in the metekel administrative zone of benishangul gumuz regional state in the northwestern part of ethiopia. The district is one of the largest districts in metekel administrative zone. It is bounded by the districts of guba and dangur in the north, bullen in the east, agallometi, and yaso in the south, and serba abbay and sherkole in the west. The latitudinal and longitudinal position of the district are between 90 57' 30" to 11^0 08' 45" north and 35^0 09' 09” to 35^0 50' 25" east (Figure 1).

2.1.1 Topography

The topography of the study area is undulating and has only a few plain fields. The altitudes of wombera district ranges between 576 to 2615masl. The district is stratified into: higher, middle and lower agro-ecologies based on an altitudinal range, vegetation strata, and crop productivity. In the lower ranges (576 to 1200 masl), *combretum-terminalia* forest and woodland is the most dominant vegetation. The majority of the study area falls within the lower altitude. The higher altitudes range between 2001-2616 masl. Dry afromontane forests with different sub-layers are the dominant vegetation. Middle agro-ecology altitudes range between 1201 and 2000 masl. Coffee, fruits, spices and vegetables are abundant in the middle altitude. The vegetation layers are mainly dominated by *albizia schimperiana*, *albizia gummifera, millettia ferruginea, cordia africana,* and *ficus sp.*

2.1.2. Climate

Bullen metrology station represents the middle altitude of the wombera district. Annual temperatures range between a minimum of 11.9^{o}C and a maximum of 30.6^{o}C with an average of 20.7^{o}C; annual rainfall was 1560 mm. The Guba district climate data represents the lower altitude climate of wombera; annual temperatures range between a minimum of 18.8^{o}C and a maximum of 37.2^{o}C with an average of 25.7^{o}C; annual rainfall was 1210 mm (Figure 2).

Middle altitude (weyinadega)

Shinasha and Oromo ethnic groups primarily populate the middle agro-ecological zones (Woinadega); the area is conducive for mixed agriculture and beekeeping: They mainly dependent on agroforestry farming (coffee and spice under shade trees) (WARD, 2014). The crops include cereal crops (teff), lentils (maize, finger millet), pulse (bean, pea, chickpea), oilseeds (*Niger seed*), root crops (potato, *enset, yams, anchote, carrots, beetroot*), vegetables (cabbage, onion, tomato), spices (hot pepper, ginger), fruits (mango, papaya, banana, orange, lemon, avocado), and cash crops (coffee and gesho)

Lowland (Bereha)

The gumuz ethnic group lives in the lowlands. Shifting cultivation, locally known as “Malaya”, is the most important economic activity in the lowland area. It can also be translated as work, implying that labour and agriculture are synonymous. Agriculture is primarily carried out by hand with the use of a hoe. Every year, a Gumuz family clears new forest land, or 'kanja,' to grow sorghum, millet, maize, finger millet, sesame, cotton, tobacco, cassava, and various spices, while some of the previous plots are still in use and others have been abandoned. Animal husbandry and poultry are significant complementary activities to hoe agriculture, although they are not the primary source of income. In Gumuz, the purpose and use of the small cattle and goat stocks are different from what is common among pastoralists and neighbouring highlanders. First, since the Gumuz are hoe cultivators and not plough farmers, cattle (particularly oxen) are not relevant for farming (Ward, 2014).

Vegetation

The vegetation of the wombera district has three strata of vegetations along altitudinal gradients. The lower altitude vegetation of wombera is part *Combretum-Terminalia* woodland and wooded grassland as classified by Tesfaye Awas (2007). The middle altitude vegetation is dominated by *Albizia schimperiana*. This type of vegetation is associated with the coffee growing area.

Wild animals

Wild animals such as the Bush Pig, Leopard, Anubis Baboon, Colobus Monkey, and lions, Common Duiker, Several Cats, and Common Bush Buck, are abundant in the forests Patches. Gumuz ethics depend upon shifting cultivation and hunting; they cultivate the ground after slash-burning for 3-5 years, then abandon it for wild animals and seek for vegin woodland. This trend had been going on for many years, turn by turn. During slash-burning, wild animals relocate to surrounding forests, abandoned farms, and neighbouring countries. The wild animals move back and forth to the abandoned lands and forests alternatively. Fire is another serious issue at lower elevations. Fire is set off on a yearly basis for farming and hunting, but it can sometimes happen accidentally. The wild animals are adapted to these cyclic disturbances of shifting cultivation and deliberate and uncontrolled fire. These adaptation and routine practices are indigenous conservation mechanisms for the local inhabitants (Ward, 2014).

Livestock Population

Livestock husbandry is the other agricultural activity next to crop cultivation. Table 4 shows the animal population in the Wombera district from 2008 to 2018. Inhabitants of the highlands engage in agriculture and animal husbandry, while those at the medium altitudes engage in agroforestry, with coffee and spices as the main products. Because livestock diseases are common at the middle and lower altitude ranges, animal husbandry is lower compared to higher altitude. The people in the low altitude areas depend mainly on shifting agriculture, hunting and primitive gold mining (Ward, 2014).

2.2. Vegetation data

Vegetation data were collected in PMFP, ABFP and BMFP from September to October in respectively. A series of nested quadrates following (Stohlgren et al., 1995) were laid at 150 meters intervals along transects and transects were laid 300 meters apart along an altitudinal gradient.Different quadrates sizes: (1) 20 m × 20 meters was used for sampling of trees with stem diameter at breast height (DBH) >2.5 cm. Canopy cover of each tree was calculated by measuring side branches at right angles as the side of the square, and the ratio of each species was computed to 20 by20 plot area ; (2) 5 m × 5 m quadrates nested in the larger quadrates for shrubs, seedlings, saplings and (3) 1 m × 1 m quadrates nested in the 5 m × 5 m quadrates for the herbs and grass (Appendix-Figure 3).

The percentage foliage cover of each herbaceous species was also estimated in each plot and the mean cover was computed. All plant specimens were collected, temporarily tagged with plot numbers and labels assigned to species, pressed and brought to the National Herbarium (ETH) for identification and storage. Species were identified at the National Herbarium (ETH) of Addis Ababa University by using the taxonomic keys in the various volumes of the Flora of Ethiopia and Eritrea (Hedberg & Edwards, 1989; Edwards *et al*., 1995; Phillips, 1995; Edwards *et al*., 1997; Hedberg *et al*., 2003; Mesfin Tadesse, 2004; Hedberg *et al*., 2006, 2009a, 2009b).The specimens were also compared with authenticated species. Botanical names and authorities were verified using the species and family lists in Volume 8 of the Flora of Ethiopia and Eritrea (Hedberg *et al*., 2009).

2.3. Data analysis

2.3.1. Frequency and Relative Frequency of species

The likelihood or chance of discovering a species in a specific sample area or plots is known as frequency. Mathematicaly, frequency in this study is expressed as a percentage of the total number of plots in which individuals of a given species were recorded divided by the sum total number of the plots taken in the study area.

The following formulas were used in Microsoft Excel spreadsheet programme.

$$\textbf{Frequency (F)} = \frac{\textbf{Number of plots in which species occure}}{\textbf{Total plots laid}}$$

$$\textbf{Relative frequency } (\mathbf{R_{fr}}) = \frac{Frequency of species}{Total\ frequencies} * \mathbf{100}$$

2.3.2. Population structure (DBH and height class distributions)

The study on the population structure, which is defined as the frequency and distribution of individuals defined by DBH or height classes, was carried out for woody species based on the most widely used DBH and height classes in Ethiopia (Gemedo Dalle, 2015; Abiyot Berhanu *et al*., 2017). DBH classified was defined into 21 classes on the following interval. The lower DBH (less than 100cm) were classified at every 10cm interval, while, DBH classes greater than 100 cm were classified at every interval of 25 cm. The DBH classes were classified as: 2.5 – 10, 10.5 – 20, 20.5 – 30, 30.5 – 40, 40.5 – 50, 50.5 – 60, 60.5 – 70, 70.5– 80, 80.5– 90, 90.5– 100, 100.5– 125, 125.5– 150, 150.5– 175,175.5-200, 175.5-200, 200.5-225, 225.5-250, 250.5-275,275.5-300,325.5-350 and >350.

Height classes were classified into ten classes of 5 m intervals. The classes were classified as: 2.5≤ H ≤5, 5.5 – 10, 10.5 –15, 15.5 –20, 20.5 – 25, 25.5 – 30, 30.5 – 35, 35.5 – 40, 40.5 –45 and > 45. To show the population structure: the densities of individuals in the DBH or height classes were summed up, and diagrams were produced using the Microsoft Excel spreadsheet programme. The population structure is an important indicator of forest reproduction and recruitment (Schulz *et al*., 2009).

2.3.3. Woody species density, basal area and dominance

Density (D): is the number of individuals per unit area; It was calculated using a hectare-based count of all the individuals in the study area following (Mueller-Dombois and Ellenberg, 1974). Woody species density was expressed as the number of individuals of a species per hectare. The density and relative density of woody species were calculated using the Microsoft Excel Spreadsheet software. The total species density, which is expressed as the total number of individuals of all species in a hectare, was also calculated to calculate the relative density. Density was calculated using the following formula:

Density (Di) = Density (Di) = $\frac{\boldsymbol{Numberofspeciescounted}}{\boldsymbol{Sampled\ area\ in\ hectar}}$

The relative density was calculated using the following formula:

$$\mathbf{R_{de}} = \frac{\boldsymbol{Di}}{\sum_{i=1}^{s} \boldsymbol{Di}} \mathbf{*100}$$

Where, Rde is the relative density of a species, and Di is the density of the ith species (s); Basal area (m^2 ha-1) was measured as the cross-section area of a tree at breast height, is computed from the measurement of DBH/DSH as follows in Microsoft Excel spreadsheet programme: Ba = $\pi d^2/4$, where π = 3.14, Ba is the basal area, and d is DBH (m). However, since DBH was measured in centimetres, the formula was converted to square meters. Thus, Ba = πd2/40,000 or 0.0000785d2, where d is DBH in centimeters. The mean basal area of all investigated plots was converted to mean basal area per hectare. The basal area provides a better measure of the relative importance of tree species than Simple stem counts (Tamrat Bekele, 1993).
The dominance and relative dominance were calculated as follows:

Do = Bi × Ni,

Where Do is dominance of a species, Bi is mean basal area per species and Ni - number of
Individuals in the ith species

$$\mathbf{R_{do}} = \frac{\boldsymbol{Doi}}{\sum_{i=1}^{S} \boldsymbol{doi}} \mathbf{*100}$$

Where, Rdo is relative dominance and Doi is dominance of the ith species (s).
The variations of structure (density, basal area and dominance) among the forest patches was

2.3.4. Important value index (IVI)

In addition to indicating the relative ecological value of a given woody species in a given site, the Importance Value Index (IVI) is one of the most important tools for identifying threatened woody plants in a given site or area (Kent And Coker, 1992). The IVI of a species signifies the sum of its relative density (RDE), Relative Frequency (RFR) and relative dominance (RDO). That is, IVI = RDE + RFR + RDO. The IVI was computed in a Microsoft Excel spreadsheet programme. Consequently, woody species having the least IVI values were prioritized for conservation and management interventions.

3. Results

3.1. Frequency of Woody plants in lower altitudes

In PMFP, the frequencies of *Combretum collinum, Combretum hartmannianum, Anogeissus leiocarpa,* and *Pterocarpus lucens* were the highest, respectively. Short tress and shrub species such as *Ziziphus mauritiana* and *Gardenia ternifolia* had the highest frequencies. (Table 38 and Appendix-Table 25). In ABFP forest patches, *Terminalia macroptera, Ficus sycomorus,* and *Breonadia salicina* had the highest frequencies; among the shrub layer, *Gardenia ternifolia* had the highest frequency (Table 39 and Appendix-Table 24).

3.2. Frequency, density and basal area woody plants in middle altitude

In BMFP, *Albizia schimperiana, Albizia gummifera*, and *Millettia ferruginea* had the highest frequency and density, followed by short tree species such as *Vernonia amygdalina* and *Grewia ferruginea* (Table 40 and Appendix 23).In BMFP, *Albizia schimperiana, Sapium ellipticum,* and *Cordia africana* had the highest basal area per hectare. Shrubs such as *Vernonia amygdalina and Grewia ferruginea* had the highest basal area per hectare.

3.3. Importance value index of woody species

Pterocarpus lucens, Sterculia africana, and Anogeissus leiocarpa had the highest importance value index, followed by *Combretum collinum* and *Combretum hartmannianum.* Among the shrub layers, *Ziziphus mauritiana* had the highest IVI. In BAFP, *Ficus sycomorus* had the highest IVI, followed by *Syzygium guineense* and *Cordia africana. Gardenia ternifolia* had the highest IVI among shrub layers *(*Tables 38 and 39 and Appendices-Table 25).In BMFP, *Albizia schimperiana, Albizia gummifera,* and *Sapium ellipticum* had the highest IVI, followed by *Millettia ferruginea and Ficus sycomorus. Grewia ferruginea and Vernonia amygdalina* were the shrub layers with the highest *IVI (*Table 40 and Appendix-Table 24*).*

Table 38. Dominant Woody species structural value in PMFP

no	Species	F	AB	RF	D	RD	BA	D	RD	IVI
1	*Combretum collinum*	12	72	4.76	6.78	488.33	16.99	72	9.36	31.33
2	*Pterocarpus lucens*	18	60	7.14	7.54	452.16	15.73	60	7.8	30.88
3	*Anogeissus leiocarpa*	13	52	5.16	6.53	339.62	11.82	52	6.76	23.89
4	*Ziziphus mauritiana*	15	60	5.95	4.24	254.34	8.85	60	7.8	22.72
5	*Sterculia africana*	14	56	5.56	4.4	246.18	8.56	56	7.28	21.51
6	*Hyphaene thebaica*	10	40	3.97	4.71	188.4	6.55	40	5.2	15.81
7	*Boswellia papyrifera*	10	40	3.97	3.77	150.72	5.24	40	5.2	14.48
8	*Strychnos spinosa*	10	40	3.97	3.14	125.6	4.37	40	5.2	13.6
9	*Maytenus senegalensis*	9	27	3.57	2.54	68.67	2.39	27	3.51	9.5
10	*C.hartmannianum*	9	27	3.57	2.54	68.67	2.39	27	3.51	8.21
12	*Lannea schimperi*	8	24	3.17	1.88	45.22	1.57	24	3.12	7.89
11	*Cassia arereh*	7	21	2.78	1.65	34.62	1.2	21	2.73	7.79
14	*Dalbergia melanoxylon*	6	18	2.38	2.26	40.69	1.42	18	2.34	7.46
13	*Combretum molle*	7	21	2.78	2.64	55.39	1.93	21	2.73	7.36
15	*Terminalia laxiflora*	8	24	3.17	2.26	54.26	1.89	24	3.12	6.97
16	*Lonchocarpus laxiflorus*	7	21	2.78	1.98	41.54	1.45	21	2.73	5.8

Table 39. Dominant Woody species structural value in ABFP

No	Species	F	AD	RF	D	RD	BA	D	RD	IVI
1	*F. sycomorus*	12	45	6.06	5.65	254.34	13.74	66.15	6.62	26.41
2	*C.africana*	10	42	5.05	3.96	166.17	8.97	61.74	6.18	20.2
3	*S. kunthianum*	6	30	3.03	7.07	211.95	11.45	44.1	4.41	18.89
4	*S. guineense*	12	32	6.06	3.01	96.46	5.21	47.04	4.71	15.98
5	*B.salicina*	7	35	3.54	3.3	115.4	6.23	51.45	5.15	14.91
6	*Ficus vasta*	7	34	3.54	2.67	90.75	4.9	49.98	5	13.44
7	*G. ternifolia*	6	18.18	3.03	2.54	91.56	4.95	52.92	5.29	13.27
8	*T.schimperiana*	8	33	4.04	2.33	76.94	4.16	48.51	4.85	13.05
9	*Acacia seyal*	6	15.15	3.03	2.83	84.78	4.58	44.1	4.41	12.02
10	*T. macroptera*	6	15.15	3.03	2.36	70.65	3.82	44.1	4.41	11.26
11	*P. reclinata*	7	25	3.54	2.94	73.59	3.97	36.75	3.68	11.19
12	*A. hecatophylla*	5	12.63	2.53	3.14	78.5	4.24	36.75	3.68	10.44
13	*P. thonningii*	5	12.63	2.53	1.96	49.06	2.65	36.75	3.68	8.85
14	*S. africana*	4	8.08	2.02	4.52	72.35	3.91	23.52	2.35	8.28

Table 40. Dominant Woody species structural value in BMFP

	Species	F	AB	RF	D	RD	BA	D	RD	IVI
1	*A. schimperiana*	17	68	5.7	9.07	617.07	21.12	94.44	8.37	35.2
2	*V.amygdalina*	12	48	4.03	6.41	307.47	10.52	66.67	5.91	20.46
3	*M. ferruginea*	15	45	5.03	6.01	270.24	9.25	62.5	5.54	19.83
4	*A. gummifera*	13	40	4.36	5.34	213.52	7.31	55.56	4.93	16.6
5	*Sapium ellipticum*	12	38	4.03	5.07	192.7	6.6	52.78	4.68	15.3
6	*F. angolensis*	10	30	3.36	4	120.11	4.11	41.67	3.69	11.16
7	*F. sycomorus*	9	27	3.02	3.6	97.29	3.33	37.5	3.33	9.68
8	*Cordia africana*	9	27	3.02	3.6	97.29	3.33	37.5	3.33	9.68
9	*Grewia ferruginea*	9	27	3.02	3.6	97.29	3.33	37.5	3.33	9.68
10	*Acacia sieberiana*	8	25	2.68	3.34	83.41	2.86	34.72	3.08	8.62
11	*S. kunthianum*	8	24	2.68	3.2	76.87	2.63	33.33	2.96	8.47
12	*Ficus thonningii*	8	25	2.69	3.3	76.88	2.64	33.34	2.97	8.37
13	*Vepris angolensis*	8	24	2.68	3.2	76.87	2.63	33.33	2.96	8.27
16	*S. abyssinica*	7	21	2.35	2.8	58.85	2.01	29.17	2.59	6.95

3.4. Diameter and height class in BMFP

In BMFP, lower altitude Dry Afromontane forest patches, the dominant species: *Albizia Schimperiana, Albizia gummifera, and Millettia ferrueginea* had irregular DBH (Figure 27).

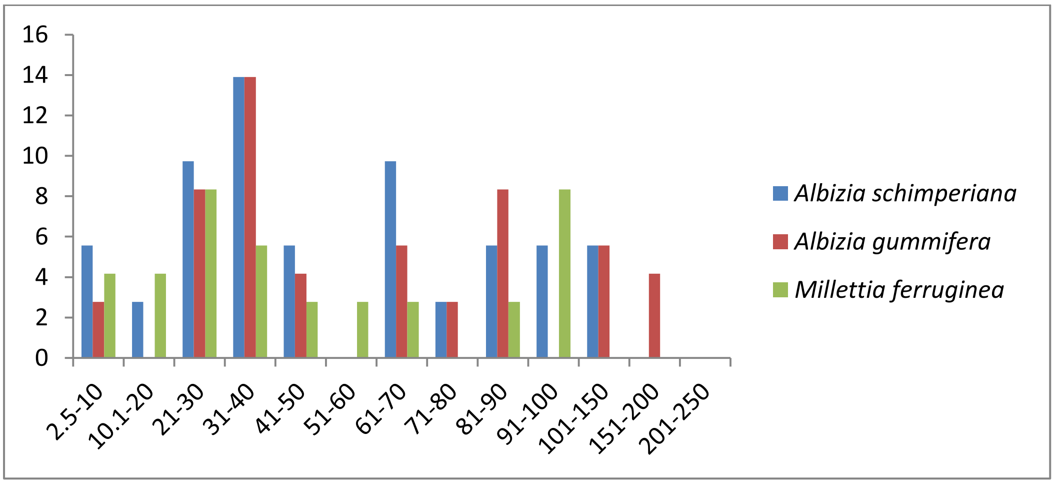

Figure 27. DBH classes density per hectare BMFP

3.5. Diameter and height lower altitude

In PMFP, the wood plant DBH class density per hectare shows an irregular pattern of population arrangements. The DBH classes 31-40 and 21-30 had the highest density per hectare, while DBH classes 71-80 and 201-250 had the least density per hectare (Figure 28). At the species level, *Anogeissus leiocarpa* had a J-shaped population structure. Combretum collinum had an inverted J-shaped population structure.

