Ecological and Ethnomedicinal study in Hirmi Woodland Vegetation and the Surrounding Districts, Tigray Regional State, Northern Ethiopia

Mehari Girmay

Addis Ababa University

Addis Ababa, Ethiopia

August, 2021

Ecological and Ethnomedicinal study in Hirmi Woodland Vegetation and the Surrounding Districts, Tigray Regional State, Northern Ethiopia

Mehari Girmay

A Dissertation Submitted to the Department of Plant Biology and Biodiversity Management

Presented in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

(Plant Biology and Biodiversity Management)

Addis Ababa University
Addis Ababa, Ethiopia
August, 2021

ADDIS ABABA UNIVERSITY
GRADUATE PROGRAMMES

Ecological and Ethnomedicinal study in Hirmi Woodland Vegetation and the Surrounding Districts, Tigray Regional State, Northern Ethiopia

By

Mehari Girmay Gebru

A Thesis Presented to the Graduate Programmes of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Plant Biology & Biodiversity Management

Approved by Examining Board:

	Name	Signature	Date
1. (Advisor)	Prof. Tamrat Bekele		3/9/21
2. (Advisor)	Prof. Sebsebe Demissew		3/9/21
3. (Advisor)	Dr. Ermias Lulekal		3/9/21
4. (External Examiner)	Dr. Gerald Eilu		3/9/21
5. (Internal examiner)	Prof. Zemede Asfaw		3/9/21

Dr. Bikila Warkineh

Chair of Department or Graduate Programme Coordinator

Abstract

Ecological and Ethnomedicinal study in Hirmi Woodland Vegetation and the Surrounding Districts, Tigray Regional State, Northern Ethiopia

Mehari Girmay, PhD Dissertation

Addis Ababa University, 2021

Drylands in Ethiopia cover a substantial area endowed with diverse plant resources. However, the landmass has received less attention compared to the moist highlands even if it has high ecological, environmental and economic importance. The present study was conducted in dryland area of Hirmi woodland vegetation to investigate the floristic composition, vegetation structure, regeneration potential of the vegetation and to document the associated ethnomedicinal knowledge of the surrounding community. Vegetation and environmental data were collected from 80 sample plots with a size of 25 m × 25 m designated as the main plots. All vascular plant species were recorded. Woody species ≥ 2 m were counted, cover-abundance values estimated and Diameter at breast height were measured. A total of 128 soil samples were collected from four land use types to investigate the regeneration potential of the study vegetation. The ethnomedicinal data were collected using semi-structured interviews, guided field walks and focus group discussions. A total of 335 informants selected through stratified random and purposive sampling participated to document data related to the use and management of medicinal plants. Shannon-wiener diversity index, cluster analysis and ordination were computed on ecological data using R-software packages. Composition, density, depth distribution and Jaccard's coefficient of similarity were computed for soil seed bank analysis. Ethnobotanical analytical tools including preference ranking, informant consensus factor, direct matrix ranking and t-tests in SPSS were employed. A total of 201 vascular plant species belonging to 163 genera and 66 plant families were recorded. Of these 5% of the total recorded species were endemic/nearly endemic to Ethiopia while 10% of the species were new records to Tigray floristic region. In terms of species number, the dominant plant families were Fabaceae (13.9%), Poaceae (10.5%), Asteraceae (6 %) and Lamiaceae (5.5%). Five plant communities were identified in the study vegetation, namely; Ziziphus mucronata - Acacia polyacantha, Combretum hartmannianum - Terminalia macroptera - Oxytenanthera abyssinica, Anogeissus leiocarpa - Ozoroa insignis, Euclea racemosa - Acacia abyssinica and Dodonaea angustifolia- Flueggea virosa. The ordination result revealed that the identified five plant communities were associated with altitude, slope, sand, silt, soil organic matter, total Nitrogen and disturbance. According to the vegetation structure result, large numbers of individual species were categorized in the lower classes of DBH and height. Anogeissus leiocarpa, Combretum hartmannianum, Ziziphus mucronata, Terminalia macroptera and Acacia polyacantha were the species with high importance value. Some endemic plant species of Hirmi were found recorded in the IUCN red list. The overall regeneration status of the study area was found to be poor. This is attributed to anthropogenic disturbances and grazing pressures. A total of 58 species representing 51 genera and 22 families were recovered from the soil seed bank. Of these, 86.2% were herbs. The total density of soil seed banks from all land-use types was 3,116.7 seeds/m^2. The highest species composition was found in the shrubland and the least number of species were found in the bare land. About 85 medicinal plant species used for the treatment of 71 human and 16 livestock ailments were documented. The majority (64.7%) of the medicinal *plants were collected from the wild environment, while the remaining (35.3%) were collected from the homegardens, fallow land and farming lands of the community. The highest informant consensus factor values were calculated for abdominal discomfort. Zehneria scabra, Plumbago zeylanica and Zingiber officinale were the most preferred medicinal plants to treat abdominal diseases. Regarding ethnomedicinal knowledge, there was a significant difference between age groups, educational status, marital status and experience of informants; however, religion and gender did not exert statistically significant differences. Overgrazing, deforestation and expansion of agriculture are the number one threats to the medicinal plants. Homegardening, fencing and plantation were among the conservation techniques used by the local community. In general, the study area is under poor regeneration status. To overcome this challenge, integrated management measures including monitoring, education and application of restoration techniques by taking into consideration the significant environmental factors associated with species diversity, IUCN threat level, ethnomedicinal services, regeneration potential and status of species are recommended to preserve and restore the study vegetation.*

Keywords: Dryland, Ethnomedicinal services, Floristic composition, Hirmi, Regeneration status, Soil seed bank, Tigray floristic region, Vegetation structure

Dedication

This dissertation is dedicated to my late father Girmay Gebru, my mother Mebrat Weldekidan and the rest of my families who were always in my side; and the local people of the study area who maintain the vegetation as well as indigenous knowledge associated with it.

Acknowledgements

First of all, I would like to express my sincere gratitude to my supervisors Prof. Sebsebe Demissew, Dr. Tamrat Bekele and Dr. Ermias Lulekal for their guidance, advice, useful comments and effective follow up of this research work. I would also like to acknowledge Dr. Bikila Warkineh (Chair of the Department) for his support and encouragement. Prof. Yacob Mulugetta, Prof. Sileshi Nemomissa, Dr. Ermias Aynekulu and Dr. Tigist Wondimu are also deeply accredited for their professional support. I gratefully acknowledge the financial support from Addis Ababa University and Rufford Small Grants (RSG). I also extend my gratitude to the following institutions: Department of Plant Biology and Biodiversity Management, Addis Ababa University for facilitating the study; the technical staff members of the National Herbarium (ETH) for their kind help during the herbarium work; the National Meteorological Service Agency of Ethiopia and Ethiopian Mapping Agency for providing meteorological data and map of the study area, respectively; Ministry of Mining and Petroleum of Ethiopia for providing me with the opportunity to study my PhD; Shire-Mai-Tsebri Agricultural Research Centre for their collaboration in data collection and soil laboratory analysis; GIZ Ethiopia (Mekele branch) for providing preliminary information about the study area; the Northwestern Zone Administration of Tigray Regional State for writing supporting letters to the study districts; local administration officials and experts for their cooperation in providing necessary information about the districts and the study site.

My special thanks go to the local inhabitants around the study area for their effort to preserve the vegetation and associated knowledge as well as their willingness in providing all the necessary information. I would like to thank Mr. Yirga Gebretsadik (staff member of Shire-Mai-Tsebri Agricultural Research Centre) for his kind cooperation in many ways starting from the reconnaissance study up to the final data collection. I also gratefully acknowledge Dr. Kflay Gebrehiwot for his technical help during my study. I deeply acknowledge the enormous support to my beloved family for their patience and strength throughout my study period. I also thank all friends who directly and indirectly participated in this study.

Above all, I thank the Almighty God for providing me with the strength to complete the study successfully. I also thank very much St. Mary, the mother of Lord Jesus Christ, who is with me at all times and in all circumstances.

Table of contents

List of figures

List of tables

List of appendices

List of Acronyms

ACB	*Acacia-Commiphora* woodland and bushland
ANRBNWZT	Agriculture and Natural Resource Bureau of North-Western Zone of Tigray Region
CBD	Convention on Biological Diversity
CCA	Canonical Correspondence Analysis
CSA	Central Statistical Agency
CTW	*Combretum-Terminalia* woodland and wooded grassland
DAF	Dry evergreen Afromontane forest and grassland complex
DBH	Diameter at Breast Height
DCA	Detrended Correspondence Analysis
DF	Degree of Freedom
EFAP	Ethiopian Forestry Action Program
FAO	Food and Agriculture organization
IBC	Institute of Biodiversity Conservation
ICF	Informant Consensus Factor
IUCN	International Union for the Conservation of Nature
IUFRO	International Union for Forestry Research Organization
IVI	Importance Value Index
m.a.s.l	Meters above sea level
m.b.s.l	Meters below sea level
MEF	Ministry of Environment and Forest
MEFCC	Ministry of Environment, Forest and Climate Change
MoA	Ministry of Agriculture
NMSA	National Metrological Service Agency
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SPSS	Statistical Package for Social Sciences
TDS	Total Dissolved Salts
TU	Tigray Upland (Tigray floristic region)
WHO	World Health Organization

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Biodiversity is defined as the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems (CBD, 1992). It can be determined by the degree of variation of life forms within a given ecosystem, biome, or entire planet which encompasses all species of plants, animals, microorganisms and ecological processes (Rawat and Agarwal, 2015). Biodiversity is also an umbrella term for the degree of nature's variety, including both the number and frequency of ecosystems, species or genes in a given assemblage (Gaston, 2000; Rawat and Agarwal, 2015). Biodiversity is not distributed evenly on earth due to topographic and other environmental determinants (Field *et al*., 2009) as well as anthropogenic factors (Bongers *et al*., 2009). Besides, biodiversity has a key role in ecosystem functioning and has been widely used as an indicator of ecosystem health (FAO, 2005). Human beings can get some ecological services such as food, fiber, medicine, water purification, recreation and protection from natural disasters. In recent times, due to the rapid increase of the human population, huge exploitation of these resources results in biodiversity loss and decline of the capacity of the ecosystem to provide such vital services (Mace *et al*., 2012).

Ethiopia is located in the horn of Africa that has enormous topographical diversity with flat-topped plateaus, high mountains, river valleys, deep gorges, rolling plains, with great variations in altitude; ranges from 116 m.b.s.l of Afar Danakil depression to 4533 m.a.s.l. of Ras Dashen (Oleg, 2012). Ethiopia shares more than 50% of the Afromontane region's land areas above 1500 meters of Africa (Tamrat Bekele, 1994) as well as extensive dryland areas (Demel Teketay, 2001). These diverse physiographic features have contributed to the formation of different ecosystems characterized by variations in species diversity, vegetation types, soil types and diverse climatic conditions (TewoldeBerhan GebreEgziabher, 1991). This designates the country in the fifth-largest floral composition in tropical Africa (Anonymous, 1997; Motuma Didita *et al.*, 2010), which encompasses about 5,757 vascular plant species with 10% endemics (Ensermu Kelbessa and Sebsebe Demissew, 2014).

The vegetation types in Ethiopia are diverse and comprises tropical rain forests (in the south and southwest), dry forests (in the north, west, south and central mountains and lowlands) and desert scrubs (in the east and northeast and parkland agroforestry on the central plateau) (Demel Teketay, 2000; Friis *et al.*, 2010). Structurally, dry forests cover from a high forest (closed canopy with tall trees) to desert scrubs. Out of that, vegetation in the dry areas encompasses the largest portion of the country (Demel Teketay, 2001; Mulugeta Lemenih and Bongers, 2011). The dryland vegetations are found in the dry landmass of Ethiopia (Mulugeta Lemenih and Taddesse Woldemariam, 2010), that are defined by emphasizing the structural attributes such as height and density; others emphasize foliar aspects (deciduous vs evergreen, small-leaved vs broad-leaved), canopy cover (open vs closed), or nature of understory vegetation (FAO, 2005; Ensermu Kelbessa and Abenet Girma, 2011). Species of *Acacia, Combretum, Terminalia,* lowland bamboo and broad-leaved deciduous plants are the most dominant in the dryland vegetation types (Friis *et al.*, 2010; Mulugeta Lemenih and Habtetmeraim Kassa, 2011). Ethiopian dryland vegetation plays considerable ecological and socio-economic roles (Mulugeta Lemenih and Bongers, 2011) and it hosts the majority of national parks (Friis *et al.*, 2010).