Terminalia brownie had a U-shaped type of population structure (Figure 28). In ABFP, the DBH class density per hectare shows irregular patterns of population arrangements. The DBH classes of 31–40 and 21–30 had the highest density per hectare. However, DBH classes 71–80 and 201-250 had the least density per hectare (Figures 28–31).

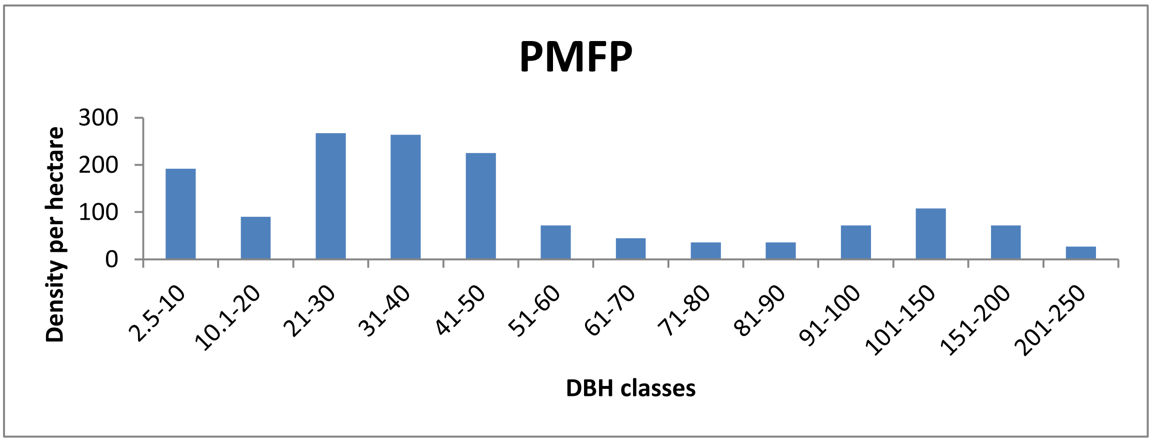

Figure 28. PMFP DBH classes

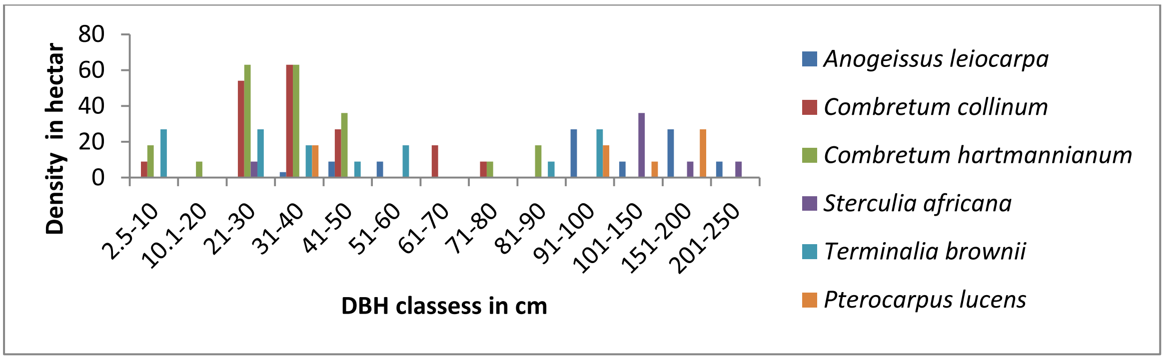

Figure 29. PMFP dominant Species DBH classes

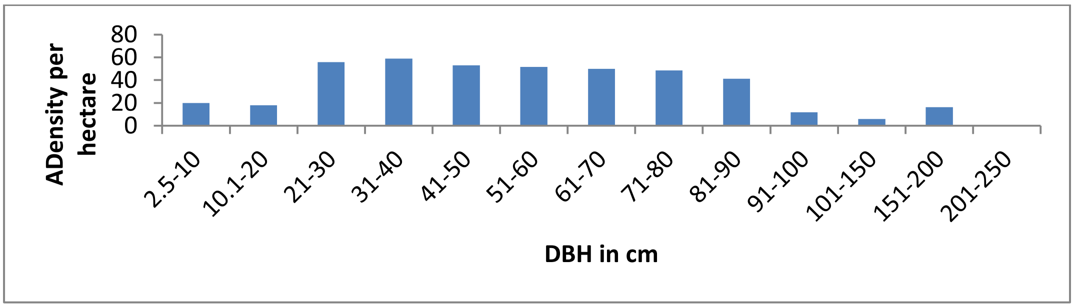

Figure 30. ABFP DBH classes

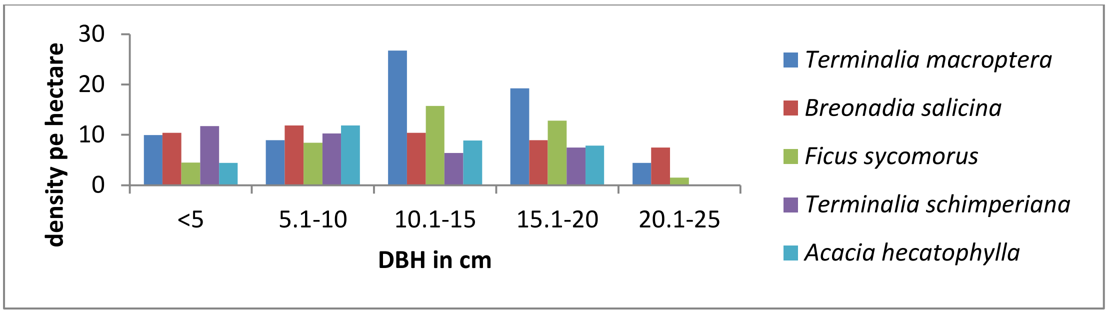

Figure 31. Dominant Woody species DBH classes in ABFP

3.6. Seedling and sapling density

The density of seedlings was higher than saplings per hectare in three forest patches. Seedling and sapling per hectare were highest in PMFP, BAFP, and BMFP, respectively. *Combretum collinum and Ziziphus mauritiana* had the highest number of seedlings and saplings per hectare in PMFP. *Syzygium guineense* had the highest seedlings in ABFP. In BMFP, *Albizia schimperiana* had the highest density per hectare (Table 41).

Table 41.Seedling per hectar in middle and lower altitudes forest

Forest patches	Seedling/ hectare	Sapling/ hectare
PMFP	2492.93	1944.48
BAFP	1447.22	1157.78
BMFP	1870.78	1421.79

4. Discussion

Combretum-Terminalia woodland and wooded grassland are characterized by small to moderately sized trees (*Combretum spp., Terminalia spp., Boswellia papyrifera, Sterculia setigera, Oxytenanthera abyssinica, Balanites aegyptiaca, Annona senegalensis, Acacia Senegal, and Acacia seyal*), along with shrubs, herbs, grasses, and sedge (Demel Teketay, 2000). This ecosystem comprises species from the genera *Combretum and Terminalia* (Combretaceae) and woody species from the Fabaceae of *Lonchocarpus laxiforus, Pterocarpus lucens, Dalbergia melanoxylon, and Piliostigma thonningii* (Tesfaye Awas *et al*., 2001; IB, 2010). Similarly, in this study, PMFP is in the *Compretum-Terminalia* woodland, which consists of the dominant woody trees: *Combretum collinum, Pterocarpus lucens, Sterculia africana,* *Anogeissus leiocarpa, Combretum molle, and Boswellia papyrifera. Hyphaene thebaica* and *Adansonia digitata* were among the riverine plants found in the woodland. The middle layer is dominated by shrubs such as *Ziziphus mauritiana and Strychnos spinosa*. The ground layer is dominated by grasses and a few herbs in intact forests.

ABFP forest is also in *Compretum-Terminalia* woodland and partly in a middle-altitude forest. A few species of ABFP were found in middle-altitude vegetation, whereas others were found in lower-altitude vegetative ecology. The prominent upper canopy trees in the forest areas were *Ficus sycomorus, Syzygium guineense, Terminalia schimperiana, Breonadia salicina,* and *Ficus vasta. Syzygium guineense and Breonadia salicina* are completely riverside trees. *Gardenia ternifolia and Rhus ruspolii* were the dominant shrubs. Few species of PMFP vegetation, such as *Pterocarpus lucens, Sterculia africana, Hyphaene thebaica,* and *Piliostigma thonningii*, were rarely available.

Dry broadleaved deciduous forest, including *Combretum-Terminalia* woodland and wooded grassland between 500 and 1800 meters above sea level, is the predominant kind of natural vegetation in Benshangul Gumuz (UNDP, 2017). Vegetation was intentionally burned in most years, with most woody species adapted to fire (Demel Teketay, 2000). Similarly, PMFP and ABFP are found in dry and wet kola and deciduous woodland. The tree species shed their leaves during the long dry season and regain them during the wet summer season. The herbaceous vegetation layer also withers away in the same manner as the leaves of the trees. So the rejuvenation and the withering are annual phenomena. The litter falls, and the herbaceous biomass creates a huge flammable material that burns towards the middle of the dry season. The fire is also an annual episode that removes deadwood, dry herbaceous material, and little fall. Thus, the plant communities in the area are highly resistant to fire in that they do not succumb to the heat of the bush fire.

4.1 Importance value index of woody species

According to Mehari Girmay (2020), the importance value index of woody species is an important parameter in Compretum-Terminalia woodlands. In this study, the IVI ranges from 0.53 to 31.33 in PMFP and ABFP. In PMFP, the highest IVI values are *Pterocarpus lucens*, *Sterculia africana*, *Anogeissus leiocarpa*, and *Combretum* *collinum*, respectively.The highest degree of adaptability to lower altitude agroecology among the huge woody trees; their frequency, DBH, and abundance, which contribute to IVI. According to Demel Teketay (2000), the majority of woody species are fire-adapted, and every year, vegetation is purposefully burned. The high DBH value suggests their long-term adaptability and compatibility with ecology in a wider range of conditions, including fire, low moisture, and nutrient deficiency in the soil. According to the inhabitants, the fire had been burning annually in the lower ecology for decades. In contrast to plants at higher and middle altitudes, the rate of soil layer formation was quite slow. The sandy nature of the soil, annual foliage burn, high erosion by wind, and floods from high land down the sloping gradients contributed to poor soil layer formation. The soil seed bank and seed rain of those plants germinate and grow into seedlings and mature plants under the influence of fire. Fire contributes the highest value to ecological adaptation at lower altitudes. The second group of plants with a higher IVI value was *Boswellia papyrifera*, *Lannea fruticosa*, and Lannea welwitschii. *Hyphaene thebaica, Adansonia digitata, and Phoenix reclinata* had higher IVI among riverside woody trees.

In ABFP, the highest IVI of *Ficus sycomorus* and *Syzygium guineense* among woody trees is their greater ecological significance than other woody trees. *Ficus sycomorus* has a high frequency and a high DBH that contribute to its IVI. It is generally abundant near a river and far away from the riverbanks. *Syzygium guineense* and *Breonadia salicina* are completely riverside forests. *Terminalia schimperiana*, *Cordia africana*, *Breonadia salicina*, and *Ficus vasta* were the second groups of woody trees that had higher adaptation. The highest IVI of *Gardenia ternifolia* and *Rhus ruspolii* among the shrubs was their adaptation as shade-tolerant under large woody trees.

4.2. Conservation traditions

In woodland agroecology, shifting cultivation and semi-agroforestry are unique means of conservation strategy. They deforest intact forests and burn the slash for crop cultivation. After three to five years of cultivation, they abandon the cropland and look for other forest patches. The abandoned lands are regenerated within 6 to 10 years (Berihun Mekonnen, 2004).Discussions with locals reveal that, there are various ways that vegetation regenerates some species sprout from the ruminant slash woods, some species regenerate from roots that survive in the soil, and some species regenerate from soil seed banks from soil or animal-dispersed seeds. Thus, shifting cultivation is one way of conserving strategy Gumuz ethnic groups in woodland agroecology.

The species richness and diversity showed a bell-shaped pattern along the altitudinal gradient with a peak at intermediate altitudes and a declining pattern towards the lower and upper altitudes (Motuma Didita *et al*., 2010). The floristic abundance and diversity of woodland species increase from PMFP to ABFP due to relative altitudinal gradients. The increment is related to the increase in altitude, which further increases moisture.

4.3. Floristic compositions of middle altitude

In the Tara Gedam and Zege Peninsula forests, climax tree species such as *Albizia gummifera* and *Millettia ferruginea* were found to have the highest density (Alemnew Alelign *et al*., 2007; Haileab Zegeye *et al*., 2011).Albizia schimperiana, Albizia gummifera, and Millettia ferruginea were also the most common species in this study, followed by shrubs like Vernonia amygdalina and Grewia ferruginea. Tree species like *Albizia gumifera* and *Albizia schimperiana* have an ecological influence by protecting subsurface water, preserving soil fertility, and maintaining the land's humidity on the farm (Melaku Getahun, 2016). Similarly, in this study, the conservation methods in BMFP are primarily related to agro-forestry, traditional belief practices, and beekeeping. Agro-forestry agriculture is the source of income for those living in the middle latitudes. They have grown coffee near the river edge under vast, unbroken forests, preserving tree species such as *Cordia africana*, *Albizia gumifera*, and *Albizia schimperiana* for decades; they possess forest patches named after their clan, preventing unauthorized entry. They also have local agreements or customs that force the community not to extract specially selected species like *Ficus sure* and *Ficus sycomorus* around the mouths of rivers and streams. These trees used social gatherings, such as “eqube” (microeconomic activity), and annual rituals. They keep *Ficus sycomorus* around river banks for cattle to arrive under during intensive sunlight, heavy rain, and windy conditions. Thus, *Ficus sycomorus is conserved* by social and traditional custums. The practice is an analogy to the northern parts of Ethiopia, where they conserve church forests at local scales (e.g., Alemayehu

Wassie *et al.*, 2010; Asmelash Berhane *et al*., 2013), but there is no information on the contribution of church forests to the conservation of biodiversity and ecosystem services at a larger scale.

The higher frequency, abundance, and DBH of *Albizia schimperiana*, *Albizia gummifera,* and *Millettia ferruginea* contributed to a higher basal area per hectare in BMFP. Among shrubs, *Vernonia amygdalina* had a higher basal area per hectare. Their higher frequency and abundance are related to ecological adaptation to the middle layer. These plants had higher regenerative potential than others.

Among the woody trees in BMFP, Albizia schimperiana, Albizia gummifera, Sapium ellipticum, and Millettia ferruginea had the highest IVI, indicating their good ecological adaptability to middle-altitude agroecology. These woody tree species had the highest regeneration potential. The seed bank germinates massively, and the root proliferates when the steam part of the plant is damaged or slashed. The edible seeds of *Albizia schimperiana*, *Albizia gummifera,* and *Millettia ferruginea* are widely distributed by wild animals. *Fagaropsis angolensis, Ficus sycomorus, Stereospermum kunthianum, Acacia sieberiana, and Cordia africana* were the second group in BMFP with a higher IVI. The irregularity of DBH and height of *Albizia Schimperiana*, *Albizia gummifera,* and *Millettia ferrueginea* in BMFP were related to species regeneration and dispersal. These species massively produce seeds that are edible by wild animals and dispersed widely. They also regenerate through soil seed bank, root proliferation when the stem part is damaged, and sprouting of slashed stems.

Conclusion

Combretum-Terminalia woodland and wooded grassland consist of the dominant woody trees: *Combretum collinum, Pterocarpus lucens, Sterculia africana, Anogeissus leiocarpa, Combretum molle, and Boswellia papyrifera*. *Hyphaene thebaica* and *Adansonia digitata* were among the riverine plants found in the woodland. ABFP forest is also in *Compretum-Terminalia* woodlands and partly in middle-altitude forest. The prominent upper canopy trees in the forest areas were *Ficus sycomorus, Syzygium guineense*, *Terminalia schimperiana*, *Breonadia* *salicina*, and *Ficus vasta*. *Syzygium guineense* and *Breonadia salicina* are completely riverside trees. These plants have adapted to fire and shallow soil layers. BMFP shares a boundary with ABFP, which is the middle altitude, dominated by *Albizia schimperiana*, *Albizia gummifera*, and *Millettia ferruginea*. Shifting cultivation is a unique conservation strategy in PMFP and ABFP, whereas agroforestry is a prominent trend in BMFP.

CHAPTER SEVEN

7. General Discussion

7.1 General discussion

7.1.1. Floristic Composition and Diversity

The vegetation of the district is classified under the dry evergreen Afromontane forest and grassland complex and the *Combretum-Terminalia* woodland and wooded grassland, following Friis *et al.* (2011). Thus, among the forest patches of Wombera district, GTFP, SLFP, and MBF are under DAF; BMFP is as moist Afromontane forests, and PMFP and ABFP are classified as Combretum-Terminalia woodland and wooded grassland. The general vegetation richness of a forest was due to an altitudinal gradient, as stated in different studies (examples: Zerihun Woldu *et al.*, 1989; Kumelachew Yeshitila and Tamrat Bekele, 2002; Motuma Didita *et al*., 2010; Tadesse Woldemariam *et al*., 2008; Schmitt *et al*., 2010; Ermias Lulekal, 2014). Similarly, the vegetation richness of the district is due to an altitudinal gradient that extends from 560-2015 m.a.sl. The Ethiopian flora is very heterogeneous and has a rich endemic plant species (Ensermu Kelbessa & Sebsebe Demissew, 2014). The diversification is due to landscape structure (Demel Teketay, 2001; EBI, 2014; Friis *et al*., 2011). Thus, the topographic structure, undulating landscape, deep gorges, mountain peaks, plains, rivers, and river gorges created microclimates that harboured different plant species.

7.1.2. Floristic composition Pioneer intimidates and climax forests

In Pioneer forest patches shrubs and lower canopy trres facilitate the establishment of woody late-successional plant species and thus can positively affect reforestation success in many different ecological settings (Gómez et al., 2004). Similarly, in this study, pioneer forests were dominated by fast-growing tree species such as *Nuxia congesta*, *Maesa lanceolata*, *Maytenus arbutifola*, and *Acacia abyssinica.* These plants colonize grasslands, farmlands, bare land, and abandoned lands and eventually develop pioneer forests. Lower-layer canopy trees can survive and regenerate in low nutrient soil than middle- and upper-layer canopy trees. According to Althof (2005), pioneer species are fast-growing and light-demanding, with seeds only germinating in full sunlight and seedlings not surviving in the shade. These species are the first members of the succession stage.