The forests that originally existed in northern and central Ethiopia have almost disappeared (EFAP, 1994; Feoli *et al.,* 2002). This was associated with direct or indirect anthropogenic and environmental factors (Noss, 1999). Habitat loss and change, over-harvesting, pollution, agricultural expansion and climate change have a direct cause for global biodiversity loss whereas population growth, changes in economic activities, socio-political factors, cultural factors and technological changes are indirect drivers (Wood *et al.,* 2000; Demel Teketay, 2001; IBC, 2009). Studies conducted by Miles *et al.* (2006) and Abeje Eshete *et al.* (2011) showed that although the entire biodiversity of the country is under serious threat of deforestation, overexploitation, overgrazing, degradation and invasive species, the impact is significant and intense in dryland vegetation relatively with other forests. This pressure might be associated with the substantial role of the vegetation in food security, livelihood diversification, fodder, human health care and environmental conservation (Demel Teketay, 2005a; Mulugeta Lemenih and Habtetmeraim Kassa, 2011).

The roles of plant species in health care services are accounted a long time history in Ethiopia (Dawit Abebe and Estifanos Hagos, 1991) and in the entire world as well (Martin, 1995). About 65-80% of the world's population in developing countries depends essentially on herbal remedies for their primary healthcare due to poverty and lack of access to modern medicine (Awoyemi, 2012). Ethiopia is one of the developing countries with 80% of its population dependent on traditional medicine. For a long time, local people have been practicing traditional knowledge and perceptions to categorize plant species based on their service provision to human beings (Dawit Abebe and Estifanos Hagos, 1991). However, the destruction of plant resources with the loss of indigenous knowledge on the traditional medicine of the country is accelerating from time to time (Dawit Abebe, 2001; Mirutse Giday *et al*., 2003). To tackle the problem, studies conducted at different times and in different parts of the country suggested that the need for urgent documentation of indigenous knowledge related to plant use and management. Studies conducted by Gidey Yirga (2010), Girmay Zenebe *et al.* (2012), Abraha Teklay *et al.* (2013), Kalayu Mesfin *et al.* (2013), Tadesse Beyene (2015), Gebrekidan Abrha *et al.* (2018) and Leul Kidane *et al*. (2018) described that the local community in Tigray region practices the traditional medicinal plants and require investigations in depth. Though people around Hirmi woodland vegetation are endowed with indigenous knowledge of how to use and conserve herbal plants to secure their health as well as the health of their livestock, it is not yet scientifically documented.

According to the report from the Ministry of Agriculture (MoA) in 2003, Tigray is one of the most environmentally degraded regions in Ethiopia left only with a remnant patch of natural vegetation. The original vegetation is cramped around religious and worship areas where religion and culture forbid cutting trees and removal of plants and in limited other isolated and protected areas (MoA, 2003; Nyssen *et al*., 2007). The long history of extensive land clearance, early human settlement, poor farming practices, growth in population and frequent droughts in the region are the major causative factor to have the largest degraded area in Ethiopia (Nyssen *et al*., 2007). Other scholars such as Mitku Haile and Kindeya Gebrehiwot (2000) have stated that Tigray is characterized by a low degree of vegetation cover, over-cultivation, relatively high population density, unpredictable rainfall and frequent droughts, severe soil erosion and steep slopes. Those factors lead to having less vegetation distribution, habitat degradation and eventually poor support for the society's livelihood sustainability.

To reverse the region's ecological degradation, the Ministry of Environment and Forest (MEF) in collaboration with concerned stakeholders (GIZ and Tigray region agricultural sector), has been organizing various participatory forest management approaches that were facilitated by the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) secretariat (MEF, 2015). Furthermore, in recent times the regional government shows an interest in ecological restoration of degraded dry landmasses through societal and organizational involvements. From the rehabilitation and conservation plans, participatory forest management and area closures have gained great attention for conservation mechanisms at various levels (Fitsum Hagos *et al.*, 1999; Emiru Brhane *et al.*, 2006). However, the rehabilitation and restoration approaches for the degraded vegetation are efficient after understanding the regeneration potential from persistent soil seed banks or seedling banks (Demel Teketay, 2005b). Soil seed bank is seeds that can remain dormant for a period in the soil until their germination is triggered by an environmental change (Simpson *et al*., 1989) and anthropogenic involvements (Feyera Senbeta and Demel Teketay, 2001; Carey and Watkins, 1993). They are essential in providing information for management purposes (Harper, 1977) and play a significant role in biodiversity maintenance, ecosystem restoration and conservation of genetic variability through replacing adult plants (Mulugeta Lemenih and Demel Teketay, 2006). Soil seed bank exhibits variations in space as well as time. They are also display both horizontal and vertical dispersion, reflecting initial dispersal onto the soil and subsequent movement (Feyera Senbeta and Demel Teketay, 2002).

Biodiversity conservation prioritization is based on species distribution, regeneration potential, endemism, threats and services in relation to various ecological processes or environmental gradients. Investigating these features are critical and needs to be considered in the design of biodiversity conservation programs (Reid, 1998). However, there is a lack of these ecological information in the study vegetation. The required information on how the vegetation is important for the surrounding community for healthcare is also not studied. Thus, this study is important to investigate the vegetation ecology of Hirmi woodland as well as to document the use and management of traditional medicinal plants by the surrounding communities.

1.2. Statement of the research problem

Terrestrial biodiversity represents the richest diversity in the tropics and near to the equator (Gaston, 2000). This could be the result of the warm climate, high primary productivity and diverse topography in the region (Field *et al.,* 2009). About 40% of the global tropical forest area (Mayaux *et al.,* 2005) and 14% of the total African land surface which is harboring 25% of the African natural vegetation (Abeje Eshete *et al.,* 2011) is covered by dry woodland vegetation. Though the dryland area has high ecological, environmental and economic importance (Muys *et al.,* 2006; Getachew Tadesse *et al.,* 2008), currently the vegetation resources in this landmass are facing serious problems due to human interferences and very poor stakeholders' attention given than of the moist vegetation (Zenebe Girmay, 2020). Deforestation and habitat degradation in the dryland area resulted in several socio-economic and environmental challenges that bring a strong impact on the capacity of the vegetation to provide rich ecosystem services (Nyssen *et al.,* 2007). To mitigate these challenges, the conservation of biodiversity in the dryland ecosystems has been receiving greater international attention from time to time (Mulugeta Lemenih and Bongers, 2011; Zenebe Girmay, 2020). Effective conservation activities in dryland vegetations definitely demand an in-depth investigation on environmental determinants such as soil properties, elevation, habitat suitability, habitat diversity as well as species interaction (Arponen, 2012; Abyot Yismaw *et al.,* 2014).

According to a study conducted by Demel Teketay (2001), about 65% of the Ethiopian landmass is covered by dryland ecosystems, whereby 12% of human and 20% of livestock populations reside. It is also the center of biodiversity, endemism and grazing (Tefera Mengistu *et al.,* 2005). Moreover, dry forests or woodland vegetation types cover a wide range in northern Ethiopia (Kidane Georgis, 2010). Following the long history of land degradation, many land rehabilitation and conservation programs have been carried out in northern Ethiopia in general, Tigray region in particular. However, inadequate investigation of ecological information makes the effectiveness of biodiversity conservation policy and strategy render in a challenge for its implementation as it intends (EFAP, 1994; Demel Teketay, 2001).

Hirmi woodland is one of the dryland vegetation types stretched in the north to the Tekeze River (Fitsum Hagos *et al.,* 1999). An assessment conducted by the Ethiopian REDD+ secretariat

(MEF, 2015) and National Sustainable Land Management Program (Gerben, 2013) reveals the study vegetation to be identified as one of the vegetation potential areas that require ecosystem restoration and conservation approaches. According to the annual report from the Agriculture and Natural Resource Bureau of North-Western Zone of Tigray Region (2017) despite the Hirmi woodland vegetation was a protected area to preserve the wildlife, the plant resources are dwindling continuously because of human and livestock pressures. Yilma Abebe (2010) also suggested that proper ecological studies are imperative to preserve the vegetation which is home to many wildlife as well as critical for the production of natural gum and incense. Investigation of plant community types and the driving environmental and anthropogenic factors shaping the existing vegetation could serve as the basis for taking effective conservation measures (Pimm and Raven, 2000; Brooks *et al.*, 2002). Besides, soil seed bank study is important in providing information for the future restoration and management basis of the vegetation (Harper, 1977).

In other aspects, dryland vegetations particularly *Combretum–Terminalia* woodland and wooded grassland and *Acacia-Commiphora* woodland and bushland, in Northern Ethiopia are known in supporting the local community in herbal medicines and other services (Ensermu Kelbessa and Abenet Girma, 2011). A study conducted by Ermias Lulekal *et al*. (2013) showed that though traditional medicinal plants play a significant role in supporting primary healthcare in Ethiopia, inadequate investigation has been done to scientifically document, explore and promote their uses and associated knowledge dynamics. Thus, ethnomedicinal investigation in districts surrounding Hirmi vegetation has a crucial role in conserving and documenting medicinal plants and the associated knowledge. While people use medicinal plants for their health care from the vegetation of their vicinities, it is a good trend to associate it with the concern of conservation and medicinal services (Stolton and Dudley, 2010).

There are no earlier investigations done on floristic composition, structure, community types, threats, regeneration status and soil seed bank of the Hirmi vegetation so far. The herbal services of the vegetation to the surrounding community are also not studied. Therefore, this study was conducted to fill the existing gap and serve as a tool for running effective conservation and sustainable utilization of the study vegetation.

1.3. Research questions, hypotheses and objectives

1.3.1 Research questions

i. What is the floristic composition, structure and diversity of the Hirmi woodland vegetation?

ii. What type of plant communities exist in Hirmi woodland vegetation?

iii. What are the environmental variables that determine the patterns of plant community formation?

iv. What are the disturbance factors impacting the vegetation in the study areas?

v. What is the regeneration status of woody species in the study area?

vi. What is the floristic composition in the soil seed bank from different land use types in the study area?

vii. Do the land use types of the study area show variations in soil seed bank density?

viii. What are the traditional medicinal plants used by the people in the study area?

ix. What are the threats for the medicinal plants and conservation practices used by the local communities?

1.3.2 Research hypotheses

In this study the following hypotheses were tested;

1. Hirmi woodland vegetation is one of the dryland ecosystems with high vascular plant species diversity in Tigray region, Ethiopia.
2. Human activities and environment determinates have a relationship with plant the distribution in Hirmi woodland vegetation.
3. The regeneration status and potential of the study area is under good/fair status.
4. People around Hirmi vegetation have the knowledge on utilization and management of traditional medicinal plants used for the treatment of human and livestock ailments.

1.3.3. Objectives

1.3.3.1. General objective

The general objective of this research was to study the vegetation ecology and ethnomedicine in Hirmi woodland vegetation and the surrounding districts, Tigray Regional State, Northern Ethiopia.

3.3.3.2. Specific objectives

The specific objectives of this research were to:

i. document the floristic composition, structure and regeneration status.
ii. describe plant community types.
iii. examine the relationship between selected environmental determinants with the community types.
iv. investigate the soil seed bank flora from different soil layers and land use types.
v. document medicinal plants and associated indigenous knowledge in the community and its environs.
vi. identify existing threats to the medicinal plants and the vegetation in the study area.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Biodiversity

The term biodiversity encompasses a broad spectrum of biotic scales, from genetic variation within species to biome distribution on the planet (Purvis and Hector, 2000). It can be defined as the total number, variety and variability of living organisms as well as the diversity of the ecosystem they are living in (CBD, 1992). Biodiversity includes all living organisms (animals, plants, fungi and microbial groups inclusive of genetic diversity and ecosystem/landscape diversity in their interactive state contributing to a multitude of services of relevance to sustaining the ecological integrity for the benefit of humankind (Kumaraswamy and Udayakumar, 2011). Identifying areas with high biodiversity along environmental gradients are used for healthy ecosystem functioning as well as biodiversity conservation priority setting and to get sustainable ecosystem services (Vieira *et al.*, 2007).