Intermediately disturbed pioneer forests had higher species richness and diversity than intact and highly disturbed pioneer forests. In parts of moderately disturbed forests, the availability of free space allows establishments (seed germination and growth) for newly dispersed species. Intact forests have no free available space for newly arriving species to host. In intact forests, the competition may be interspecific or intraspecific among the species for space and resources that hinder the entry and growth of other species. Similarly, Althof (2005) stated that species richness was highest in disturbed forest sites. It is a mixture of pioneer, climax, and bushland species that could be recorded there. Therefore, high species richness is not a suitable indicator for forest quality. In highly disturbed forests, the over-extraction and selective cutting of trees by residents and grazing by animals minimize the composition and diversity. They over-extract different tree species at different DBH and height levels. The grazing animals consume the seedlings and saplings of the middle and upper canopy trees, and the ground layer is covered by herbs and grasses.

7.1.3. Floristic composition Intimidate forest

Middle-layer canopy trees: *Allophyllus abyssinicus, Hagenia abyssinica,* and *Dombeya torrida, and climbers: Lagenaria siceraria, Urera hypselodendron, Kalanchoe Clematis simensis, Jusminum abyssinicum,* and *Stephania abyssinica* form intermediate forest patches. Similar to intact pioneer forests, the ground layer of intact intermediate forests is covered in a sparse understory of grasses and herbs. On the other hand, areas that had been moderately disturbed were covered with grasses, herbs, and seedlings of various woody species.

In disturbed sites, secondary forests, and forest edges, *Rytigynia neglecta*, *Croton macrostachyus, Maytenus arbutifolia, and Bersama abyssinica* act as gap fillers (Tamrat Bekele, 1993; Gemedo Dalle & Masresha Fetene, 2004; Abiyot Berhanu *et al*., 2017). In the current study, the ground layer of disturbed forest is occupied with invasive woody trees, herbaceous plants, grasses, and a few seedlings and saplings in parts of the forest that have been overharvested by the local people and grazed by domestic animals. Saplings and lower DBH plants of *Syzygium guineense, Ficus sur,* *Olea europaea, Allophyllus abyssinicus, Prunus Africana, Apodytes dimidiata, and Ekebergia capensis* also dominated the intermediate forest. Moderately disturbed intermediate forests had greater diversity than intact and highly disturbed forests. In extensively disturbed forests, certain species that seek disturbance, such *as Schefflera abyssinica* and *Croton macrostachyus* flourish because of the free space.

7.1.4. Floristic composition Climax forest

The upper canopy trees: *Syzygium guineense, Ficus sur*, *Olea europaea*, *Prunus africana*, *Apodytes dimidiata*, and *Ekebergia capensis*, established the climax forests. According to previous studies (Tamrat Bekele, 1993; Zerihun Woldu, 1999; Friis *et al*., 2010), species such as *Podocarpus falcatus*, *Apodytes dimidiata*, *and Prunus africana* cover the top canopy. According to Althof (2005), climax species are all plant species that evolved after the pioneer species and happened at various phases of the succession of the early and later climax species. Climax forests with varying degrees of disturbance are made up of upper canopy trees, some middle layer canopy trees, and a small number of lower canopy trees that can withstand shade.In Climax intact forest parts, the ground layer are covered by a few herbs and grasses. Mother trees negatively influence the germination of seeds and the establishment of seedlings under their canopies (White, 1983; Bin et al., 2012). Similarly, seedlings and saplings are lower in intact forests. The lower abundance of ground layer flora, seedlings, and saplings in an intact climax may be due to (1) excessive shadow that prevents light and air from penetrating the canopy and (2) the allelopathic action of upper canopy trees, which inhibits the germination of soil seed banks.

In moderately disturbed climax forest parts, the upper canopy trees are similar in composition with those intact forest parts; however, the ground layer is covered with more grasses, herbs, seedlings, and saplings. *Teclea nobilis and Maytenus arbutifola cover the lowest layer*. *Schefflera abyssinica and Croton macrostachyus* cover the middle layer. Similarly, Zerihun Woldu (1999) explained dry Afromontane forests as multistoried vegetation with a nonuniform top layer of tall, emergent trees above the vegetation mass. A study by Feyera Senbeta (2006) also elaborated that the moist afromontane forest forms three strata: upper, middle and lower. Rahman *et al*. (2009) also classify the canopy of trees in forest strata as dominant, co-dominant, intermediate and suppressed. In the current study, the forest layer is classified vertically as lower canopy in pioneer, middle canopy in intermidiate and upper canopy in climax forests.

7.1.5. Floristic compositions of middle altitude

In BMFP, which is the middle altitude forest patch, *Albizia schimperiana*, *Albizia gummifera,* and *Millettia ferruginea* were dominant, followed by shrubs such as *Vernonia amygdalina* and *Grewia ferruginea*. Climax tree species such as *Albizia gummifera* and *Millettia ferruginea* were also reported as having the highest density in Tara Gedam and Zege Peninsula forests, respectively (Alemnew Alelign et al., 2007; Haileab Zegeye et al., 2011).

7.1.6. Floristic composition of woodland Forests

PMFP is in the *Compretum-Terminalia* woodland, which consists of the dominant woody trees: *Combretum collinum, Pterocarpus lucens, Sterculia africana, Anogeissus leiocarpa, Combretum molle, and Boswellia papyrifera; Hyphaene thebaica and Adansonia digitata* were the riverine vegetation of the woodland species. The middle layer was dominated by shrubs such as *Ziziphus mauritiana and Strychnos spinosa.* The ground layer is mainly dominated by grasses and a few herbs in intact forest parts. Similarly, ABFP is also in *Cmpretum-Terminalia* woodland, close to the moist Afromontane forests. ABFP shares a few species with the middle-altitude vegetation and more species with the lower-altitude vegetation ecology. *Ficus sycomorus, Syzygium guineense, Terminalia schimperiana, Breonadia salicina,* and *Ficus vasta* were the dominant upper canopy trees of the forest patches. *Syzygium guineense* and *Breonadia salicina* are completely riverside trees. These species were situated below the mountain foot. *Gardenia ternifolia* and *Rhus ruspolii* were the dominant shrubs. Studies by other scholars (Tesfaye *et al.*, 200; Ib *et al.*, 2010) also stated that the ecosystem comprises species from the genera Combretum and Terminalia (Combretaceae) and woody species from the Fabaceae of *Lonchocarpus laxiforus, Pterocarpus lucens, Dalbergia melanoxylon, and Piliostigma thonningii*.

PMFP and ABFP are in the deciduous woodlands of the dry and wet ecosystems of Ethiopia, respectively. The tree species shed their leaves during the long dry season and regain them during the wet summer season. The grass is burned throughout the dry season so that fresh grass grows in the summer (Tesfaye *et al.*, 2001; Ib *et al.*, 2010). The herbaceous vegetation layer also withers away in the same manner as the leaves of the trees. So, the rejuvenation and the withering are annual phenomena. The litter falls, and the herbaceous biomass creates a huge flammable material that burns towards the middle of the dry season. The fire is an annual event that removes dead wood, dry herbaceous debris, and litter. The plant communities in the area are highly resistant to fire in that they do not succumb to the heat of the bush fire. Frequent intensive disturbances, such as fire, are another factor in the decrement of seedlings and lower DBH trees along the altitudinal gradients.

7.2 Land use land cover change

Seven major LULCC types: forest, woodland, scrub/bushland, grassland/rangeland, farmland, water bodies, and settlements were identified using the field data and satellite images of Landsat MSS 1973, Landsat TM 1985, Landsat ETM+ 2000, and Landsat OLI/TIRS 2016. The woodlands have the highest proportions among the identified LULCCs. The farmland was the second dominant and increased drastically; the woodlands, forests, and shrublands were decreasing in size. Settlements, farmlands, and grasslands were increasing in size. Six indirect driving forces, such as demographics, socio-culture, economy, natural disasters, institutions, and technological development, were identified. Five direct driving forces, such as farming, fire, logging, and. grazing, were also identified. Landuse and cover change is a complex process influenced by environmental and social factors at various spatial and temporal scales (Valbuena *et al*., 2008; Rindfuss *et al*., 2004). Land use changes are increasingly known as the consequence of actors and factors' interactions (Bakker and van Doorn, 2009). Similarly, in the district, the LULC is the result of the interaction of the direct and indirect driving forces. The demographic driving force was the leading agent of LULCCs from 1973 to 2016 in the three agroecological activities, followed by culture and economic income activities. Farming activities were the highest among the proximate causes of LULCCs from 1973–2016 in the higher, middle, and lower agroecological zones. Forests, woodland, and shrublands were converted to croplands annually. Among the temporal disasters, fire had the highest impact on LULCCs in the lower altitudes between 1973 and 1985, followed by logging and firewood collection.

7.2. Conclusion

From 142 sampling plots, 375 species representing 90 families and 70 genera were gathered, with the richest genera and families being Fabaceae, Asteraceae, and Poaceae. These plants were classified into six plant community types: *Nuxia congesta-Maesa lanceolata (CI), Allophyllus abyssinicus-Hagenia abyssinica (CII), Apodytes dimidiata-Prunus Africana (CII), Combretum collinum-Pterocarpus lucens (CIV), Ficus sycomorus-Acacia hecatophylla (V*) and *Albiza schimperiana-Millettia ferruginea (VI).*

Forest ecology establishment begins with grasslands, farmlands, and bare lands colonized by lower-canopy trees, forming pioneer forests. Transitional forest patches emerge, with middle-canopy trees dominating. Upper-canopy trees emerge, forming climax forests, the last stage of the forest layer. Plant species composition is influenced by disturbance gradients and vegetation succession stages, with pioneer species impacting land usage and intermediate stages allowing varied plant species to survive. In the intermediate stage phase of forest patches, the pioneer species are declining while the climax forests are increasing in species composition. Along age gradients, species diversity was highest in intermediate, pioneer, and climax forest patches, respectively. Along disturbance gradients, plant species diversity was highest in moderately disturbed forest patches, followed by intact and highly disturbed forest patches, respectively. Lower-layer canopy trees can survive and regenerate in lower soil nutrients than middle- and upper-canopy trees. Middle-canopy trees dominated in intermediate forests, but upper-canopy trees dominated in climax forests.

Vegetation distribution is greatly affected by altitude, slope, and disturbance factors such as grazing, fire, logging, and firewood collection. Altitude and fire mainly determine the distribution of vegetation in the district. The existence of forest resources in the district is greatly due to traditional conservation practices like shifting cultivation of the gumuze ethnic group in lower altitudes, private own forest patches in higher altitudes and agroforestry forest conservation mechanisms in middle altitudes.

The woodlands account for the highest proportions among the identified LULCCs. The farmland was the second dominant and was increasing drastically from year to year. Woodlands, forests, and shrublands were decreasing; however, settlements, farmlands, and grasslands were increasing. The demographic driving force was the leading agent of LULCCs from 1973 to 2016 in the three agroecological activities, followed by culture and economic-generating activities. Farming activities were the highest among the proximate causes of LULCCs from 1973–2016 in the higher and middle agroecological zones. Vegetable covers were directly converted to croplands annually. Among the temporal disasters, a fire had the highest impact on LULCC in the lower altitude from 1973 and 1985. Logging and firewood collection had second and third values at higher altitudes.

7.3. Recommendations

This study finaly recommended the stake holders:

1,The objective of the study was to assess the floristic structural composition, diversity, and richness of the six selected forest patches; however, some parameters, like the carbon inventory, soil seed bank, and soil nutritional composition, were not investigated and should be studied in future research.

2. Further studies on the vegetation structure of climax, intermediate, and pioneer forests should be conducted using advanced vegetation modelling approaches.
3. Forest conservationists should plan reforestation initiatives taking into account the pioneer, middle, and climax successional patterns.
4. Government and non-governmental organizations should promote cultural forest conservation initiatives, including shifting agriculture to lower agro-ecology, agroforestry at medium altitude, and private forest ownership and protection at higher altitude.
5. The LULCC should be carried out further by combining vegetation structure along altitudinal and disturbance gradients with more visible satellite images with small pixel sizes and modelling techniques.

6.Using plant resources for different purpose such as charcoal (CH), firewood (FW), timber/furniture (TF), poles/posts (PP), farm tools/handles (FT), carvings/utensils (CU), animal feed (FA), medicine/stimulant (MS), house fence (HF), and traditional ceremonial (TC) should be substituted with synthesized factory products.

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APPENDICES

Appendix 1. Topography

The topography of the study area is undulating type and has only a few plains. The altitude of the wombera district ranges from 576 to 2615.All three agro-ecological zones have different and intricate topography.The district entire land area was divided into three agroecologies: higher altitude (dega), middle altitude (weyina dega), and lower altitude (kola).The classifications of agroecology were based on the vegetation strata, crop productivity and altitude range. Combretum-Terminalia forest and woodland dominate the lower elevations, ranging from 576 to 1,200 ma.s.l.

The majority of the study area lay in the lower altitude followed by higher altitude area with altitudes ranging between 2001-2616 ma.s.l.The middle agroecology ranges between 1201 and 2000 ma.s.l.The vegetation layers mainly dominated by: *Albizia schimperiana*, *Albizia gummifera*, *Millettia ferruginea Cordia africana*, and *Ficus.sp.* Dry Afromontane forests with different sub-layers dominate the upper elevations.

Appendix 2. Geology and soils

The soil types of wombera district are classified into five types as shown in Appendix-Figure 2: Dystic nitosols (50%), Eutric nitosols or chromic verti (16.66%), Orthic acrisols or dystric nitosols (16.66%) and Dystric combisoles (11.11%) (FAO, 2000). The soil type in the lower and higher altitude is Dystic nitosols. The vegetation in the higher altitudes: GTFP, SLFP and MBFP and lower altitudes (PMFP) are on Dystic nitosols. According to Mohr (1972), the bulk of the plateau where the Afromontane vegetation occurs is characterized by Black soil that consists of volcanic rocks.

Appendix 3.Demographic and Socio-Economic Characteristics

Peoples of different ethnic affiliations with their distinct languages, cultural practices and socio-economic formations inhabit the district. Gumuz, Shinasha, Oromo, and Amhara are the most predominant ethnic groups. Other ethnic groups, such as Agaws, Tigryans, and Berta, are few in number. Nilo-Saharan (Gumuz and Berta), Omotic (Shinasha), Cushitic (Oromo and Agaw), and Semitic (Amhara and Tigryans) are the four Ethiopian languages families represented in the district (APBBGCA, 2013). According to the Ethiopian CSA census report of 2007, the district has 60000 people (29196 men and 30804 women) (Appendix-Table 1). According to demographic forecasts of 2014, the population has grown to 73029 people, an increase of 1816 people per year.

Appendix-Table 1 Population census and projection

	Urban and rural			**Urban**			**Rural**		
	Both sex	Male	Female	Both sex	Male	Female	Both sex	Male	Female
2007	60,000	29196	30804	5476	2619	2857	54524	26577	27947
2014	73029	35424	37605	9773	4659	5114	63256	30765	32491
2016	76920	37288	39660	11119	5290	5829	65829	31998	33831

Source: CSE 2007, projection 2014 and 2016

Appendix 4. Human Population parameters

The data were collected from primary and secondary sources. The primary data was obtained from households living in or adjacent to forest patches. Target populations were selected based on the distance of the village from the forest boundary.At the end of the preliminary survey, 3155 households were identified as the total population (Appendix-Table 2).

Appendix-Table 2. . Population sampled, FGD, and KII

Study sites	Stastical sampling		Purposive sampling		
	HH	sampled	FGD	KII	Total
GTFP	800	50	8	5	62
SLFP	900	51	10	6	69
MBFP	1000	54	10	5	74
BMFP	600	52	8	6	70
BAFP	450	51	10	6	67
PMFP	280	45	8	5	62
Total	3155	305	54	33	406

HH= house hold, FGD =Focus group discussion, and KII = Key informant interview

Appendix 5. The livelihood of the population

Highland settlers (Dega)

Shinasha, Oromo, and Amhara ethnic inhabit on the highlands, according to the district administrative settlement classification. The study area altitudes range from 2000 to 2,615 meters above sea level, with few mountains exceeding 2600 meters in some places, primarily in the centre of the district. The highland is conducive for mixing farming; the crops grown in the highland part of Wombera include cereals (teff, barley, wheat, and *barley)*, pulse (bean, pea, chickpea), oilseeds (*niger seed, Guizotia abyssinica) seed and linseed (Linum usitatissimum),* root crops (potato) and, vegetables (cabbage, onion, tomato).

Appendix 6. The animal population

Wild animals

Wild animals such as the Bush Pig, Leopard, Hyena, Anubis Baboon, Colobus Monkey, and lions, Common Duiker, Several Cats, and Common Bush Buck, are abundant in the forests Patches. Gumuz ethics depend upon shifting cultivation and hunting; they cultivate the ground after slash-burning for 3-5 years, then abandon it for wild animals and seek out woodland. This trend had been going on for many years, turn by turn. During slash-burning, wild animals relocate to surrounding forests, abandoned farms, and neighbouring countries. The wild animals move back and forth to the abandoned lands and forests alternatively. Fire is another serious issue at lower elevations. Fire is set off on a yearly basis for farming and hunting, but it can sometimes happen accidentally. The wild animals are adapted to these cyclic disturbances of shifting cultivation and deliberate and uncontrolled fire. These adaptation and routine practices are indigenous conservation mechanisms for the local inhabitants.

Livestock Population

Livestock husbandry is the other agricultural activity next to crop cultivation. Appendix-Table 3 shows the animal population in the Wombera district from 2008 to 2018. Inhabitants of the highlands engage in agriculture and animal husbandry, while those at the medium altitudes engage in agroforestry, with coffee and spices as the main products. Because livestock diseases are common at the middle and lower altitude ranges, animal husbandry is lower compared to higher altitude. The people in the low altitude areas depend mainly on shifting agriculture, hunting and primitive gold mining (Ward, 2014).

Appendix-Table 3. Number of livestock and types

Animals	Year and number of livestocks								
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cattle	92869	93658	93,756	94,123	94,564	95675	95832	96150	96450
Sheep	32539	34756	34,897	36342	36, 875	37123	37431	37500	37634
Goats	30056	30234	30,352	31546	31, 764	32520	32528	32570	32765
Mules	1065	1189	1263	1466	1479	1543	1620	1710	1920
Horses	1253	1432	1465	1533	1584	1693	1718	1748	1825
Donkeys	8291	8563	8649	9067	9075	9114	9123	9143	9165
Chickens	76451	76876	76,987	78,543	78764	79243	79473	79754	79875
Total	242524	246708	247369	252620	254105	256911	255525	258575	259634

Source 2007 census

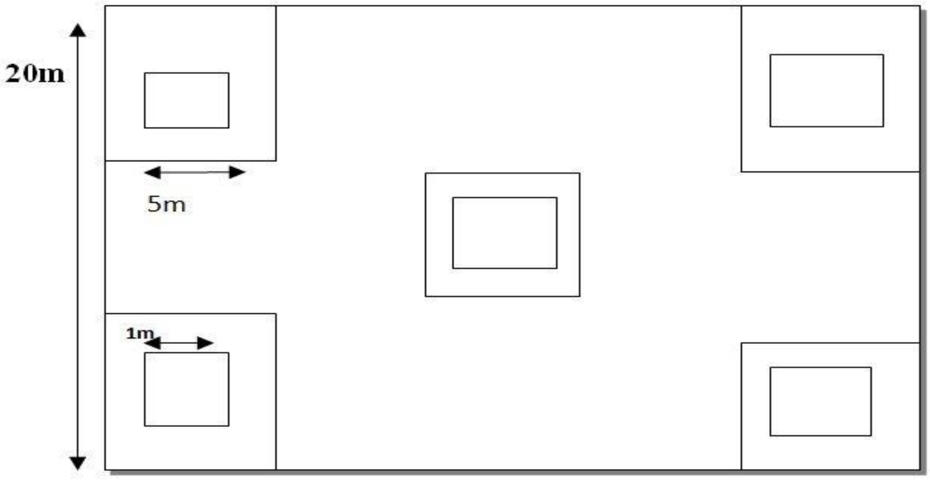
Appendix 7 .Forest patches selection in the district

The six forest patches were selected because of their accessibility and proximity to roads and inhabitants. They were selected to sample vegetation, physical parameters, disturbance factors and environmental data: Gesengesa-Tumi forest patch (GTFP), Senkora-lopi patch (SLFP) and Menesib-Babo patch (MBFP), Bolele-Minjo patch (BMFP), Ababuta-Begondi forest patch (ABFP) and Pire-Muse forest patch (PMFP) (Figure 1). The six forest patches were studied for general evaluation, whereas GTFP, SLFP, and MBFP were used to analyze the dynamics of forest patches along age and disturbance gradients. Features of the forests were summarized in Appendix-Table 4.