Plant diversity is one component of biodiversity that refers to the species and genetic variety of plants that exist in all terrestrial and aquatic regions of the earth (CBD, 1992). Plant species diversity represents millions of years of evolution and provides an important visible expression of biodiversity. Healthy ecosystems based on plant diversity provide the conditions and processes that sustain life and are essential to the well-being and livelihoods of humankind (FAO, 2005). Plants play a huge role in providing ecosystem services such as supporting (nutrient cycling, soil formation, primary production), provisioning (food, fresh water, wood, fiber, fuel), regulating (climate regulation, flood regulation, disease regulation, water purification) and cultural value (aesthetic, spiritual, educational, recreational) (Sharrock *et al.*, 2014).

2.1.1. The concept of vegetation ecology

Vegetation is the naturally growing plant cover of the earth and comprises all plant species growing in a very great diversity of assemblage and whose phytosociology deals with floristic structure, development, distribution and definition of plant communities (Fosberg, 1961). Plant communities differ in their structure and the structure of any vegetation can be considered from many perspectives (Kent, 2012). Mueller-Dombois and Ellenberg (1974) identified five levels of vegetation structure, which are hierarchically integrated. These levels include vegetation physiognomy, biomass structure, life form structure, floristic structure and stand structure. Vegetation physiognomy is defined as the external appearance of vegetation. The biomass structure is a more concise concept that relates specifically to the spacing and height of plants forming the matrix of a vegetation cover. Life form structure relates to the composition of growth forms or life forms of plants in vegetation. Growth forms include trees, shrubs and herbs. Floristic structure relates to the floristic composition. Stand structure or community structure involves population structure analysis, where population curves of different species are compared (Fosberg, 1961; Mueller-Dombois and Ellenberg, 1974).

Vegetation ecology is the study of the plant cover and its relationships with the environment, also called synecology. It is a complex scientific undertaking, both regarding the overwhelming variation of its object of study in space and time and its intricate interactions with abiotic and biotic factors. It is a very modern science with important applications in well-known social activities, notably nature management, in particular the preservation of biodiversity, sustainable use of natural resources and detecting 'global change' in the plant cover of the Earth (Fosberg, 1961; Van der Maarel, 2005).

2.1.2. Environmental drivers and vegetation diversity

Plant ecology is basically influenced by two factors: spatial factors (neutral processes) and environmental (niche processes) (Li *et al.*, 2011; Lan *et al.*, 2012). Plant diversity can indicate two types of spatial structure: (1) autogenous structure, which is independent and not affected by any environmental variation; and (2) exogenous structure, which is a result of spatially structured environmental variables. Practically, spatial structuring is complex as the spatial pattern in plant community which is cumulative of various environmental and dispersal factors (Fortin and Dale, 2005). Regarding other factors so-called environmental drivers, it can be either natural or manmade (Lyaruu *et al.*, 2000; Lan *et al.*, 2012). Different scholars suggested that the impacts of environmental drivers on plant diversity are not uniform. For instance, a study conducted by Hegazy (1998) indicates that floristic composition and abundances are strongly influenced by the variation in soil properties, Lan *et al.* (2012) advocate topography is the major environmental driver for species diversity. Other environmental drivers such as elevation (Kreft and Jetz, 2007; Körner, 2000), habitat diversity (Pausas *et al.*, 2003), temperature (Rosenzweig, 1995) has a significant role in plant diversity. Understanding what drives the geographic variation of species richness is a fundamental goal of ecology and biogeography. Strong correlations between environmental variables and species richness have been found for many taxa at all spatial scales across the globe, with the highest species richness occurring in warm and wet areas (Wright *et al.*, 1993; Brooks *et al.*, 2002).

Another process such as species biotic factors such as dispersal, biotic interactions and gap dynamics has a strong relationship with species distribution (Wyatt and Silman, 2004). Furthermore, anthropogenic disturbance (habitat fragmentation and loss, tree logging, deforestation) (Mittermeier *et al.*, 1998; Lyaruu *et al.*, 2000) has a definite correlation with plant diversity. Subsequently, species richness varies greatly among different regions across the globe (Latham and Ricklefs, 1993).

2.2. The vegetation types of Ethiopia

Ethiopia is characterized by a wide range of ecological, edaphic and climatic condition that accounts for the wide diversity of its biological resources in terms of both flora and fauna (TewoldeBerhan GebreEgziabher, 1991). It has enormous genetic resources and diversity that range from afro-alpine vegetation to desert scrub. The country is one of the origins for domesticated crops and their wild and weedy relatives. It is also estimated that there are 238 vascular plant famileis and 5,757 species (including subspecies) recorded in Ethiopia (Ensermu Kelbessa and Sebsebe Demissew, 2014).

The most frequently cited studies on the vegetation of Ethiopia in relation to anthropogenic and environmental factors were by; Pichi-Sermolli (1957), White (1983), Friis (1992), Tamrat Bekele (1993), Zerihun Woldu (1999), Demel Teketay (2001), Feoli *et al.* (2002) and Friis and Sebesebe Demissew (2001). These studies are basic inceptions for the recent studies done in a different part of the country. However, the classification of the Ethiopian vegetation was very complex due to great variation in altitude, temperature as well as moisture within very short horizontal distances (Zerihun Woldu, 1999).

Despite the classification of Ethiopian vegetation types was attempted by different authors including White (1983), Friis *et al.* (1992), Sebsebe Demissew *et al.* (1996), Friis and Sebesebe Demissew (2001) a much improved, recent and better described Ethiopian vegetation classification system was proposed by Friis *et al.* (2010). According to Friis *et al.* (2010), the vegetation potential in Ethiopia was classified into twelve major vegetation types. 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) Afro-alpine 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).