Appendix-Table 4. General Features of forest patches

Forest patches	Altitude	Landscape	General features
GTFP	2000-2400	Flat & undulating	Semi-Closed by residents Oval in shape, the core zone or the intact in the center
SLFP	2000-2615	Flat and undulating	Semi-Closed by residents elongated shape the disturbance gradients along the length of forest
MBFP	1800-2500	Flat and undulating	Semi-Closed by residents exposed to anthropogenic disturbance
BMFP	1600-2000	Highly undulating	Open, for disturbance
ABFP	1000-1600	undulating	Open for disturbance such as fire and over exploitation by local community and others
BMFP	1600-2000	Highly undulating	Open, for disturbance
PMFP	576-1000	Flat	Open highly and exposed to disturbance such as fire and local community and others

Source**:** collected by Girma Gudesho (2016)



Appendix-Figure 1 Quadrants and Nested quadrates

Appendix-Table 5. Indirect driving force of LULCC

Indirect Driving forces	Descriptions
Demographic	Population dynamics: population growth, and population movement from somewhere.
Economic	In addition to farming activity for food security they engage in different income generating job opportunities: timber production, cash crop harvesting, charcoal production, pole harvesting and fire wood harvesting, and mining for their livelyhood.
Technological and infrastructure advancement	Improvements of rural road networks, Access to markets, improvements of farming technologies from manual, animal plogh to mechanized agriculture such tractors, combines etc. Access to agricultural inputs: Fertilizers, herbicides, hybrids of seeds and animals.
Institutional policy change	Resettlements programs due natural disasters, conflicts and economic policy. Investments for economic developments. Making free access of natural resource for the community. Biasness for natural resource conservation.
Socio-cultural	Using resource for social or cultural values. Natural resource extraction for socio-cultural practice such as' Meskel' ceremony, different tree species were extracted for specific cultural celebration for high land dwellers, over exploitation of forest resouces. Burning forest for sake of hunting,avoiding dangerous wild animals such as snake
Disaster	Disaster that cause permanent LULCC: long years of drought, heavey floods, and Land slides

Appendix-Table 6.Direct driving causes of LULCC

Direct cause	Descriptions
Farming (crop cultivations)	Farming activity includes growing of crops, vegetables, cash crops in farm lands, forest, shrub lands, woodlands
Temporal Disaster (Fire, wind, flood	Fire is used to prepare farmlands, for hunting, grass regeneration, fighting wild dangerous wildlife however, and unwise use may result in destructions of an ecosystem in lower and middle altitude.
Logging	Logging to extract timber for construction and other domestic uses
Fire wood	used for cooking and light
Grazing (by livestock)	Livestock graze grass, herbaceous and seedling of large trees

Appendix-Table 7. LULCC differentiated during field survey

LULCCs	Descriptions
Dense Forests	A land covers by Pioneer tress to climax forests
Disturbed forest	A forest which disturbed by local community
Highly disturbed forest	A forest where the resources are highly over extracted
Shrub	Small tree, shrubs, bushes and pioneer forests on abandon lands
Grass land	The land covered by grass and herbaceous.
Settlement	It includes urban centers, villages and camps
Water bodies	It includes rivers, dams and swamps and wet lands
Wood lands	The land covered with both open and closed (high) woodland with dominant species of Combretum-Terminalia wood land vegetation.
Farm lands	all cultivated land which includes crops (teff, barley, wheat), vegetable (cabbage, fruits), and cash crops(sesame)
Plantations	Plantations including Eucalyptus trees and Junipers procera
Riverine vegetations	All vegetations by the sides of rivers
Forest coffee	Coffee farm with upper canopy trees and coffee tree as understory
Wetlands	Bogs and muddy areas,
Rocks	Rock surfaces
Sand and stone quarry	Sandy areas and stone areas
Roads	Different sizes of rural rods

Appendix-Table 8 Floristic composition of GTFP, SLFP and MBFP

Species	Family	Type	Vernicular	Code
Acacia abyssinica Hochst. ex Benth.	Fabaceae	Tree	dodota	GSM91
Acanthus pubescens (Oliv.) Engl.	Acanthaceae	Shrub	kossoru	GSM67
Achranthes aspera L.	Amaranthaceae	herb		GSM111
Achyrospermum schimperi (Hochest.ex	Laminaceae	herb	kusayee	GSM22
Allophyllus abyssinicus (Hochest.) Radlk.	Sapindaceae	Tree		GSM92
Amaranthus spinosus L	Amaranthaceae	herb	iyassu	GSM23
Ampelocissus bombycina (Bak.) Planch.	Vitaceae	herb		GSM115
Apodytes dimidiata E. Mey. ex Arn.	Icacinaceae	Tree		GSM93
Arisaema schimperanum Schott	Araceae	herb	Boqoolo or	GSM24
Asparagus africanus Lam.	Asparagaceae	herb	Sariiti	GSM25
Baden prestinaria	Asteraceae	herb	Keloo	GSM26
Bersama abyssinica Fresen.	Melianthaceae	Shrub		GSM116
Bidens biternata (Lour.) Merr.& Sherff	Asteracea	herb	Qamate keloo	GSM27
Bidens ghedoensis Mesfin	Asterace	herb	keloo	GSM28
Bidens pilosa L.	Asteraceae	herb	Maxxanne	GSM29
Bothriocline schimperi Oliv. &Hiern ex	Asteraceae	herb	Tufoo	GSM117
Brucea antidysenterica J.F. Mill.	Simaroubaceae	Shrub	Qomanyo	GSM68
Buddleja polystachya Fresen.	Loganiaceae	Tree		GSM118
Caesalpinia decapetala (Roth) Alston	Fabaceae	Climber	Harangama	GSM10
Canthium oligocarpum Hiern	Rubiaceae	Shrub		GSM119
Carduus schimperi Sch. Bip. ex. A. Rich	Asteraceae	herb	qoratti hare	GSM30

Clematis simensis Fresen.	Ranunculaceae	Climber	Fiiti	GSM01
Croton macrostachyus Huchst.ex Del.	Ephorbiaceae	Tree	Bakkanniisa	GSM120
Cyathula uncinulata (Schrad.) Schinz	Amaranthaceae	herb	Qamate	GSM31
Cynodon dactylon (L.) Pers.	Poaceae	herb	Coqorsa	GSM45
Cynoglosum geometricum (Bak. & Wright)	Boraginaceae	herb	Maxxanee	GSM32
Cyperus digitatus Roxb.	Cyperaceae	herb	Caffee	GSM46
Cyperus fischerianus A.Rich.	Cyperaceae	herb	qunii	GSM17
Cyperus longus L.	Cyperaceae	herb	Qunni	GSM47
Cyperus richardii Steud.	Cyperaceae	herb	Qunni	GSM48
Cyphostemma cyphopetalum (Fresen.)	Vitaceae	herb		GSM121
Datura stramonium L.	Solanaceae	herb	Asaangira	GSM49
Digitaria abyssinica (Hochst.ex arich.stap	Poaceae	herb	Margaa	GSM18
Dombeya torrida (J. F. Gmel.) P. Bamps	Sterculiaceae	Tree	adanissa	GSM138
Dracaena steudneri Engl.	Dracaenaceae	Tree		GSM95
Ebelia schimperi Vatke	Myrsinaceae	Climber	Anquu	GSM03
Echinops ellenbeckii O.Hoffm.	Asteraceae	Shrub	Sokoruu	GSM86
Species	Family	Type	Local Name	Code
Echinops giganteus A.Rich.	Asteraceae	herb	Koshoshila	GSM33
Ekebergia capensis Sparrm.	Meliaceae	Tree		GSM112
Eleusine jaegeri Pilg.	Poaceae	herb		GSM124
Eragrostis paniciformis (A.Br.)	Poaceae	herb	marga	GSM50
Eriosema scioanum Avetta	Fabaceae	herb		GSM34
Erythrina brucei Schweinf.	Fabaceae	Tree	Welensuu	GSM126
Euphorbia abyssinica Gmel.	Euphorbiaceae	Tree		GSM125
Euphorbia candelabrum Kotschy	Euphorbiaceae	Tree	adamii	GSM96
Ficus sur Forssk.	Moraceae	Tree		GSM140
Guizotia schimperi Sch. Bip.ex Walp.	Asteraceae	herb		GSM35

Hagenia abyssinica (Brace) J.F. Gmel	Rosaceae	Tree	hetoo	GSM97
Heteropogon contortus (L.).	Poaceae	herb	Marga	GSM51
Hibiscus flavi folius Ulbar.	Malvaceae	herb	Hincinni	GSM36
Hibiscus macranthus Hochst.	Malvaceae	herb	Hincinni	GSM52
Hygrophila auriculata (Schum.)	Acanthaceae	herb	bale	GSM53
Hygrophila auriculata (Schum.)	Acanthaceae	herb	Baalanw	GSM37
Hyparrhenia rufa (Nees) Stapf	Poaceae	herb	Daggala	GSM54
Impatiens aethiopica Grey-Wilson	Balsaminaceae	herb	ansosila	GSM38
Jusminum abyssinicum Hochst. ex DC	Oleaceae	Climber	echilbee	GSM04
Justicia schimperiana (Hochst. ex Nees)	Acanthaceae	Shrub	Dhumuuga	GSM72
Kalanchoe petitiana A.Rich.	Crassulaceae	Climber	bosoqee	GSM05
Lagenaria abyssinica (Hook.f.) C. Jeffrey	Cucurbitaceae	Climber	sexanaa	GSM06
Lagenaria abyssinica (Hook.f.) C. Jeffrey	Cucurbitaceae	Climber		GSM07
Lagenaria siceraria (Molina) Standley	Cucurbitaceae	Climber	Buqqe	GSM12
Laportea alatipes Hook.f.	Uriticaceae	herb	Dobbii	GSM39
Lippia javanica (Burm.f.) Spreng.	Verbenaceae	herb		GSM40
Maesa lanceolata Forssk.	Myrsinaceae	Tree	abayii	GSM129
Maytenus arbutifola	Celestraceae	Tree	Kombolcha	GSM131
Maytenus arbutifolia (A.Rich)Wilezek	Celestraceae	Tree	Kombolcha	GSM130
Maytenus undata (Thunb.) Blackelock	Celestraceae	Tree	Kokolfaa	GSM113
Medicago laciniata (L.)	Fabaceae	herb	sidisaa	GSM66
Mikania capensis DC.	Asteraceae	herb	hiddaa reffaa	GSM132
Mikania sagittifera B. Robinson	Asteraceae	herb		GSM133
Myrica salicifolia A. Rich.	Myricaceae	Tree	Jimmaa	
Myrsine africana L.	Myrsinaceae	Shrub		GSM72
Nicandra physaloides (L.) Gaertn.	Solanaceae	herb	Hawwixii	GSM41

Nicotiana tabacum L.	Solanaceae	herb	Tamboo nyaata	GSM42
Nuxia congesta R.Br. ex Fresen	Loganiaceae	Tree		GSM134
Olea europaea L.subsp.cuspidata	Oleaceae	Tree	Ejerrsa	GSM98
Osyris arborea Wall. ex. Wight	Santalaceae	Tree	wattoo	GSM99
Osyris quadripartita Decne	Santalaceae	Shrub	Waatoo	GSM90
Panicum monticola Hook.f.	Poaceae	herb	Marga-Gogorri	GSM55
Pavonia procumbens (Wight & Arn.)	Malvaceae	herb	Doobi	GSM56
Pavonia urens Cav.	Malvaceae	Climber	Maxxanne	GSM13
Penisetum schimperi A. Rich.	Poaceae	herb	megera	GSM19
Pennisetum clandestinum Chiov.	Poaceae	herb	serdoo	GSM20
Pennisetum sphacelatum Th.Dur. and Schinz	Poaceae	herb	Migira	GSM21
Periploca linearifolia Quart.Dill. & A.Rich.	Asclepiadaceae	Climber	Hidda dimaa	GSM08
Phoenix reclinata Jacq.	Arecaceae	Tree	Meexxi	GSM100
Phytolacca dodecandra L'Herit.	Phytolaccaceae	Shrub	Andoode	GSM73
Pittosporum viridiflorum Sims	Pittosporaceae	Tree	solee	GSM111
Plantago lanceolata L.	Plantaginaceae	herb	Qorxobi	GSM57
Podocarpus falcatus (Thunb.) R.B.ex Mirb.	Podocarpaceae	Tree	Birbirsa	GSM114
Premna schimperi Engl.	Lamiaceae	Tree	Urgeessa	GSM106
Prunus africana (Hook. f.) Kalkam	Rosaceae	Tree	Oomi	GSM107
Rhamnus prinoides L' Her.	Rhamnaceae	Tree		GSM101
Rhamnus staddo	Rhamnus	Tree	qaddidaa	GSM102
Rhoicissus tridentata (L. f.) Wild& Drummond	Vitaceae	Shrub	hidarefa	GBS66
Rhus glutinosa A.rich.	Anacardiaceae	Tree	Xatesaa	GSM136
Rhus ruspolii Engl.	Anacardiaceae	Shrub		GSM74
Rhus vulgaris Meikle	Anacardiaceae	Shrub		GSM84
Ricinus communis L.	Euphorbiaceae	Shrub	Qobo	GSM75

Rosa abyssinica Lindely	Rosaceae	Climber	qaqii	GSM11
Rothmannia urceliiformiis (Hiern.) Robyns	Rubiaceae	Shrub	Bururi	GSM76
Rubia cordifolia L.	Rubiaceae	herb	maxxannee	GBS29
Rubus apetalus Poir.	Rosaceae	Shrub	Gora	GSM77
Rubus steudneri Schweinf.	Rosaceae	Shrub	Goraa	GSM88
Rumex abyssinicus Jacq.	Polygonaceae	herb	Dhangago	GSM58
Rumex nepalensis Spreng	Polygonaceae	herb	Timiji	GSM59
Rumex nepalensis Spreng.	Polygonaceae	herb	tulti	GBS46
Rumex nervosus Vahl	Polygonaceae	Shrub	dhaangagoo	GBS81
Rytigynia neglecta (Hiern.) Robyns	Rubiaceae	Shrub	Mixo	GSM85
Salix mucronata Thunb.	Salicaceae	Tree	Alaltuu	GSM103
Salix subserrata Willd.	Salicaceae	Tree	Alaltu	GSM110
Schefflera abyssinica (Hochst. ex A.Rich.)	Araliaceae	Tree	Gatamaa	GSM104
Species	Family	Type	Local Name	Code
Snowdenia polystachya (Fresen.) Pilg.	Poaceae	herb	Muuja	GSM60
Solanecio gigas (Vatke) C.Jeffrey	Asteraceae	Shrub	Bosoqa	GSM89
Solanecio mannii (Hook.f.) C. Jeffrey	Asteraceae	Shrub		GSM69
Solanecio tuberosus (Sch.Bip.) C. Jeffrey	Asteraceae	Shrub		GSM70
Solanum anguivi Lam.	Solanaceae	herb	Hiddi-Sare	GSM61
Solanum incanum L.	Solanaceae	Shrub		GSM71
Solanum marginatum L.f.	Solanaceae	Shrub	Hiddi-Warabessa	GSM78
Sonchus asper L.	Asteraceae	herb	Qoraattii haree	GSM43
Sonchus bipontini Asch.	Asteraceae	herb		GSM44
Spermacoce sphaerostigma (A.Rich.) vatke	Rubiaceae	herb		GSM65
Sporobulos pyramidalis P.Beauv.	Poaceae	herb	Muri	GSM62
Stephania abyssinica Dillin and A.Rich.) Warp.	Menispermaceae	Climber	kalalaa	GSM14

Syzygium guineense (Wild.) DC.	Myrtaceae	Tree	Badessa	GSM139
Teclea nobilis Del.	Rutaceae	Tree	Hadheesa	GSM105
Toddalia asiatica (L.) Lam.	Rutaceae	Climber	harangaamaa	GSM09
Trifolium burchellianum Ser.	Fabaceae	herb		GSM137
Trifolium multinerve A.Rich.	Fabaceae	herb	Siddisa	GSM63
Urera hypselodendron (A.Rich.) Wedd.	Urticaceae	Climber	Lanqessa	GSM15
Urtica simensis Steud.	Urticaceae	herb	Gurgubbe	GSM64
Usnea africana	Lichen	herb	Harrii mukaa	GSM16
Vernonia adoensis Sch. bip. ex Walp.	Asteraceae	Shrub	Sooyyama	GSM79
Vernonia amygdalina Del.	Asteraceae	Shrub	Eebicha	GSM80
Vernonia auriculifera Hiern.	Asteraceae	Shrub	Reeji	GSM81
Vernonia brachycalyx O.Hoffm.	Asteraceae	Shrub	Sooyyama	GSM82
Vernonia filigera Oliv.& Hiern.	Asteraceae	Shrub	Sooyyama	GSM02
Vernonia *ruppellii* Sch. Bip. ex Walp.	Asteraceae	Shrub	Sooyyama	GSM83
Warburgia ugandensis Sprague	Canellaceae	Tree	Biifti	GSM109

Appendix-Table 9. Floristic composition of BMFP

Species	Family	Type	Vernicular	Code
Acacia sieberiana DC	Fabaceae	Tree	Ramso	GBS82
Acanthus sennii Chiov.	Acanthaceae	Shurb	Sokorruu	GBS54
Acokanthera schimperi	Apocynaceae	Tree	Temenehey	GBS127
Adhatoda schimperiana (hochst.ex nees)	Acanthaceae	Shurb	Sensel	GBS76
Albizia gummifera (J. F. Gmel.)	Fabaceae	Tree	Anbabessa	GBS83
Albizia schimperiana Oliv.	Fabaceae	Tree	Mukarba	GBS84
Amaranthus spinosus L.	Amaranthaceae	Herb		GBS35
Andropogon schirensis Hochst. ex A. Rich.	poacea	Herb		GBS9
Asparagus africanus Lam.	Asparagaceae	Herb	saritii	GBS14
Asystasia gangetica (L.) T. Anders.	Acanthaceae	Herb		GBS36
Azadirachta indica	Miliaceae	Tree	Galano	GBS85
Bidens ghedoensis Mesfin	Asteraceae	Herb	keloo	GBS34
Bidens pachyloma (Oliv. & Hiern)Cufod.	Asteraceae	Herb	keloo	GBS15
Bidens pilosa L.	Asteraceae	Herb		GBS37
Bidens prestinaria (Sch.-Bip.) Cuf.	Asteraceae	Herb		GBS38
Borassus aethiopum Mart.	Arecaceae	Tree		GBS128
Buddleja polystachya Fresen	Loganiaceae	Shurb	Anfare	GBS79
Cadaba farinosa Forssk. Subsp. farinosa	Capparidaceae	Shurb		GBS55
Calotropis procera (Ait)Ait.f.	Asclepiadaceae	Tree	Tobiaw	GBS125