Dry evergreen Afromontane forest and grassland complex (DAF), *Combretum–Terminalia* woodland and wooded grassland (CTW), *Acacia-Commiphora* woodland and bushland (ACB) and evergreen scrub characterize the forest remnants in northern Ethiopia (Sebsebe Demissew *et al.,* 1996). The vast majority of Ethiopian forest resources are found in the dry land area and have a significant role in supporting the inhabitant's life (Mulugeta Lemenih and Bongers, 2011). A study conducted by Kindeya Gebrehiwot (1997) reveals that the remaining forest patches in the Tigray region are predominantly dry forest types. The vegetation type of Hirmi is predominated by *Acacia- Commiphora* woodland and bushland and *Combretum–Terminalia* woodland (Yilma Abebe, 2010; Gerben, 2013). However, a patch of dry evergreen Afromontane forest species covers the elevated western and northern part of the study area. These vegetation types are discussed under the following sub-sections.

2.2.1. Dry forests in Ethiopia

Dry forests are defined differently in different literature by taking into account their structure, environmental wetness, length of the dry season, topography and growth forms (FAO, 2005; Ensermu Kelbessa and Abenet Girma, 2011). According to the definition by FAO (2005), dry forests are woodlands that are now considered to be forests (MFECC, 2017) include *Acacia-*

Commiphora narrow-leaved deciduous forest, lowland bamboo forest, *Combretum-Terminalia* broad-leaved and riverine forests located in these dry landmasses. One of the prominent features of dry forests is their seasonality with respect to rainfall compared with the rain forests where the environment is stable throughout the year (Demel Teketay, 2005a). These resources are believed to greatly contribute to climate change mitigation in dryland ecosystems (Musse Tesfaye and Mesele Negash, 2018). Africa and the world's tropical land have the largest proportion of dry forest ecosystems (Mayaux *et al.,* 2005; Mulugeta Lemenih and Bongers (2011). The drylands of Ethiopia consist of a wide range of agro-ecologies including the arid; semi-arid and dry sub-humid landmass. The majority of the agricultural land and forest resource of the county is found in this environment (Kidane Georgis, 2010). *Acacia–Commiphora* woodlands, *Combretum–Terminalia* woodlands and Dry Evergreen Afromontane forest and grassland complex are the typical designated for dry forests (Mulugeta Lemenih and Bongers, 2011). About 90% of the Tigray Regional State landmass is covered by dryland (Mulugeta Lemenih and Habtetmeraim Kassa, 2010).

2.2.1.1. *Acacia-Commiphora* woodland and bushland (ACB)

This vegetation type is characterized by drought-resistant trees and shrubs, which are either deciduous or with small evergreen leaves with rich in gum and resin-producing *Acacia*, *Boswellia* and *Commiphora* species (Motuma Didita, 2007). It is the species-rich vegetation type (Friis *et al*., 2010). This vegetation type occurs in the northern, eastern, central and southern parts of the country between 400 and 1800 m a.s.l. The plant genera that characterize the vegetation type include *Acacia*, *Commiphora*, *Balanites*, *Capparis*, *Combretum* and *Terminalia* (Friis and Sebsebe Demissew, 2001; Sebsebe Demissew *et al.,* 2004). As a result of utilizing the plants for firewood and charcoal, this vegetation is becoming more vulnerable to human impacts and increasingly declining (Zerihun Woldu, 1999). This vegetation type is a notable center of endemism for mammals, particularly antelopes at the Horn of Africa. However, protected areas including the national parks under this vegetation type are being degraded by human activities (Friis and Sebsebe Demissew, 2001; Friis *et al.,* 2010).

2.2.1.2. *Combretum-Terminalia* woodland and wooded grassland (CTW)

The vegetation is distributed from 400-1800 m.a.s.l. and is named also as broad-leaved deciduous woodland, which is characterized by small to moderate-sized trees with fairly large deciduous leaves (Friis *et al.,* 2010). The vegetation type is characterized by plant species like *Boswelia papyrifera, Lannea schimperi, Anogeissus leocarpus* and*Oxytenanthera abyssinica*. This vegetation is also rich in herbaceous plants in cover and species composition (Zerihun Woldu, 1999; Sebsebe Demissew *et al.*, 2004). According to Sebsebe Demissew *et al*. (2004), the vegetation type occurs along the western escarpment of the Ethiopian Plateau, from the border regions of Ethiopia and Eritrea to western Kefa and the Omo Zone. The most economically important forest products were obtained from the *Combretum-Terminalia* broad-leaved deciduous forest (Ensermu Kelbessa and Abenet Girma, 2011). The vast area CTW are mainly used as grazing sites for livestock of transhumance which are increasing due to feeding shortage, expansion of crop cultivation and increasing cattle population in the highlands. Furthermore, CTW are a source of food, fodder, honey, medicinal plants and wood for fuel and construction (Ensermu Kelbessa and Abenet Girma, 2011).

2.2.1.3. Dry Evergreen Afromontane forest and grassland complex (DAF)

This vegetation type represents a complex system of successions involving extensive grasslands rich in legumes, shrubs and small to large trees to closed forests occurring in an altitudinal range of 1500-3200(-3400) m.a.s.l. with an average annual temperature and rainfall of 14-25°C and 700-1100 mm, respectively (Friis, 1992; Friis *et al.,* 2010). Over 50% of the African highlands are found in Ethiopia, which contributes to Afromontnae vegetation (Tamrat Bekele, 1993), out of that dry Afromontane forests comprise the largest part (Demel Teketay, 2005a). This forest originally occupied a large area in the northern, central, southern and southeastern highlands of Ethiopia (Friis *et al.,* 2010). Currently due to various factors they vegetation type is restricted in some areas. The dominant trees in this forest type consist of *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Podocarpus falcatus*, etc (Zerihun Woldu, 1999) and grass genera; *Eragrostis, Pennisetum*, *Panicum*, *Sporobolus* and *Hyparrhenia* (TewoldeBerhan Gebre Egziabher, 1988).

The DAF is inhabited by the majority of the Ethiopian population for centuries. It provides fuelwood, construction materials, farm implements, edible fruits, honey, medicinal plants, grazing area and game for hunting with some tree species acting as a buffer during hardship periods. As a result, the forests have diminished and been replaced by scrublands and farmlands in most areas of the country (Zerihun Woldu, 1999; Demel Teketay, 2005a). Despite the degradation is common in all parts of the country, it is severe in northeastern Ethiopia in particular. This was due to the long history exploitation of by the inhabitants, thus forests have virtually disappeared, most of the mountainsides are bare and the springs and streams which used to have water the whole year round are dry in the dry season (Zerihun Woldu, 1999).

2.3. Threats to plant diversity in Ethiopia

According to IBC (2009), biodiversity loss has a direct and indirect cause. Deforestation and land degradation, overexploitation, overgrazing, invasive species, pollution and climate change have a direct cause, whereas poverty, population growth, lack of alternative livelihoods, inadequate policy support and inappropriate investment are among the indirect causes of biodiversity degradation and loss. Based on the assessment by EFAP (1994), vegetation resources are disappearing at a very alarming rate in Ethiopia, even before we have a chance to study and document them. If the trend of deforestation continues there may lead to the dangerous decline or loss of biodiversity. Environmental degradation and continuous deforestation on most vegetation ecosystems is a serious environmental problem in Ethiopia which is facing at the present (FAO, 1996; Nebiyu Abesha, 2009). This loss in biological diversity ultimately implies economic losses to the country and the world as a whole (Yitebitu Moges *et al.*, 2010). Of those, clearing natural vegetation for agriculture is the foremost significant threat to ecosystem biodiversity**.** Continued vegetation degradation can cause more and more loss of biodiversity unless management measures are designed and implemented (Million Bekele, 2011).

Much of the natural resource of the county is recently found in south-western, despite these forests were originally existed in central and northern Ethiopia have almost disappeared (EFAP, 1994). Forest disturbance in northern Ethiopia has a 3000-year history (Darbyshire *et al.*, 2003) and soil erosion following vegetation clearance in Tigray occurred in the middle Holocene (Bard *et al.*, 2000). In 2003, the natural forest cover in Tigray was only 0.2 % of the total landmass of the region indicating the severe forest degradation in the region. Fuelwood and charcoal contribute 69.2 and 2.5 % of the household energy consumption in Tigray, respectively (MoA, 2003). This wanes the forest cover of the region. Different research in selected areas of Tigray proved that woody vegetation and built-up area increased strongly from time to time due to the implemented extensive ecological restoration (Meire *et al.*, 2013).

2.4. Natural Regeneration and soil seed bank

2.4.1. Natural Regeneration

Natural regeneration refers to the natural process by which plants replace themselves through self-sown seeds (Evans, 1992). It is a key ecological process and a central component of forest ecosystem dynamics and restoration of degraded forest lands (Demel Teketay, 2005b). Natural regeneration dynamics is an extremely complex process that depends on environmental factors such as the distribution of rainfall, topographic variation, edaphic factors, solar radiation, soil characteristics, seed viability and herbivore (McLaren and McDonal, 2003; Enoki and Abe, 2004). Sustainable forest utilization is only possible if adequate information on the regeneration dynamics and factors influencing important canopy tree species are available. If native long-lived trees are unable to regenerate in a given forest, then there is little hope for maintaining and the semblance of normal forest functioning in the long term (Harrington *et al.*, 1997).

Regeneration status of species in a community can be accessed from the total population dynamics of seedlings and saplings in the forest community. The overall pattern of population dynamics of seedlings, saplings and adults of a plant species can exhibit the regeneration profile, which is used to determine their regeneration status (Khan *et al.*, 1987; Duchok *et al.*, 2005). A population with a sufficient number of seedlings and saplings depicts satisfactory regeneration behavior, while the inadequate number of seedlings and saplings of the species in a forest indicates poor regeneration (Khan *et al.*, 1987; Khumbongmayum *et al.*, 2006). Seedling densities in forest understory's are dynamic and rates may vary among species and in gap and shade environments. Information on seedling ecology can provide options for forest development through improvement in recruitment, establishment and growth of the desired species.

Natural regeneration is essential for the preservation and maintenance of biodiversity. It has a significant implication on the conservation and restoration of degraded natural forests (Getachew Tesfaye *et al.,* 2010). Knowledge about the pattern of natural regeneration is important to answer the basic question of forest management (Hossain *et al*., 1999). Hence, conducting an investigation on the natural regeneration of remnant natural forests in Ethiopia in general and in the Hirmi forest particularly enables us to conserve and sustainable utilization of the vegetation.

2.4.1.1. Factors affecting natural regeneration

The nature of forest/woodland communities depends on the ecological characteristics in sites, species diversity and regeneration status of species (Duchok *et al*., 2005). Natural regeneration could be affected by abiotic (environment) and biotic (over-story structure) factors (Borja, 2014). Micro-environmental factors vary with seasonal changes, which affect the trees' growth stage i.e. seedling, sapling, coppice and young trees that maintain the population structure. A reduction in precipitation, especially drought can limit the regeneration potential and composition of plants because almost all species are very susceptible to environmental factors at the seedling stages (Khumbongmayun *et al*., 2006; Khaine, 2015). In addition, species composition at regeneration stages varied in regions within a narrow range of annual rainfall. Borja (2014) also estimated by simulation analysis that species diversity and composition at the regeneration stage could change in upcoming decades due to an increase in temperature and a decrease in precipitation. On the other hand, changes in over story structure (biotic factor), such as species distribution and canopy cover, could directly affect the diversity, survivorship and composition of natural regeneration of some species (Khumbongmayun *et al.,* 2006; Bose, 2016).

Factors that potentially influence regeneration at the early stage are those that determine the probability of seedling establishment and those that affect seedling survival and growth. Seed availability can be influenced by local seed rain (recently dispersed seeds), soil seed bank (dormant seeds in the soil) and seedling bank (established, suppressed seedlings in the understory) (Demel Teketay, 2005b). In another aspect, the variation in the relative abundance of size classes and population structure of species is the result of past and present disturbance as well as the management history of the forest. Based on the intensity of disturbance species show variation in population structure pattern reflected through the difference in the abundance of different size classes (Tamrat Bekele, 1994). Size class distribution or population structure, therefore, gives a good indication for the impact of disturbance and forest successional trends. Regeneration status of a given forest in general and a species, in particular, can be affected by several anthropogenic disturbances including fire, grazing, livestock grazing and logging (Alemayehu Wassie *et al.*, 2009), natural drivers such as light intensity, drought (Demel Teketay, 2005b; Vieira and Scariot, 2006), treefall gaps (Alemayehu Wassie *et al.*, 2009), rainfall (Osem *et al.*, 2009) as well biological interface (Bose, 2016). Required information on the regeneration status of the different forest types in Ethiopia is scanty (Demel Teketay, 2005b). Having forest regeneration information and the existed bottleneck enables the decision-makers and other concerned stakeholders to set a proper mitigation measure for the forest threats in the county.