Calpurnia aurea (Alit) Benth.	Leguminosae	Herb	Cheka	GBS39
Capparis erythrocarpos Isert	Capparidaceae	Shurb		GBS86
Carissa spinarum L.	Apocynaceae	Shurb		GBS87
Celtis africana Burm. f.	Ulmaceae	Tree	caa'ii	GBS89
Clausena anisata (Willd.)Benth.	Rutaceae	Shurb	ulumayii	GBS56
Clausena anisata Hook.f. ex Benth	Rutaceae	Shurb	Hulimay	GBS77
Clematis longicauda Steud. ex A. Rich.	Ranunculaceae	Climber	fitee	GBS5
Clutia abyssinica Jaub. & Spach.	Euphorbiaceae	Shurb	ulee lonii	GBS58
Coffea arabica L.	Rubiacae	Shurb	buna	GBS59
Commelina imberbis Ehrenb.ex Hassk.	Commelinaceae	Herb		GBS40
Corchorus olitorius L.	Tiliaceae	Herb		GBS41
Cordia africana Lam.	Boraginaceae	Tree	Abangae,	GBS90
Crotalaria rosenii (Pox) Milne-Redh. ex Polhill	Fabaceae	Shurb	atarakuruphe	GBS60
Croton macrostachyus Del.	Euphorbiaceae	Tree	Bakanissa	GBS91
Cucurbita pepo L.	Cucurbitaceae	Herb	dabaqula	GBS16
Cyathula uncinulata (Schrad.) Schinz	Amaranthaceae	Herb	maxanne	GBS17
Cymbopogon citratus (DC ex Nees) Stapf	Fabaceae	Herb	'tej sar'	GBS18
Datura stramonium L.	Solonaceae	Herb	Asangra	GBS42
Dodonaea angustifolia L. f.	Sapindaceae	Shurb	xadachaa	GBS61
Dovyalis abyssinica (A. Rich.) Warb.	Flacourtiaceae	Shurb	koshimii	GBS62
Dracaena afromontana Mildbr.	Dracenaceae	Tree	afarfatuu	GBS92

Dracaena steudneri Engl.	Dracaenaceae	Tree		GBS93
Echinops longisetus A. Rich.	Asteraceae	Herb	Qoraattii	GBS19
Ehertia cymosa Thonn.	Boraginaceae	Tree	ulagaa	GBS94
Ekebergia capensis Sparrm	Meliaceae	Tree	Sombo	GBS95
Ensete ventricosum (Welw.)	Musaceae	Tree	Balawarkea	GBS96
Entada abyssinica Steud. ex A. Rich.	Fabaceae	Tree	Ambalta	GBS97
Fagaropsis angolensis	Rubiaceae	Tree	Mukeye	GBS98
Ficus ovata Vahl	Moraceae	Tree		GBS99
Ficus sur	Moraceae	Tree	Arbu	GBS100
Ficus sycomorus L.	Moraceae	Tree	Kiltu, oda	GBS101
Ficus thonningii Blume	Moraceae	Tree	Danbi	GBS102
Ficus vasta Forssk (Moraceae)	Moraceae	Tree		GBS103
Flacourtia indica (Burm.f.) Merr.	Flacourtiaceae	Shurb	hudhaa	GBS63
Galineria saxifraga (Hochst.) Bridson	Rubiaceae	Tree	mixo	GBS104
Grewia ferruginea Hochst. ex A. Rich.	Tiliaceae	Tree		GBS105
Helinus mystacinus (Ait.) E. Mey. ex Steud.	Rhamnaceae	Climber	hudha	GBS1
Impatiens ethiopica Grey-Wilson.	Balsaminaceae	Herb		GBS20
Impatiens rothii Hook. f.	Balsaminaceae	Herb	ansosila	GBS21
Ipomoea cairica (L.) Sweet	Convolvulaceae	Herb	hida antuta	GBS22
Juniperus procera Endl.	Cupressaceae	Tree	gatira	GBS129
Justitia ladanoides Lam.		Herb		GBS43

Kalanchoe lanceolata Forssk.	Crassulaceae	Herb	Bosoke	GBS78
Lagenaria siceraria (Molina) Standi.	Cucurbitaceae	Herb	buqehadha'a	GBS23
Landolphia buchananii (Hall.f.)	Apocynaceae	Climber	Hidda geeboo	GBS51
Leucaena leucocephala Lam.	Fabaceae	Tree	-	GBS106
Lippia adoenesis Hochst. ex Walp.	Verbenaceae	Shurb	kussayee	GBS64
Maesa lanceolata Forssk.	Myrsinaceae	Tree	Abayi	GBS107
Millettia ferruginea(Hochst.) Bak.	Fabaceae	Tree	sotalo	GBS124
Momordica foetida Schumach.	Cucurbitaceae	Herb		GBS44
Musa x paradisiaca L.	Musaceae	Herb		GBS24
Myrica salicifolia A. Rich.	Myricaceae	Tree	barodoo	GBS109
Nicandra physaloides (L.) Gaertn.	Solanaceae	Herb	asangiraa	GBS25
Nicotiana tabacum L.	Solanaceae	Herb	tamboo	GBS26
Ocimum urticifolium Roth	Lamiaceae	Shurb	anchabii	GBS65
Olinia rochetiana A.Juss.	Oliniaceae	Tree	solee	GBS110
Oncoba spinosa Forssk.	Flacourtiaceae	Tree	Akuku	GBS111
Oplismenus hirtellus (L.) P. Beauv.	Poaceae	Herb	Ashuffee	GBS27
Osyris quadripartita Decn.	Santalaceae	Tree	wato	GBS112
Pennisetum thunbergii Kunth	Poaceae	Herb		GBS10
Phragmenthera macrosolen (A. Rich.) M.	Loranthaceae	Herb	digalu	GBS28
Podocarpus falcatus (Thunb.) Mirb.	Podocarpaceae	Tree	Birbissa	GBS113
Polypogon schimperianus (Hochst. ex	Poaceae	Herb	Daggala	GBS11

Protea gaguedi J.F. Gmel.	Proteaceae	Tree		GBS126
Pterolobium stellatum (Forssk.) Brenan	Fabaceae	Climber	harangama	GBS2
Rhamnus prinoides L'Herit.	Rhamnaceae	Tree	Gesho	GBS114
Rhamnus staddo A. Rich.	Rhamnaceae	Tree	qadiidaa	GBS115
Rhus vulgaris Meikle	Anacardiaceae	Tree	dabobessaa	GBS116
Ricinus communis L.	Euphorbiaceae	Shurb	Kobo	GBS68
Rottboellia cochinchinensis (Lour.) Clayton	Poaceae	Herb		GBS12
Rytigynia neglecta (Hiern) Robyns	Rubiaceae	Shurb	mixoo	GBS70
Sapium ellipticum (Krauss) Pax	Euphorbiaceae	Tree	Bosoka	GBS117
Schefflera abyssinica (Hochst. ex A. Rich.	Araliaceae	Tree	Hafarfatu	GBS134
Senna didymobotrya (Fresen) Irw. &Barn.	Fabaceae	Shurb	kishikishii	GBS71
Sesbania sesban (L.) Merr.	Fabaceae	Shurb	-	GBS72
Setaria megapbylla (Steud.) Th. Dur. &Schinz	Poaceae	Herb	Jajjaba	GBS30
Sporobolus africanus (Poir.) Robyns & Tournay	Poaceae	Herb	murii	GBS13
Sporobolus africanus (Poir.) Robyns & Tournay	Poaceae	Herb	murii	GBS31
Stereospermum kunthianum Cham.	Bignomiaceae	Tree	Botoro	GBS118
Syzygium guineense (Willd.) DC. Subsp afromontanum	Myrtaceae	Tree	badessa	GBS120
Syzygium guineense (Willd.) DC. Supsp guineense	Myrtaceae	Tree	gossu	GBS121
Tamarindus indica L.	Fabaceae	Tree		GBS131
Tapinanthus heteromorphus (A. Rich.]Danser	Loranthaceae	Shurb	Digaluu	GBS73
Teclea nobilis Del.	Rutaceae	Tree	hadhessa	GBS122

Terminalia schimperiana Hochst.	Combretaceae	Tree	Gaarrii	GBS132
Trifolium pichisermollii Gillett	Fabaceae	Herb	sidisa	GBS47
Trifolium schimperi A. Rich.	Fabaceae	Herb	sidisa	GBS48
Urera hypselodendron (A.Rich.)Wedd.	Urticaceae	Climber	lanqessaa	GBS53
Urtica simensis Steudel	Urticaceae	Herb	gurgubee	GBS32
Vepris angolensis	Rubiaceae	Tree	dobbii	GBS123
Vernonia amygdalina Del.	Asteraceae	Shurb	Abicha	GBS74
Vernonia theophrastifolia Schweinf. ex Oliv. & Hiern	Asteraceae	Herb		GBS49
Vernonia thomsoniana Oliv. & Hiern ex Oliv.	Asteraceae	Shurb	Reji	GBS75
Vigna membranacea A. Rich.	Fabaceae	Herb		GBS8
Wissadula rostrata (Schumach. & Thonn.) Hook.f.	Malvaceae	Herb		GBS50
*Zehneria scabra (Linn. f.) Sond**	Cucurbitaceae	Herb	sokoke	GBS33

Appendix-Table 10. Floristic composition of PMFP and BAFP

Species	Family	Type	Local name	Code
Acacia hecatophylla Steud. ex A. Rich. (Fabaceae)	*Fabaceae*	Tree	Quatsirqa	GGMRD42
Acacia polyacantha Willd. (Fabaceae)	*Fabaceae*	Tree	Sipe	GGMDR42
Acacia seyal Del.	Fabaceae	Tree	Meela	GGMRD43
Acalypha ornata A. Rich	Euphorbiaceae	Shrub		GGMRD34
Acanthus polystachyus Del.	*Acanthaceae*	Herb	Dadiha	GGMDR56
Adansonia digitata L.	Bombacaceae	Tree		GGMRD57
Aframomum alboviolaceum (Ridl.) K.Schum.	Zingiberaceae	Herb		GGMRD24
Albizia malacophylla (A. Rich.) Walp.	Fabaceae	Tree	Ansisiwa	GGMDR43
Amaranthus spinosus L.	*Amaranthaceae*	Herb	Tekihinenuwa	GGMRD12
Ampelocissus schimperiana (Hochst. ex A. Rich.) Planch.	Vitaceae	Herb	Antsiqina	GGMDR11
Andropogon pseudapricus stapf	Poaceae	Herb		GGMRD11
Andropogon schirensis Hochst. ex A. Rich.	Poaceae	Herb	Amberta	GGMRD06
Annona senegalensis Pers.	Annonaceae	Tree	Bambutta	GGMRD36
Anogeissus leiocarpa (A. DC.) Guill. & Perr.	*Combretaceae*	Tree	Sigah	GGMRD44
Asparagus flagellaris (Kunth) Baker	*Asparagaceae*	Shrub	Eliya	GGMDR25
Asparagus racemosus	Asparagaceae	Shrub		GGMDR33
Asystasia gangetica (L.) T. Andress.	*(Acanthaceae)*	Herb	Derguya	GGMDR12
Balanites aegyptiaca (L.) Del.	*Balanitaceae*	Climber	Qota	GGMRD02

Bidens pilosa L.	*Asteraceae*	Herb	Wasqenda	GGMRD13
Bidens prestinaria (Sch. Bip.) Cufod.	*Asteraceae*	Herb	Egile	GGMDR13
Borassus aethiopum Mart.	*Arecaceae*	Tree	Dur	GGMDR44
Boswellia papyrifera (Del.) Hochst.	Burseraceae	Tree	Golgola	GGMRD45
Breonadia salicina (Vahl) Heppehr & Wood	*Rubiaceae*	Tree	Dijiha	GGMRD35
Bridelia scleroneura Muell. Arg.	*Euphorbiaceae*	Tree	Ejjiga	GGMDR41
Carissa spinarum L.	*Apocynaceae*	Climber	Simah	GGMRD26
Cassia arereh Del.	Fabaceae	Shrub		GGMDR57
Celosia trigyna L.	*Amaranthaceae*	Herb	Yedinkuwa	GGMRD14
Chlorophytum blepharophyllum Schweinf. ex Baker	Anthericaceae).	Herb		GGMRD23
Cissus cornifolia (Bak.) Planch.	Vitaceae	Herb	Antsiqina Guanja	GGMDR14
Cissus populnea Guill. & Perr.	*Vitaceae*	Climber	Iwe	GGMRD04
Clematis hirsuta Perr. & Guill.	*Ranunculaceae*	Climber	Tirmenzuwa	GGMRD03
Clerodendrum alatum Güerke	*Verbenaceae*	Herb	Jiggnewiya	GGMRD15
Combretum collinum Fresen.	*Combretaceae*	Tree	Engifa	GGMDR45
Combretum hartmannianum Schweinf.	*Combretaceae*	Tree	Jipiwa	GGMRD46
Combretum hartmannianum Schweinf.	*Combretaceae*	Tree	Jipiwa	GGMRD58
Combretum molle R. Br. ex G. Don	Combretaceae	Tree	Enquha	GGMDR35
Commelina imberbis Ehrenb. ex Hassk.	*Commelinacae*	Herb	Ibeshanta	GGMDR15
Commiphora pedunculata (Kotschy & Peyr.) Engl.	Burseraceae	Shrub	Golgolofale	GGMDR27

Corchorus olitorius L.	*Tiliaceae***	Herb	Laliqa	GGMRD16
Cordia africana Lam.	Boraginaceae	Tree	Banja	GGMDR46
Costus spectabilis (Fenzl) K. Schum.	*Zingiberaceae*	Herb	Yempedema	GGMDR58
Crossopteryx febrifuga (Afzel. ex G. Don) Benth.	*Rubiaceae*	Herb	Piwe	GGMDR16
Cucumis pustulatus Naud ex Hook.f.	*Cucurbitaceae*	Climber	Weqneniwa	GGMDR02
Cymbopogon caesius (Hook. & Arn.) Stapf.	*Poaceae*	Herb	Mamusa	GGMDR06
Cynodon nlemfuensis Vanderyst	*Poaceae*	Herb	Sasiqida	GGMRD07
Dalbergia boehmiiTaub.	*Fabaceae*	Tree	Tsaba	GGMDR36
Dalbergia melanoxylon Guill. & Perr.	*Fabaceae*	Shrub	Shangur	GGMRD28
Dioscorea cochleari-apiculata De Wild.	Dioscoreaceae	Climber		GGMDR04
Dioscorea praehensilis Benth.	*Dioscoreaceae*	Climber	Echa	GGMRD05
Dombeya buettneri K. Schum	Sterculiaceae	Shrub		GGMDR34
Entada africana Guill. & Perr.	Fabaceae	Tree	Bambeluwa	GGMRD37
Ficus sur Forssk.	*Moraceae*	Tree	Ebeya	GGMRD47
Ficus sycomorus L	*Moraceae*	Tree	Fuqa	GGMDR47
Ficus thonningii Blume	*Moraceae*	Tree	Tseera	GGMRD48
Ficus vasta Forssk	Moraceae	Tree		GGMRD56
Flueggea virosa (Willd.) Voigt.	*Euphorbiaceae*	Shrub	Weele	GGMDR28
Gardenia ternifolia Schum. & Thonn.	*Rubiaceae*	Tree	Kota	GGMDR48
Gladiolus abyssinicus (Brongn. ex Lemaire)	Iridaceae	Herb		GGMDR62
Grewia flavescens Juss.	*Tiliaceae*	Climber	Hattab	GGMDR03

Grewia mollis A.Juss. (Tiliaceae)	*Tiliaceae*	Shrub	Gediya	GGMRD29
Grewia velutina (Forssk.) Vahl	*Tiliaceae*	Shrub	Gideya	GGMRD27
Hibiscus cannabinus L.	*Malvaceae*	Herb	Tisha	GGMRD17
Hyparrhenia anthistirioides(Hochst. ex A. Rich.) Stapf	Poaceae	Herb	Bidigua	GGMDR07
Hyparrhenia filipendula (Hochst.) Stapf.	*Poaceae*	Herb	Hesiniya	GGMRD59
Hyparrhenia hirta (L) Stapf	Poaceae	Herb		GGMRD10
Hyphaene thebaica (L.) Mart.	Arecaceae	Tree	Babenga	GGMRD49
Hypoxis angustifolia Lam.	Hypoxidaceae	Herb		GGMDR23
Justicia ladanoides Lam.	*Acanthaceae*	Herb	Elangiya	GGMDR17
Kotschya africana Endl.	Fabaceae	Shrub		GGMRD33
Lannea fruticosa (Hochst. ex A. Rich.) Engl.	Anacardiaceae	Tree	Bilga	GGMDR59
Lannea schimperi (A. Rich.) Engl.	Anacardiaceae	tree		GGMDR61
Lannea welwitschii (Hiern) Engl.	Anacardiaceae	Tree	Biilga	GGMRD60
Leonotis nepetifolia (L.) R.Br.	Lamiaceae	Herb	Achiquwa	GGMDR60
Lonchocarpus laxiflorus Guill. & Perr.	Fabaceae	Tree	Beewa	GGMRD61
Maytenus senegalensis (Lam.) Exell	Celastraceae	Climber	Bembeda	GGMDR01
Momordica foetida Schum.	Cucurbitaceae	Herb	Beda	GGMRD18
Ochna leucophloeos Hochst. ex A. Rich.	Ochnaceae	Tree	Andidiha	GGMDR49
Ocimum canum Sims.	*Lamiaceae*	Tree	Biyangua	GGMRD50
Oncoba spinosa Forssk.	Flacourtiaceae	Tree	Atsisa	GGMDR50

Oxytenanthera abyssinica (A. Rich.) Munro	*Poaceae*	Herb	Enta	GGMRD08
Ozoroa pulcherrima (Schweinf.) R. & A. Fernand.	Anacardiaceae	Tree	Ejimbaya	GGMRD51
Pavetta gardeniifolia A. Rich.	*Rubiaceae*	Tree	Reba	GGMDR37
Pennisetum ramosum (Hochst). Schwinf	Poaceae	Herb		GGMDR10
Pennisetum schweinfurthii Pilg.	Poaceae	Herb	Begngira	GGMDR08
Pennisetum thunbergii Kunth	Poaceae	Herb	Etissayaqua	GGMRD25
Pennisetum unisetum (Nees) Benth. (Poaceae)	Poaceae	Herb	Pille	GGMRD09
Phoenix reclinata Jacq.	*Arecaceae*	Tree	Goha	GGMDR51
Physalis peruviana L.	*Solanaceae*	Herb	Ejisiya	GGMDR18
Piliostigma thonningii (Schum.) Milne-Redh.	*Fabaceae*	Tree	Mecha	GGMRD38
Protea gaguedi J. F. Gmel.	*Proteaceae*	Tree	Edeeduwa	GGMDR38
Pterocarpus lucens Guill. & Perr.	*Fabaceae*	Tree	Chaya	GGMRD52
Rhus ruspolii Engl	Anacardiaceae	Herb		GGMDR22
Rhus ruspolii Engl.	*Anacardiaceae*	Tree	Silgalo	GGMRD39
*Ricinus communis L. **	*Euphorbiaceae*	Tree	Bogonda	GGMDR39
Rottboellia cochinchinensis (Lour.) Clayton	*Poaceae*	Herb	Eboba	GGMDR09
Rumex abyssinicus Jacq.	*Polygonaceae*	Herb	Eyampisah	GGMRD19
Saba comorensis (Boj.) Pichon	*Apocynaceae*	Herb	Bishqor	GGMDR19
Sapium ellipticum (Krauss) Pax	*Euphorbiaceae*	Tree	Tseiya Fudi	GGMDR52
Sarcocephalus latifolius (J. E. Smith) E. A. Bruce.	Rubiaceae	Shrub	Andowa	GGMRD30
Securidaca longepedunculata Fresen.	*Polygalaceae*	Shrub	Siqida	GGMDR29

Senna obtusifolia (L.) Irwin & Barneby	Fabaceae	Herb	Alkola	GGMRD20
Solanum alatum Moench.	Solanaceae	Herb	Antutiya	GGMDR20
Sterculia africana (Lour.) Fiori	*Sterculiaceae*	Tree	Ephuwa	GGMRD53
Stereospermum kunthianum Cham.	Bignoniaceae	Tree	Andegila	GGMRD40
Strychnos innocua Del.	Loganiaceae	Tree	Begiya	GGMDR40
Strychnos spinosa Lam.	Loganiaceae	Shrub	Anderkukuwa	GGMRD62
Syzygium guineense (Willd.) DC. subsp guineense	*Myrtaceae*	Tree	Diwa	GGMRD41
Syzygium guineense (Willd.) DC. Subspmacrocarpa	*Myrtaceae*	Tree	Shawa	GGMDR53
Tacca leontopetaloides (L.) O. Ktze.	Taccaceae	Shrub	Feeferentseon	GGMDR32
Tamarindus indica L.	*Fabaceae*	Tree	Dhoga	GGMRD54
Terminalia laxiflora Engl. & Diels	*Combretaceae*	Tree	Bora	GGMDR54
Terminalia macroptera Guill. & Perr.	Combretaceae	Tree	Babegoha	GGMRD55
Tragia doryodes M. Gilbert	Euphorbiaceae	Herb	Bebdaja	GGMDR24
Tristemma mauritianum J.F. Gmel.	*Melastomataceae*	Herb	Metseeya	GGMDR26
Triumfetta annua L.	*Tiliaceae*	Herb	Eqephaqiwa	GGMRD21
Vernonia hochstetteri Sch.-Bip.	*Asteraceae*	Shrub	Ebicha	GGMDR30
Vernonia theophrastifolia Schweinf. ex Oliv. & Hiern	*Asteraceae*	Herb	Egidima	GGMDR21
Vigna membranacea A. Rich.	*Fabaceae*	Herb	Dheberimugu	GGMDR05
Vitex doniana Sweet.	*Verbenaceae*	Tree	Tisheza	GGMDR55
Wissadula rostrata (Schum. & Thonn.) Hook.f.	Malvaceae	Herb	Banshzegona	GGMRD22

Ximenia americana L.	*Olacaceae*	Shrub	Heya	GGMRD31
Ziziphus abyssinica Hochst. ex A. Rich.	Rhamnacae	Shrub	Anguga	GGMDR31
Ziziphus mauritiana Lam.	*Rhamnacae*	Shrub	Songah	GGMRD32

Appendix-Table 11 . Number of species, family and genera DAF

Family	Genera	No sp	%species
Asteracea	18	22	15.83
Poaceae	10	12	8.63
Fabaceae	4	6	4.32
Polygonaceae	4	6	4.32
Solanaceae	4	6	4.32
Ephorbiaceae	3	5	3.60
Malvaceae	3	5	3.60
Rosaceae	4	5	3.60
Rubiaceae	3	5	3.60
Cyperaceae	2	4	2.88
Acanthaceae	2	3	2.16
Amaranthaceae	2	3	2.16
Anacardiaceae	2	3	2.16
Celestraceae	2	3	2.16
Uriticaceae	1	3	2.16
Vitaceae	1	3	2.16
Araliaceae	1	2	1.44
Cucurbitaceae	1	2	1.44
Lamiaceae	1	2	1.44
Loganiaceae	1	2	1.44
Myrsinaceae	1	2	1.44
Oleaceae	1	2	1.44
Rutaceae	1	2	1.44
Salicaceae	1	2	1.44
Santalaceae	1	2	1.44
Melianthaceae	1	1	0.72
Myrtaceae	1	1	0.72
Araceae	1	1	0.72

Arecaceae	1	1	0.72
Asclepiadaceae	1	1	0.72
Asparagaceae	1	1	0.72
Balsaminaceae	1	1	0.72
Boraginaceae	1	1	0.72
Canellaceae	1	1	0.72
Crassulaceae	1	1	0.72
Cucurbitaceae	1	1	0.72
Dracaenaceae	1	1	0.72
Icacinaceae	1	1	0.72
Urticaceae	1	1	0.72
Menispermaceae	1	1	0.72
Moraceae	1	1	0.72
Phytolaccaceae	1	1	0.72
Pittosporaceae	1	1	0.72
Plantaginaceae	1	1	0.72
Podocarpaceae	1	1	0.72
Ranunculaceae	1	1	0.72
Rhamnaceae	1	1	0.72
Rhamnus	1	1	0.72
Sapindaceae	1	1	0.72
Simaroubaceae	1	1	0.72
Sterculiaceae	1	1	0.72
Verbenaceae	1	1	0.72

Appendix-Table 12. Number of species, family and genera BMFP

Family	Genera	NO Species	Species%
Fabaceae	13.00	15.00	13.27
Asteraceae	6.00	8.00	7.08
poacea	5.00	8.00	7.08
Moraceae	3.00	5.00	4.42
Rubiacae	4.00	5.00	4.42
Cucurbitaceae	2.00	4.00	3.54
Euphorbiaceae	2.00	4.00	3.54
Flacourtiaceae	1.00	3.00	2.65
Rhamnaceae	2.00	3.00	2.65
Rutaceae	2.00	3.00	2.65
Solanaceae	2.00	3.00	2.65
Acanthaceae	1.00	2.00	1.77
Amaranthaceae	1.00	2.00	1.77
Apocynaceae	1.00	2.00	1.77
Balsaminaceae	1.00	2.00	1.77
Boraginaceae	1.00	2.00	1.77
Capparidaceae	1.00	2.00	1.77
Dracaenaceae	1.00	2.00	1.77
Loranthaceae	1.00	2.00	1.77
Meliaceae	1.00	2.00	1.77
Musaceae	1.00	2.00	1.77
Myrtaceae	1.00	2.00	1.77
Tiliaceae	1.00	2.00	1.77
Urticaceae	1.00	2.00	1.77
Verbenaceae	1.00	2.00	1.77
Ranunculaceae	1.00	1.00	0.88
Anacardiaceae	1.00	1.00	0.88
Araliaceae	1.00	1.00	0.88
Arecaceae	1.00	1.00	0.88

Asclepiadaceae	1.00	1.00	0.88
Asparagaceae	1.00	1.00	0.88
Bignomiaceae	1.00	1.00	0.88
Combretaceae	1.00	1.00	0.88
Commelinaceae	1.00	1.00	0.88
Convolvulaceae	1.00	1.00	0.88
Crassulaceae	1.00	1.00	0.88
Cupressaceae	1.00	1.00	0.88
Lamiaceae	1.00	1.00	0.88
Leguminosae	1.00	1.00	0.88
Loganiaceae	1.00	1.00	0.88
Malvaceae	1.00	1.00	0.88
Myricaceae	1.00	1.00	0.88
Myrsinaceae	1.00	1.00	0.88
Oliniaceae	1.00	1.00	0.88
Podocarpaceae	1.00	1.00	0.88
Proteaceae	1.00	1.00	0.88
Santalaceae	1.00	1.00	0.88
Sapindaceae	1.00	1.00	0.88
Ulmaceae	1.00	1.00	0.88

Appendix-Table 13 . Number of species, family and genera in Lower altitude

Family	General	Species	%Species
Fabaceae	12	15	12.20
Poaceae	11	13	10.57
Combretaceae	5	7	5.69
Anacardiaceae	4	6	4.88
Euphorbiaceae	4	6	4.88
Rubiaceae	3	5	4.07
Tiliaceae	4	5	4.07
Asteraceae	4	4	3.25

Moraceae	2	4	3.25
Acanthaceae	2	3	2.44
Arecaceae	2	3	2.44
Vitaceae	2	3	2.44
Amaranthaceae	1	2	1.63
Apocynaceae	1	2	1.63
Asparagaceae	1	2	1.63
Burseraceae	1	2	1.63
Cucurbitaceae	1	2	1.63
Dioscoreaceae	1	2	1.63
Lamiaceae	1	2	1.63
Loganiaceae	1	2	1.63
Malvaceae	1	2	1.63
Myrtaceae	1	2	1.63
Polygalaceae	1	2	1.63
Rhamnacae	1	2	1.63
Solanaceae	1	2	1.63
Sterculiaceae	1	2	1.63
Verbenaceae	1	2	1.63
Zingiberaceae	1	2	1.63
Annonaceae	1	1	0.81
Anthericaceae	1	1	0.81
Balanitaceae	1	1	0.81
Bignoniaceae	1	1	0.81
Bombacaceae	1	1	0.81
Boraginaceae	1	1	0.81
Celastraceae	1	1	0.81
Commelinacae	1	1	0.81
Flacourtiaceae	1	1	0.81
Hypoxidaceae	1	1	0.81
Iridaceae	1	1	0.81
Melastomataceae	1	1	0.81

Ochnaceae	1	1	0.81
Olacaceae	1	1	0.81
Proteaceae	1	1	0.81
Ranunculaceae	1	1	0.81
Taccaceae	1	1	0.81

Appendix-Table 14. Structural value in pioneer of GTFP

Species	Fr	AB	RFr	BA	Dom	Rdom	De	RDe	IVI
Acacia abyssinica	9.00	62.00	6.66	1.75	108.63	31.14	172.22	14.60	52.39
Nuxia congesta	7.00	55.00	5.18	1.55	85.49	24.50	152.78	12.95	42.63
Maytenus arbutifola	5.00	40.00	3.70	1.13	45.22	12.96	111.11	9.42	26.08
Maesa lanceolata	8.00	45.00	5.92	1.41	63.59	18.23	125.00	10.59	34.74
Bersama abyssinica	6.00	19.00	4.44	0.04	0.71	0.20	52.78	4.47	9.12
Syzygium guineense	4.00	17.00	2.96	0.80	13.61	3.90	47.22	4.00	10.86
Vernonia amygdalina	6.00	16.00	4.44	0.50	8.04	2.30	44.44	3.77	10.51
Stephania abyssinica	5.00	12.00	3.70	0.01	0.10	0.03	33.33	2.82	6.55
Brucea antidysenterica	7.00	11.00	5.18	0.26	2.90	0.83	30.56	2.59	8.60
Apodytes dimidiata	4.00	9.00	2.96	0.28	2.54	0.73	25.00	2.12	5.81
Periploca linearifolia	6.00	14.00	4.44	0.02	0.31	0.09	38.89	3.30	7.82
Allophyllus abyssinicus	6.00	7.00	4.44	0.33	2.31	0.66	19.44	1.65	6.75
Ekebergia capensis	3.00	8.00	2.22	0.31	2.51	0.72	22.22	1.88	4.82
Rubus steudneri	6.00	11.00	4.44	0.02	0.24	0.07	30.56	2.59	7.10

Rosa abyssinica	6.00	7.00	4.44	0.01	0.10	0.03	19.44	1.65	6.12
Rhoicissus tridentata	3.00	6.00	2.22	0.01	0.07	0.02	16.67	1.41	3.65
Teclea nobilis	2.00	7.00	1.48	0.22	1.54	0.44	19.44	1.65	3.57
Prunus africana	3.00	5.00	2.22	0.24	1.18	0.34	13.89	1.18	3.73
Vernonia ruppellii	3.00	6.00	2.22	0.02	0.10	0.03	16.67	1.41	3.66
Salix mucronata	2.00	6.00	1.48	0.19	1.13	0.32	16.67	1.41	3.22
Rhus glutinosa	2.00	5.00	1.48	0.16	0.79	0.23	13.89	1.18	2.88
Olea europaea	3.00	4.00	2.22	0.19	0.75	0.22	11.11	0.94	3.38
Solanum marginatum	2.00	5.00	1.48	0.00	0.02	0.01	13.89	1.18	2.66
Rytigynia neglecta	2.00	5.00	1.48	0.12	0.59	0.17	13.89	1.18	2.83
Rhus vulgaris	2.00	4.00	1.48	0.09	0.38	0.11	11.11	0.94	2.53
Justicia schimperiana	2.00	5.00	1.48	0.00	0.02	0.01	13.89	1.18	2.66
Hagenia abyssinica	6.00	10.00	4.44	0.47	4.71	1.35	27.78	2.35	8.14
Ficus sure	2.00	4.00	1.48	0.22	0.88	0.25	11.11	0.94	2.67
Acanthus pubescens	6.00	6.00	4.44	0.00	0.01	0.00	16.67	1.41	5.86
Rubus apetalus	2.00	3.00	1.48	0.05	0.16	0.05	8.33	0.71	2.23
Pittosporum viridiflorum	3.00	8.00	2.22	0.02	0.18	0.05	22.22	1.88	4.16
Phytolacca dodecandra	2.00	3.00	1.48	0.03	0.10	0.03	8.33	0.71	2.22

Total	135.00	425.00	99.90	10.48	348.88	100.00	1180.56	100.05	299.95

Appendix-Table 15. Structural value in pioneer of SLFP

Species	Fr	AB	Rfr	BA	Dom	Rdom	De	RDe	IVI
Nuxia congesta	9	58	8.25	1.64	95.07	30.96	161.11	14.54	53.75
Acacia abyssiniea	9	50	8.25	1.57	78.50	25.56	138.89	12.54	46.35
Maesa lanceolata	9	40	8.25	1.13	45.22	14.72	111.11	10.03	33.00
Maytenus arbutifola	7	35	6.42	1.37	48.08	15.66	97.22	8.77	30.85
Rosa abyssinica	5	18	4.59	0.02	0.41	0.13	50.00	4.51	9.23
Rubus apetalus	4	13	3.67	0.04	0.48	0.16	36.11	3.26	7.08
Rubus steudneri	4	13	3.67	0.03	0.33	0.11	36.11	3.26	7.04
Stephania abyssinica	4.00	12.00	3.67	0.02	0.18	0.06	33.33	3.01	6.74
Vernonia amygdalina	4	12	3.67	0.09	1.13	0.37	33.33	3.01	7.04
Hagenia abyssinica	5	15	4.59	1.06	15.90	5.18	41.67	3.76	13.52
Apodytes dimidiata	4	9	3.67	0.71	6.36	2.07	25.00	2.26	7.99

Rhus glutinosa	3	10	2.75	0.08	0.79	0.26	27.78	2.51	5.51
Acanthus pubescens	4	13	3.67	0.02	0.20	0.06	36.11	3.26	6.99
Brucea antidysenterica	3	14	2.75	0.02	0.25	0.08	38.89	3.51	6.34
Bersama abyssinica	3	13	2.75	0.02	0.21	0.07	36.11	3.26	6.08
Jusminum abyssinicum	3	10	2.75	0.01	0.13	0.04	27.78	2.51	5.30
Pittosporum viridiflorum	2	13	1.83	0.02	0.21	0.07	36.11	3.26	5.16
Dombeya torrida	8	15	7.34	0.71	10.60	3.45	41.67	3.76	14.55
Ficus sure	2	6	1.83	0.57	3.39	1.10	16.67	1.50	4.44
Phytolacca dodecandra	4	9	3.67	0.01	0.10	0.03	25.00	2.26	5.96
Prunus africana	2	6	1.83	0.42	2.54	0.83	16.67	1.50	4.17
Allophyllus abyssinicus	3	7	2.75	0.49	3.46	1.13	19.44	1.75	5.63
Clematis simensis	4	9	3.67	0.01	0.10	0.03	25.00	2.26	5.96
Ekebergia capensis	2	4	1.83	0.28	1.13	0.37	11.11	1.00	3.20
Olea europaea	2	3	1.83	0.21	0.64	0.21	8.33	0.75	2.79
Total	109	407	99.95	10.53	315.39	100.00	1130.55	100.05	300.00

Appendix-Table 16. Structural value in pioneer of MBFP

	Fr	AB	Rfe	BA	Dom	Rdom	De	Rde	IVI
Maesa lanceolata	9	60.00	6.12	1.70	101.74	33.79	166.67	13.52	53.43
Maytenus arbutifola	8	62.00	5.44	1.46	90.53	30.06	172.22	13.97	49.47
Nuxia congesta	9	45.00	6.12	1.06	47.69	15.84	125.00	10.14	32.10
Maytenus undata	8	22.00	5.44	0.17	3.80	1.26	61.11	4.96	11.66
Bersama abyssinica	9	25.00	6.12	0.03	0.79	0.26	69.44	5.63	12.02
Vernonia amygdalina	4	15.00	2.72	0.35	5.30	1.76	41.67	3.38	7.86
Rubus apetalus	4	14.00	2.72	0.44	6.15	2.04	38.89	3.15	7.92
Dombia torrida	5	12.00	3.40	0.34	4.07	1.35	33.33	2.70	7.46
Rhamnus staddo	3	12.00	2.04	0.28	3.39	1.13	33.33	2.70	5.87
Syzygium guineense	5	10.00	3.40	0.71	7.07	2.35	27.78	2.25	8.00
Vernonia auriculifera	4	15.00	2.72	0.50	7.51	2.49	41.67	3.38	8.59
Allophyllus abyssinicus	4	9.00	2.72	0.49	4.45	1.48	25.00	2.03	6.23
Rubus steudneri	6	16.00	4.08	0.02	0.30	0.10	44.44	3.60	7.79
Rosa abyssinica	6	15.00	4.08	0.02	0.28	0.09	41.67	3.38	7.55

Brucea antidysenterica	8	13.00	5.44	0.02	0.20	0.07	36.11	2.93	8.44
Prunus africana	3	8.00	2.04	0.44	3.52	1.17	22.22	1.80	5.01
Ekebergia capensis	4	7.00	2.72	0.38	2.69	0.89	19.44	1.58	5.19
Kalanchoe petitiana	5	13.00	3.40	0.02	0.21	0.07	36.11	2.93	6.40
Stephania abyssinica	5	10.00	3.40	0.01	0.13	0.04	27.78	2.25	5.70
Vernonia ruppellii	5	5	3.40	0.21	1.03	0.34	13.89	1.13	4.87
Rhus vulgaris	3	5.00	2.04	0.24	1.18	0.39	13.89	1.13	3.56
Salix mucronata	2	4.00	1.36	0.13	0.50	0.17	11.11	0.90	2.43
Apodytes dimidiata	2	4.00	1.36	0.25	1.00	0.33	11.11	0.90	2.60
Olea europaea	2	4.00	1.36	0.25	1.00	0.33	11.11	0.90	2.60
Rytigynia neglecta	2	4.00	1.36	0.13	0.50	0.17	11.11	0.90	2.43
Rhus glutinosa	3	3.00	2.04	0.07	0.21	0.07	8.33	0.68	2.79
Pittosporum viridiflorum	3	3.00	2.04	0.04	0.11	0.04	8.33	0.68	2.75
Ficus sure	3	3.00	2.04	0.22	0.66	0.22	8.33	0.68	2.94
Periploca linearifolia	4	2.00	2.72	0.15	0.29	0.10	5.56	0.45	3.27
Rumex nervosus	3	6.00	2.04	0.01	0.04	0.01	16.67	1.35	3.41
Phytolacca dodecandra	2	8.00	1.36	0.01	0.08	0.03	22.22	1.80	3.19
Teclea nobilis	2	8.00	1.36	0.59	4.70	1.56	22.22	1.80	4.72
Rhoicissus tridentata	2	4.00	1.36	0.00	0.00	0.00	11.11	0.90	2.26

Total	147	446	100	10.72	301.12	100	1238.89	100.478	300.48

Appendix-Table 17. Structural value in Intermediate of GTFP

	Fr	Rfr	AB	BA	Dom	Rdom	De	Rde	IVI
Dombeya torrida	7	4.61	35.00	4.80	167.97	35.47	97.22	9.28	49.36
Allophyllus abyssinicus	8	5.26	30.00	4.11	123.41	26.06	83.33	7.96	39.28
Hagenia abyssinica	6	3.95	20.00	2.57	51.42	10.86	55.56	5.31	20.11
Myrsine africana	8	5.26	45.00	0.03	1.56	0.33	125.00	11.94	17.53
Stephania abyssinica	8	5.26	11.00	0.01	0.09	0.02	30.56	2.92	8.20
Salix mucronata	3	1.97	12.00	0.93	11.11	2.35	33.33	3.18	7.50
Olea europaea	4	2.63	12.00	1.75	20.98	4.43	33.33	3.18	10.24
Premna schimperi	8	5.26	10.00	0.01	0.13	0.03	27.78	2.65	7.94
Osyris quadripartita	4	2.63	10.00	0.60	6.00	1.27	27.78	2.65	6.55
Apodytes dimidiata	5	3.29	12.00	1.85	22.21	4.69	33.33	3.18	11.16
Pittosporum viridiflorum	4	2.63	15.00	0.51	7.71	1.63	41.67	3.98	8.24
Syzygium guineense	4	2.63	10.00	1.54	15.43	3.26	27.78	2.65	8.54
Rosa abyssinica	4	2.63	13.00	0.02	0.23	0.05	36.11	3.45	6.13

Bersama abyssinica	6	3.95	8.00	0.01	0.09	0.02	22.22	2.12	6.09
Ekebergia capensis	5	3.29	8.00	1.26	10.08	2.13	22.22	2.12	7.54
Rhus glutinosa	4	2.63	6.00	0.26	1.54	0.33	16.67	1.59	4.55
Ficus sure	3	1.97	8.00	1.33	10.62	2.24	22.22	2.12	6.34
Ebelia schimperi	4	2.63	11.00	0.01	0.16	0.03	30.56	2.92	5.58
Nuxia congesta	3	1.97	6.00	0.41	2.47	0.52	16.67	1.59	4.09
Osyris arborea	4	2.63	6.00	0.36	2.16	0.46	16.67	1.59	4.68
Acacia abyssinica	2	1.32	7.00	1.10	7.71	1.63	19.44	1.86	4.80
Rubus steudneri	4	2.63	9.00	0.01	0.10	0.02	25.00	2.39	5.04
Prunus africana	4	2.63	6.00	0.89	5.36	1.13	16.67	1.59	5.35
Phytolacca dodecandra	3	1.97	6.00	0.02	0.12	0.03	16.67	1.59	3.59
Jusminum abyssinicum	2	1.32	9.00	0.01	0.12	0.02	25.00	2.39	3.73
Myrica salicifolia	2	1.32	12.00	0.03	0.31	0.07	33.33	3.18	4.56
Periploca linearifolia	2	1.32	7.00	0.02	0.16	0.03	19.44	1.86	3.21
Rubus apetalus	2	1.32	4.00	0.01	0.02	0.00	11.11	1.06	2.38
Maytenus arbutifola	8	5.26	4.00	0.31	1.23	0.26	11.11	1.06	6.58
Brucea antidysenterica	6	3.95	9.00	0.08	0.69	0.15	25.00	2.39	6.48
Teclea nobilis	6	3.95	9.00	0.31	2.78	0.59	25.00	2.39	6.92
Maesa lanceolata	3	1.97	3.00	0.15	0.46	0.10	8.33	0.80	2.87

Rhoicissus tridentata	2	1.32	2.00	0.00	0.01	0.00	5.56	0.53	1.85
Vernonia amygdalina	3	1.97	2.00	0.10	0.21	0.04	5.56	0.53	2.55

Appendix-Table 18.Structural value in Intermediate of SLFP

Species	Fr	Rfe	AB	BA	Dom	Rdom	De	Rde	IVI
Allophyllus abyssinicus	9.00	6.57	35.00	4.50	157.47	32.81	97.22	8.82	48.20
Hagenia abyssinica	8.00	5.84	30.00	3.60	107.98	22.50	83.33	7.56	35.90
Myrsine africana	9.00	6.57	60.00	0.08	4.63	0.96	166.67	15.11	22.65
Maytenus arbutifola	6.00	4.38	25.00	1.29	32.14	6.70	69.44	6.30	17.37
Dombeya torrida	7.00	5.11	20.00	3.09	61.70	12.86	55.56	5.04	23.00
Osyris arborea	5.00	3.65	8.00	0.27	2.19	0.46	22.22	2.02	6.12
Bersama abyssinica	6.00	4.38	20.00	0.25	4.94	1.03	55.56	5.04	10.45
Prunus africana	5.00	3.65	16.00	2.19	35.10	7.31	44.44	4.03	14.99
Ficus sure	4.00	2.92	11.00	1.51	16.59	3.46	30.56	2.77	9.15
Apodytes dimidiata	4.00	2.92	12.00	1.65	19.75	4.11	33.33	3.02	10.06

Stephania abyssinica	7.00	5.11	11.00	0.02	0.18	0.04	30.56	2.77	7.92
Brucea antidysenterica	7.00	5.11	11.00	0.01	0.16	0.03	30.56	2.77	7.91
Ekebergia capensis	3.00	2.19	10.00	1.29	12.86	2.68	27.78	2.52	7.39
Clematis simensis	7.00	5.11	4.00	0.01	0.02	0.00	11.11	1.01	6.12
Periploca linearifolia	4.00	2.92	10.00	0.01	0.14	0.03	27.78	2.52	5.47
Jusminum abyssinicum	5.00	3.65	5.00	0.01	0.04	0.01	13.89	1.26	4.92
Phytolacca dodecandra	4.00	2.92	8.00	0.01	0.09	0.02	22.22	2.02	4.95
Premna schimperi	4.00	2.92	8.00	0.01	0.08	0.02	22.22	2.02	4.95
Rhus glutinosa	3.00	2.19	9.00	0.10	0.87	0.18	25.00	2.27	4.64
Olea europaea	2.00	1.46	7.00	1.10	7.68	1.60	19.44	1.76	4.82
Maesa lanceolata	3.00	2.19	8.00	0.29	2.33	0.49	22.22	2.02	4.69
Rosa abyssinica	3.00	2.19	13.00	0.02	0.22	0.05	36.11	3.27	5.51
Ebelia schimperi	3.00	2.19	11.00	0.08	0.93	0.19	30.56	2.77	5.16
Vernonia amygdalina	3.00	2.19	5.00	0.18	0.91	0.19	13.89	1.26	3.64
Nuxia congesta	3.00	2.19	4.00	0.31	1.23	0.26	11.11	1.01	3.45
Acacia abyssinica	3.00	2.19	3.00	0.24	0.71	0.15	8.33	0.76	3.09
Osyris quadripartita	2.00	1.46	12.00	0.44	5.24	1.09	33.33	3.02	5.58
Syzygium guineense	2.00	1.46	4.00	0.58	2.33	0.49	11.11	1.01	2.95
Teclea nobilis	2.00	1.46	4.00	0.32	1.27	0.26	11.11	1.01	2.75

Lagenaria abyssinica	2.00	1.46	5.00	0.01	0.03	0.01	13.89	1.26	2.73
Rubus steudneri	2.00	1.46	8.00	0.01	0.08	0.02	22.22	2.02	3.49

Appendix-Table 19. Structural value in Intermediate of MBFP

Species	Fr	Rfe	AB	BA	Dom	Rdom	De	Rde	IVI
Allophyllus abyssinicus	8.00	4.97	31.00	3.19	98.83	27.02	86.11	8.16	40.15
Dombeya torrida	5.00	3.11	28.00	2.64	73.91	20.21	77.78	7.37	30.68
Maytenus arbutifola	8.00	4.97	25.00	1.93	48.21	13.18	69.44	6.58	24.73
Albizia schimperiana	6.00	3.73	12.00	1.65	19.75	5.40	33.33	3.16	12.28
Bersama abyssinica	9.00	5.59	6.00	0.33	1.97	0.54	16.67	1.58	7.71
Dracaena steudneri	3.00	1.86	4.00	0.31	1.23	0.34	11.11	1.05	3.25
Domb.quin	3.00	1.86	13.00	1.00	13.03	3.56	36.11	3.42	8.85
Hagenia abyssinica	3.00	1.86	13.00	1.00	13.03	3.56	36.11	3.42	8.85
Apodytes dimidiata	6.00	3.73	12.00	1.03	12.34	3.37	33.33	3.16	10.26
Vernonia amygdalina	4.00	2.48	14.00	0.76	10.70	2.93	38.89	3.68	9.09
Vernonia auriculifera	4.00	2.48	13.00	0.71	9.23	2.52	36.11	3.42	8.43
Stephania abyssinica	4.00	2.48	16.00	0.03	0.55	0.15	44.44	4.21	6.84
Prunus africana	5.00	3.11	8.00	0.69	5.48	1.50	22.22	2.11	6.71
Maytenus undata	6.00	3.73	4.00	0.31	1.23	0.34	11.11	1.05	5.12

Rhus glutinosa	3.00	1.86	12.00	0.72	8.64	2.36	33.33	3.16	7.38
Rubus apetalus	4.00	2.48	14.00	0.03	0.42	0.11	38.89	3.68	6.28
Ebelia schimperi	6.00	3.73	7.00	0.02	0.16	0.04	19.44	1.84	5.61
Rhoicissus tridentata	4.00	2.48	13.00	0.04	0.54	0.15	36.11	3.42	6.05
Rubus steudneri	4.00	2.48	12.00	0.04	0.46	0.12	33.33	3.16	5.77
Syzygium guineense	2.00	1.24	9.00	0.77	6.94	1.90	25.00	2.37	5.51
Brucea antidysenterica	6.00	3.73	4.00	0.01	0.05	0.01	11.11	1.05	4.79
Salix mucronata	3.00	1.86	7.00	0.54	3.78	1.03	19.44	1.84	4.74
Schefflera abyssinica	3.00	1.86	9.00	0.95	8.59	2.35	25.00	2.37	6.58
Maesa lanceolata	3.00	1.86	9.00	0.94	8.50	2.32	25.00	2.37	6.55
Ekebergia capensis	5.00	3.11	3.00	0.26	0.77	0.21	8.33	0.79	4.11
Ficus sure	4.00	2.48	4.00	0.87	3.48	0.95	11.11	1.05	4.49
Croton macrostachyus	2.00	1.24	11.00	0.75	8.30	2.27	30.56	2.89	6.41
Olea europaea	2.00	1.24	6.00	0.46	2.78	0.76	16.67	1.58	3.58
Kalanchoe petitiana	4.00	2.48	5.00	0.02	0.08	0.02	13.89	1.32	3.82
Premna schimperi	3.00	1.86	8.00	0.03	0.20	0.06	22.22	2.11	4.02
Mikania capensis	4.00	2.48	4.00	0.01	0.05	0.01	11.11	1.05	3.55
Jusminum abyssinicum	4.00	2.48	2.00	0.01	0.01	0.00	5.56	0.53	3.01
Lagenaria abyssinica	3.00	1.86	4.00	0.01	0.05	0.01	11.11	1.05	2.93

Myrsine africana	3.00	1.86	7.00	0.02	0.16	0.04	19.44	1.84	3.75
Teclea nobilis	2.00	1.24	6.00	0.33	1.97	0.54	16.67	1.58	3.36
Phytolacca dodecandra	2.00	1.24	6.00	0.02	0.11	0.03	16.67	1.58	2.85
Clematis simensis	2.00	1.24	4.00	0.01	0.05	0.01	11.11	1.05	2.31
Myrica salicifolia	2.00	1.24	4.00	0.01	0.05	0.01	11.11	1.05	2.31
Periploca linearifolia	2.00	1.24	5.00	0.02	0.08	0.02	13.89	1.32	2.58
Urera hypselodendron	3.00	1.86	4.00	0.01	0.05	0.01	11.11	1.05	2.93
Pavonia urens	2.00	1.24	2.00	0.01	0.01	0.00	5.56	0.53	1.77

Appendix-Table 20. Structural value in Climax of GTFP

Species	Fr	RFr	AB	De	RDe	Ba	Do	ReDom	IVI
Apodytes dimidiata	6.00	9.09	22.00	61.11	11.11	26.95	592.90	22.69	42.90
Prunus africana	4.00	6.06	21.00	58.33	10.61	18.38	385.88	14.77	31.44
Maytenus arbutifola	7.00	10.61	17.00	47.22	8.59	18.78	319.25	12.22	31.41
Olea europapaea	5.00	7.58	17.00	47.22	8.59	16.36	278.16	10.65	26.81
Syzygium guineense	3.00	4.55	19.00	52.78	9.60	23.28	442.23	16.93	31.07
Schefflera abyssinica	5.00	7.58	12.00	33.33	6.06	0.11	1.26	0.05	13.68

Brucea antidysenterica	8.00	12.12	17.00	47.22	8.59	0.04	0.63	0.02	20.73
Bersama abyssinica	9.00	13.64	14.00	38.89	7.07	0.03	0.43	0.02	20.72
Allophyllus abyssinicus	3.00	4.55	14.00	38.89	7.07	12.25	171.50	6.56	18.18
Ekebergia capensis	4.00	6.06	12.00	33.33	6.06	12.60	151.20	5.79	17.91
Teclea nobilis	3.00	4.55	9.00	25.00	4.55	7.88	70.88	2.71	11.80
Ficus sur	3.00	4.55	9.00	25.00	4.55	12.30	110.74	4.24	13.33
Acanthus pubescens	4.00	6.06	7.00	19.44	3.54	0.02	0.11	0.00	9.60
Podocarpus falcatus	2.00	3.03	8.00	22.22	4.04	10.94	87.50	3.35	10.42

Appendix-Table 21. Structural value in Climax of SLFP

Species	Fr	RFr	AB	De	RDe	Ba	Do	RDom	IVI
Apodytes dimidiata	8.00	8.70	35.00	97.22	11.91	33.69	1179.06	26.57	47.18
Prunus africana	7.00	7.61	34.00	94.44	11.57	26.78	910.35	20.52	39.70
Ekebergia capensis	6.00	6.52	33.00	91.67	11.23	31.76	1048.16	23.62	41.38
Olea europaea	6.00	6.52	29.00	80.56	9.87	22.84	662.29	14.93	31.32
Syzygium guineense	3.00	3.26	18.00	50.00	6.13	14.18	255.15	5.75	15.14
Brucea antidysenterica	9.00	9.78	20.00	55.56	6.81	0.06	1.26	0.03	16.62
Bersama abyssinica	9.00	9.78	17.00	47.22	5.79	0.60	10.12	0.23	15.80

Maytenus arbutifola	9.00	9.78	15.00	41.67	5.11	1.18	17.72	0.40	15.29
Ficus sur	3.00	3.26	13.00	36.11	4.43	13.65	177.45	4.00	11.69
Teclea nobilis	6.00	6.52	14.00	38.89	4.77	0.77	10.72	0.24	11.53
Solanecio gigas	3.00	3.26	9.00	25.00	3.06	0.01	0.11	0.00	6.33
Allophyllus abyssinicus	3.00	3.26	9.00	25.00	3.06	8.66	77.96	1.76	8.08
Schefflera abyssinica	3.00	3.26	12.00	33.33	4.08	6.72	80.64	1.82	9.16
Myrsine africana	4.00	4.35	14.00	38.89	4.77	0.03	0.43	0.01	9.12
Acanthus pubescens	6.00	6.52	7.00	19.44	2.38	0.02	0.11	0.00	8.91
Solanum marginatum	3.00	3.26	10.00	27.78	3.40	0.01	0.14	0.00	6.67
Croton macrostachyus	4.00	4.35	5.00	13.89	1.70	1.09	5.47	0.12	6.17

Appendix-Table 22. Structural value in Climax of MBFP

Species	Fr	RFr	AB	De	RDE	Ba	Dom	RDom	IVI
Apodytes dimidiata	5.00	6.58	23.00	63.89	10.75	31.45	723.24	25.13	42.46
Albizia schimperiana	6.00	7.89	17.00	47.22	7.94	17.85	303.45	10.54	26.38
Prunus africana	7.00	9.21	27.00	75.00	12.62	33.08	893.03	31.03	52.86
Brucea antidysenterica	7.00	9.21	15.00	41.67	7.01	0.03	0.49	0.02	16.24
Syzygium guineense	4.00	5.26	17.00	47.22	7.94	17.85	303.45	10.54	23.75

Maytenus arbutifola	5.00	6.58	24.00	66.67	11.22	0.05	1.26	0.04	17.84
Ekebergia capensis	3.00	3.95	15.00	41.67	7.01	15.75	236.25	8.21	19.17
Croton macrostachyus	3.00	3.95	16.00	44.44	7.48	14.00	224.00	7.78	19.21
Teclea nobilis	6.00	7.89	10.00	27.78	4.67	0.79	7.88	0.27	12.84
Bersama abyssinica	7.00	9.21	10.00	27.78	4.67	0.13	1.26	0.04	13.93
Allophyllus abyssinicus	4.00	5.26	6.00	16.67	2.80	6.30	37.80	1.31	9.38
Ficus sur	3.00	3.95	6.00	16.67	2.80	8.20	49.22	1.71	8.46
Myrsine africana	4.00	5.26	8.00	22.22	3.74	0.02	0.14	0.00	9.01
Olea europaea	4.00	5.26	6.00	16.67	2.80	5.78	34.65	1.20	9.27
Solanecio gigas	3.00	3.95	6.00	16.67	2.80	8.20	49.22	1.71	8.46
Schefflera abyssinica	3.00	3.95	3.00	8.33	1.40	4.10	12.30	0.43	5.78

Appendix-Table 23. Structural value of plants in BMFP

Species	Fr	AB	RFr	De	RDE	Ba	Dom	RDom	IVI
Albizia schimperiana	17	68	5.70	9.07	617.07	21.12	94.44	8.37	35.20
Millettia ferruginea	15	45	5.03	6.01	270.24	9.25	62.50	5.54	19.83
Albizia gummifera	13	40	4.36	5.34	213.52	7.31	55.56	4.93	16.60

Sapium ellipticum	12	38	4.03	5.07	192.70	6.60	52.78	4.68	15.30
Vernonia amygdalina	12	48	4.03	6.41	307.47	10.52	66.67	5.91	20.46
Fagaropsis angolensis	10	30	3.36	4.00	120.11	4.11	41.67	3.69	11.16
Ficus sycomorus	9	27	3.02	3.60	97.29	3.33	37.50	3.33	9.68
Stereospermum kunthianum	8	24	2.68	3.20	76.87	2.63	33.33	2.96	8.27
Cordia africana	9	27	3.02	3.60	97.29	3.33	37.50	3.33	9.68
Ficus thonningii	8	24	2.68	3.20	76.87	2.63	33.33	2.96	8.27
Grewia ferruginea	9	27	3.02	3.60	97.29	3.33	37.50	3.33	9.68
Acacia sieberiana	8	25	2.68	3.34	83.41	2.86	34.72	3.08	8.62
Vepris angolensis	8	24	2.68	3.20	76.87	2.63	33.33	2.96	8.27
Clausena anisata	7	21	2.35	2.80	58.85	2.01	29.17	2.59	6.95
Entada abyssinica	6	18	2.01	2.26	40.69	1.39	25.00	2.22	5.62
Rytigynia neglecta	7	21	2.35	2.80	58.85	2.01	29.17	2.59	6.95
Vernonia thomsoniana	5	15	1.68	2.00	30.03	1.03	20.83	1.85	4.55
Schefflera abyssinica	7	21	2.35	2.80	58.85	2.01	29.17	2.59	6.95
Croton macrostachyus	6	18	2.01	2.40	43.24	1.48	25.00	2.22	5.71
Maesa lanceolata	7	21	2.35	2.80	58.85	2.01	29.17	2.59	6.95
Celtis africana	6	12	2.01	1.60	19.22	0.66	16.67	1.48	4.15
Pterolobium stellatum	6	12	2.01	1.60	19.22	0.66	16.67	1.48	4.15

Flacourtia indica	5	10	1.68	1.33	13.35	0.46	13.89	1.23	3.37
Dracaena steudneri	4	8	1.34	1.07	8.54	0.29	11.11	0.99	2.62
Ficus ovata	5	10	1.68	1.33	13.35	0.46	13.89	1.23	3.37
Landolphia buchananii	6	12	2.01	1.60	19.22	0.66	16.67	1.48	4.15
Teclea nobilis	5	10	1.68	1.33	13.35	0.46	13.89	1.23	3.37
Tamarindus indica	5	10	1.68	1.33	13.35	0.46	13.89	1.23	3.37
Ehertia cymosa	4	8	1.34	1.07	8.54	0.29	11.11	0.99	2.62
Borassus aethiopum	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91
Crotalaria rosenii	4	8	1.34	1.07	8.54	0.29	11.11	0.99	2.62
Protea gaguedi	4	8	1.34	1.07	8.54	0.29	11.11	0.99	2.62
Lippia adoenesis	5	10	1.68	1.33	13.35	0.46	13.89	1.23	3.37
Syzygium guineense	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91
Carissa spinarum	2	4	0.67	0.53	2.14	0.07	5.56	0.49	1.24
Clutia abyssinica	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91
Capparis erythrocarpos	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91
Dovyalis abyssinica	2	4	0.67	0.53	2.14	0.07	5.56	0.49	1.24
Dracaena afromontana	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91
Galineria saxifraga	4	8	1.34	1.07	8.54	0.29	11.11	0.99	2.62
Ocimum urticifolium	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91

Oncoba spinosa	2	4	0.67	0.53	2.14	0.07	5.56	0.49	1.24
Syzygium guineense wild	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91
Cadaba farinosa	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91
Dodonaea angustifolia	4	8	1.34	1.07	8.54	0.29	11.11	0.99	2.62
Ficus vasta	2	4	0.67	0.53	2.14	0.07	5.56	0.49	1.24
Olinia rochetiana	1	2	0.34	0.27	0.53	0.02	2.78	0.25	0.60
Acanthus sennii	2	4	0.67	0.53	2.14	0.07	5.56	0.49	1.24
Adhatoda schimperiana	3	6	1.01	0.80	4.80	0.16	8.33	0.74	1.91
Calotropis procera	2	4	0.67	0.53	2.14	0.07	5.56	0.49	1.24
Helinus mystacinus	4	8	1.34	1.07	8.54	0.29	11.11	0.99	2.62
Tapinanthus heteromorphus	2	4	0.67	0.53	2.14	0.07	5.56	0.49	1.24
Acokanthera schimperi	2	4	0.67	0.53	2.14	0.07	5.56	0.49	1.24

Appendix-Table 24. Structural value in ABFP

Species	Fr	AB	RFr	De	RDE	Ba	Dom	RDom	IVI
Ficus sycomorus	12.00	45.00	6.06	5.65	254.34	13.74	66.15	6.62	26.41
Cordia africana	10.00	42.00	5.05	3.96	166.17	8.97	61.74	6.18	20.20
Stereospermum kunthianum	6.00	30.00	3.03	7.07	211.95	11.45	44.10	4.41	18.89

Syzygium guineense	12.00	32.00	6.06	3.01	96.46	5.21	47.04	4.71	15.98
Breonadia salicina	7.00	35.00	3.54	3.30	115.40	6.23	51.45	5.15	14.91
Ficus vasta	7.00	34.00	3.54	2.67	90.75	4.90	49.98	5.00	13.44
Gardenia ternifolia	6.00	18.18	3.03	2.54	91.56	4.95	52.92	5.29	13.27
Terminalia schimperiana	8.00	33.00	4.04	2.33	76.94	4.16	48.51	4.85	13.05
Acacia seyal	6.00	15.15	3.03	2.83	84.78	4.58	44.10	4.41	12.02
Terminalia macroptera	6.00	15.15	3.03	2.36	70.65	3.82	44.10	4.41	11.26
Phoenix reclinata	7.00	25.00	3.54	2.94	73.59	3.97	36.75	3.68	11.19
Acacia hecatophylla	5.00	12.63	2.53	3.14	78.50	4.24	36.75	3.68	10.44
Piliostigma thonningii	5.00	12.63	2.53	1.96	49.06	2.65	36.75	3.68	8.85
Sterculia africana	4.00	8.08	2.02	4.52	72.35	3.91	23.52	2.35	8.28
Terminalia laxiflora	5.00	10.10	2.53	1.88	37.68	2.04	29.40	2.94	7.50
Rhus ruspolii	4.00	10.10	2.02	1.41	28.26	1.53	29.40	2.94	6.49
Syzygium guineense (wild)	4.00	6.06	2.02	3.39	40.69	2.20	17.64	1.76	5.98
Annona senegalensis	4.00	8.08	2.02	1.51	24.12	1.30	23.52	2.35	5.68
Kotschya africana	4.00	6.06	2.02	1.13	13.56	0.73	17.64	1.76	4.52
Borassus aethiopum	3.00	6.06	1.52	0.94	11.30	0.61	17.64	1.76	3.89
Ficus thonningii	3.00	4.55	1.52	2.12	19.08	1.03	13.23	1.32	3.87
Vernonia hochstetteri	5.00	7.00	2.53	0.33	2.31	0.12	10.29	1.03	3.68

Pterocarpus lucens	3.00	8.00	1.52	2.26	18.09	0.98	11.76	1.18	3.67
Oncoba spinosa	3.00	4.55	1.52	1.13	10.17	0.55	13.23	1.32	3.39
Sarcocephalus latifolius	4.00	7.00	2.02	0.66	4.62	0.25	10.29	1.03	3.30
Cassia arereh	4.00	5.00	2.02	1.41	7.07	0.38	7.35	0.74	3.14
Hyphaene thebaica	4.00	4.00	2.02	1.96	7.82	0.42	5.88	0.59	3.03
Asparagus racemosus	3.00	6.00	1.52	1.89	11.33	0.61	8.82	0.88	3.01
Entada africana	4.00	5.00	2.02	0.35	1.77	0.10	7.35	0.74	2.85
Tacca leontopetaloides	2.00	6.00	1.01	2.93	17.60	0.95	8.82	0.88	2.84
Lannea schimperi	3.00	7.00	1.52	0.66	4.62	0.25	10.29	1.03	2.79
Ocimum canum	3.00	7.00	1.52	0.49	3.46	0.19	10.29	1.03	2.73
Dombeya buettneri	3.00	6.00	1.52	0.71	4.24	0.23	8.82	0.88	2.63
Sapium ellipticum	3.00	6.00	1.52	0.71	4.24	0.23	8.82	0.88	2.63
Bridelia scleroneura	3.00	6.00	1.52	0.66	3.96	0.21	8.82	0.88	2.61
Ziziphus mauritiana	3.00	6.00	1.52	0.07	0.41	0.02	8.82	0.88	2.42
Asparagus flagellaris	3.00	5.00	1.52	0.35	1.77	0.10	7.35	0.74	2.35
Albizia malacophylla	2.00	7.00	1.01	0.49	3.46	0.19	10.29	1.03	2.23
Ochna leucophloeos	3.00	4.00	1.52	0.38	1.51	0.08	5.88	0.59	2.18
Ozoroa pulcherrima	2.00	5.00	1.01	1.41	7.07	0.38	7.35	0.74	2.13
Tamarindus indica L	2.00	5.00	1.01	0.55	2.75	0.15	7.35	0.74	1.89

Securidaca longepedunculata	2.00	5.00	1.01	0.51	2.55	0.14	7.35	0.74	1.88
Lonchocarpus laxiflorus	2.00	5.00	1.01	0.47	2.36	0.13	7.35	0.74	1.87
Protea gaguedi	2.00	5.00	1.01	0.39	1.96	0.11	7.35	0.74	1.85
Acacia polyacantha	2.00	5.00	1.01	0.35	1.77	0.10	7.35	0.74	1.84

Appendix-Table 25. Structural value of plants in PMFP

Species	Fr	AB	RFr	De	RDE	Ba	Dom	RDom	IVI
Combretum collinum	12.00	72.00	4.76	6.78	488.33	16.99	72	9.36	31.33
Pterocarpus lucens	18.00	60.00	7.14	7.54	452.16	15.73	60	7.80	30.88
Anogeissus leiocarpa	13.00	52.00	5.16	6.53	339.62	11.82	52	6.76	23.89
Ziziphus mauritiana	15.00	60.00	5.95	4.24	254.34	8.85	60	7.80	22.72
Sterculia africana	14.00	56.00	5.56	4.40	246.18	8.56	56	7.28	21.51
Hyphaene thebaica	10.00	40.00	3.97	4.71	188.40	6.55	40	5.20	15.81
Boswellia papyrifera	10.00	40.00	3.97	3.77	150.72	5.24	40	5.20	14.48
Strychnos spinosa	10.00	40.00	3.97	3.14	125.60	4.37	40	5.20	13.60
Maytenus senegalensis	9.00	27.00	3.57	2.54	68.67	2.39	27	3.51	9.50
Combretum hartmannianum	9.00	27.00	3.57	2.54	68.67	2.39	27	3.51	8.21

Cassia arereh	7.00	21.00	2.78	1.65	34.62	1.20	21	2.73	7.89
Lannea schimperi	8.00	24.00	3.17	1.88	45.22	1.57	24	3.12	7.89
Combretum molle	7.00	21.00	2.78	2.64	55.39	1.93	21	2.73	7.46
Dalbergia melanoxylon	6.00	18.00	2.38	2.26	40.69	1.42	18	2.34	7.46
Terminalia laxiflora	8.00	24.00	3.17	2.26	54.26	1.89	24	3.12	6.97
Lonchocarpus laxiflorus	7.00	21.00	2.78	1.98	41.54	1.45	21	2.73	5.80
Lannea welwitschii	8.00	24.00	3.17	2.26	54.26	1.89	24	3.12	5.80
Lannea fruticosa	6.00	18.00	2.38	1.41	25.43	0.88	18	2.34	5.62
Grewia flavescens	8.00	24.00	3.17	1.88	45.22	1.57	24	3.12	5.62
Grewia velutina	4.00	12.00	1.59	0.85	10.17	0.35	12	1.56	5.53
Adansonia digitata	8	4	3.17	6.28	25.12	0.87	4	0.52	4.58
Grewia mollis	4.00	12.00	1.59	0.85	10.17	0.35	12	1.56	4.30
Borassus aethiopum	4.00	8.00	1.59	1.13	9.04	0.31	8	1.04	3.74
Strychnos innocua	5.00	10.00	1.98	0.94	9.42	0.33	10	1.30	3.62
Commiphora pedunculata	3.00	6.00	1.19	0.75	4.52	0.16	6	0.78	2.91
Stereospermum kunthianum	4.00	8.00	1.59	1.00	8.04	0.28	8	1.04	2.91
Cucumis pustulatus	3.00	6.00	1.19	0.57	3.41	0.12	6	0.78	2.84
Dioscorea praehensilis	4.00	8.00	1.59	0.75	6.03	0.21	8	1.04	2.84
Ximenia americana	3.00	6.00	1.19	0.57	3.39	0.12	6	0.78	2.09

Tacca leontopetaloides	3.00	6.00	1.19	0.57	3.39	0.12	6	0.78	2.09
Dalbergia boehmii	2.00	2.00	0.79	0.24	0.47	0.02	2	0.26	1.07
Phoenix reclinata	2.00	2.00	0.79	0.19	0.38	0.01	2	0.26	1.07
Acacia hecatophylla	2.00	2.00	0.79	0.16	0.31	0.01	2	0.26	1.06
Dioscorea cochleari- apiculata	2.00	2.00	0.79	0.16	0.31	0.01	2	0.26	1.06
Tamarindus indica	2.00	2.00	0.79	0.16	0.31	0.01	2	0.26	1.06
Vernonia hochstetteri	3.00	2.00	1.19	0.06	0.13	0.00	2	0.26	1.06
Ziziphus abyssinica	2.00	2.00	0.79	0.06	0.13	0.00	2	0.26	1.06
Asparagus flagellaris	2.00	2.00	0.79	0.02	0.03	0.00	2	0.26	1.05
Clematis hirsuta	2.00	1.00	0.79	0.09	0.09	0.00	1	0.13	0.53
Vitex doniana	1.00	1.00	0.40	0.09	0.09	0.00	1	0.13	0.53
Ochna leucophloeos	2.00	1.00	0.79	0.08	0.08	0.00	1	0.13	0.53

Appendix-Table 26 Canopy level of woody plants

	Species	Visual	Height range	Canopy type
1	*Allophyllus abyssinicus*	3	15-25	UCT,MCL
2	*Apodytes dimidiata*	3	20-30	UCT
3	*Ekebergia capensis*	3	20-35	UCT
4	*Ficus sure*	3	15.35	UCT
5	*Olea europaea*	3	15-35	UCT
6	*Prunus africana*	3	20-35	UCT
7	*Syzygium guineense*	3	20-35	UCT
8	*Dombeya torrida*	2	15-20	MCT
9	*Hagenia abyssinica*	2	20-15	MCT
10	*Myrica salicifolia*	2	15-20	MCT
11	*Rhus glutinosa*	2	15-20	MCT
12	*Salix mucronata*	2	15-20	MCT
13	*Rhamnus staddo*	2	15-21	MCT
14	*Acacia abyssinica*	1	5.5-15.5	LCT
15	*Bersama abyssinica*	1	5.5-15.6	LCT
16	*Brucea antidysenterica*	1	5.5-15.7	LCT
17	*Maesa lanceolata*	1	5.5-15.8	LCT
18	*Maytenus arbutifola*	1	5.5-15.9	LCT
19	*Nuxia congesta*	1	5.5-15.10	LCT
20	*Osyris arborea*	1	5.5-15.11	LCT
21	*Osyris quadripartita*	1	5.5-15.12	LCT
22	*Pittosporum viridiflorum*	1	5.5-15.13	LCT
23	*Teclea nobilis*	1	5.5-15.14	LCT
24	*Vernonia amygdalina*	1	5.5-15.15	LCT
25	*Ebelia schimperi*	0		NCT
26	*Jusminum abyssinicum*	0		NCT
27	*Myrsine africana*	0		NCT
28	*Periploca linearifolia*	0		NCT
29	*Phytolacca dodecandra*	0		NCT

30	*Premna schimperi*	0		NCT
31	*Rhoicissus tridentata*	0		NCT
32	*Rosa abyssinica*	0		NCT
33	*Rubus apetalus*	0		NCT
34	*Rubus steudneri*	0		NCT
35	*Stephania abyssinica*	0		NCT
36	*Rumex nervosus*	0		NCT

Appendix 8. Checklist for Focus Group Discussion (FGD) in local language

Name of Rural Kebele ___________________________

Village Name ______________________

No. of participants_____________________

Date _____________________________________

1. What do understand about Land cover, Land use and land cover land use change

2. What are currently existing land use/land cover types in your locality?

3. What were the past LULCCs looks like before 30 years, 30 years, 20 years, and 10 ye

3. Which land use/land cover type is increasing and which is decreasing during 1973, 1985, 2000, and 2016 to this time, why?

4. Based question number 3 above, on which period do you observed a rapid land use/land cover change, why?

5. What kind of land use/land cover change do you expect in the future? And why?

6. What are the direct/proximate drivers of land use/land cover change over the last 40 years, between 1973 & 1986, 1986 & 2000 and 2000 & 2016? (Options provided: infrastructure development and urban expansion, forest encroachment for illegal and legal settlement, overgrazing, and agricultural expansion, occurrence of fire and unsustainable harvest of forest products (like firewood, charcoal, logging)

7. Which land cover is highly affected by each proximate (direct) drivers of LU/LCC?

8. What are the underlining causes along each proximate driver?

Appendix 9. Informant interview

1. Have you noted or heard any change in the LULCC in your area over the past ears and is the response? A) Yes B) No

2. If your answer to question number 2 is yes, what changes did you observed? Increase/decrease in:

(A) Agricultural land (B) Forest covers(C) Woodland (D) Scrub land E) Bush/shrub lands (F) Grassland (G) Settlement and infrastructure and (H) water body

3. What are the causes behind their increase/decrease?

4. Participation of the local communities, government and non-government organizations in resource conservation and management activities and how they are participating?

5. What do you think the cause for population dynamics in your area?

6. What major technological change occurred in the area of infrastructural development and farming activities in the last 40 years?

7. Do you think national policies and institution implemented starting from 1980s until toddy have responsibility for land use/land cover change? If yes how?

8. What major natural calamities occurred in your area in the last 40 years?

9. What are the main economic activities for the local communities in your area: 1972, 1985, 2000, and 20163. What are the causes behind their increase/decrease?

10. What major technological change occurred in the area of infrastructural development and farming activities in the last 40 years?

11. Do you think national policies and institution implemented starting from 1972 until toddy have responsibility for land use/land cover change? If yes how?

12. What major natural catastrophe occurred in your area in the last 40 years you witness or oral telling?

Appendix 10. Interview and questionair use value and regeneration ways

1. Which species of vegetation do use for fire wood and charcoal in the past and currently?

2. Which species of vegetation do use for timber and furniture in the past and currently?

3. Which species of vegetation do use for poles and posts in the past and currently?

4. Which species of vegetation do use farm tools in the past and currently?

5. Which species of vegetation do use for Carvings/Utensils in the past and currently?

6. Which species of vegetation fruit are used as food for animals in the past and currently?

7. Which species of vegetation are used as Fodder/Forage for animal feeding in the past and currently?

8. Which species of vegetation are used for bee keeping in the past and currently?

9. Which species of vegetations are used side crop/ agro-forestry how in the past and currently?

10. For which tree species do you give admiration in the past and currently?

11. Which tree species do you for treatment of different disease in the past and currently?

12. Have you ever seen that the fire caught the forest in the past and currently? (In time series)

13. Where keep your cattle for grazing in which season in the past and currently?

14. Have you ever protected the forest?

15. Which tree species do you witnessed grows from cutting wood as sapling, seed germination, Seed or is edible?

16. Have ever implemented shifting cultivation?

17. How do each species regenerate seed germination, Sprouting, ,?

Appendix-Table 27. Data collecting sheet

<table>
<tr><td rowspan="2">Region Benshangul-Gumuz,Zone :Metekel
District/woreda: Wombera
Latitude---------------Longitude------------------</td><td colspan="2">Topography and environmental conditions features</td></tr>
<tr><td>Altitude</td><td>Sample no.</td></tr>
<tr><td rowspan="7">Site and vegetation description:
Species Lists</td><td>Aspect</td><td>slope</td></tr>
<tr><td>Plot size:</td><td>latitude</td></tr>
<tr><td>Plot No.</td><td>Rainfall:</td></tr>
<tr><td colspan="2">Layer: mean height</td></tr>
<tr><td colspan="2">Layer cover (%):</td></tr>
<tr><td colspan="2">Land escape:</td></tr>
<tr><td colspan="2">Soil profile</td></tr>
</table>