2.4.2. Soil seed bank

2.4.2.1. The concepts of soil seed bank

Seeds are produced from sexually reproducing plants, thus disperse from the mother plant through various dispersal mechanisms and deliver into the soil. This trend is important to proceed with the process of regeneration potential of plant species via soil seed bank (Jaganathan *et al.*, 2015). The term soil seed bank refers to all viable seeds and fruits present on/in the soil and associated litter/humus (Demel Teketay, 2005b). It is the total number or density of viable seeds stored in soil within a given period. Soil seed bank represents a living record of the recent vegetation and a new potential seedling emergence pattern of an area in the future (Wanga *et al.*, 2005). Soil seed banks can be either transient with seeds that germinate within a year of initial dispersal or persistent with seeds that remain in the soil for more than one year. The dispersion of seeds into the soil exhibits variation in space and time (Feyera Senbeta and Demel Teketay, 2001; Simpson *et al.*, 1989).

Soil seed bank reflects partly the history of the vegetation and can play an important role in its regeneration or restoration after disturbances. It is crucial for incubation and it laid the groundwork for the recruitment, regeneration and persistence of a population (Wanga *et al.*, 2005). Seed bank composition can be used to forecast the future fate of the vegetation and understanding the population dynamics of buried viable seeds (Qiuyan *et al.*, 2011). They have been exploited in two contexts: to manage the composition and structure of existing vegetation and to restore or establish native vegetation (van der Valk and Pederson, 1989). Generally, understanding the patterns of regeneration enables us to undertake a proper forest/woodland management plan that helps to conserve biodiversity and utilize the forest ecosystem wisely and sustainably (Nirmal *et al.*, 2011).

Herbs as well as species with small size seeds, have survived throughout time, because of their persistence capacity, small size, less exposed to predators, ability to resist several adverse climatic conditions and variations in oxygen supply. This capacity is a result of a great number of seeds produced, long-term viability, continuous germination and phenotypic and genetic plasticity (Christoffoleti and Caetano, 1998).

2.4.2.2 Factors that affect soil seed bank distribution

The vertical and horizontal distribution of seeds in soil seed banks shows a variation in space and time (Feyera Senbeta and Demel Teketay, 2002). The vertical and horizontal distributions of seeds are initially related to dispersal and its mechanism that determines the pattern and distance from the parent to the surface. It is highly affected by the morphology of the seeds such as size and shape as gravity can move large and heavy seeds with a special structure (e.g. awn) deeper into the soil column than small and lighter seeds. However, if the physical structure of the soil is not suitable, the pore may not allow the seeds to pass through and reduce the chance (Harper, 1977). Seed dormancy or longevity is an important parameter for the existence of a seed bank.

Seed bank is formed by seeds either born and produced on-site or carried to the site by dispersal agents and accumulated in the soil (Emiru Brhane *et al.*, 2006; Hirsch *et al.*, 2012). The dispersal of seeds is commonly influenced by abiotic and biotic factors. The abiotic factors include dispersals due to gravity, wind, water, seed structure and characteristics of the soil; whereas the biotic factors include different dispersal agents such as animals and human beings (Carey and Watkins, 1993). The effectiveness of seed dispersal agents depends mainly on the number and quality of seeds dispersed (Barnes, 2001).

In tropics the natural vegetation is subjected to natural and human-induced disturbances which could result in different degradations or destructions. In an area with no further interference, the processes of succession are healthy and precede its normal natural process. Here, the soil seed banks serve as one of the major sources of plant re-growth (Feyera Senbeta and Demel Teketay, 2001). Different studies on tropical rain forests reported that there is a decline in the seed bank density and species with increasing soil depth. Temperature, seed size and predation/other perturbation have significant impacts on seed distribution on the soil surface (Dalling *et al.*, 1997). The number of seeds recorded from different profiles shows a variation in the density of seedlings, which reflects their distribution. An investigation on soil seed banks of various vegetation of Ethiopia depicts that high densities of seeds are found in the upper 3 centimetres of soil and gradually decline as the depth of the soil seed bank is increases (Demel Tekety and Grenstorm, 1995). This was associated with the size and persistent nature of the seeds (Christoffoleti and Caetano, 1998).

2.4.2.3. Functional role of soil seed bank

A soil seed bank is an important component for ecosystem resilience and represents a stock of regeneration potential in many plant assemblages. Information on soil bank characteristics such as species number, quality and depth distribution can provide an estimate of the regeneration potential after disturbance (Song *et al.*, 2017). This helps to scheme conservation and restoration programs in degraded ecosystems, especially in arid ecosystems. Furthermore, seed banks help plant populations to maintain their genetic variability and to withstand periods of adverse conditions and persist over time (Dainou *et al.*, 2011). It is well known from theoretical and observational studies that the existence of this component confers an advantage in habitats where environmental conditions are unpredictable and can change dramatically. Seed bank composition and density, therefore, play a crucial role in vegetation dynamics aboveground after various human and livestock interventions in the ecosystem (Luzuriaga *et al.*, 2005).

Soil seed bank is the source of regeneration for the floristic and structural diversity of the above-ground vegetation (Bakker, 1991). It represents a record of past as well as present vegetation growing in a given area and nearby environment. If an existing vegetation stand is destroyed by various causes the seed bank will immediately serve as a source from which new vegetation arises (Tefera Mengistu *et al.*, 2005). Forest ecosystems contain several specialized plant species forming persistent soil seed banks. The absence of a soil seed bank impedes the establishment of vegetation during primary succession, while the presence of a well-stocked soil seed bank permits the rapid development of species-rich ecosystems during secondary succession. Besides their significance in the regeneration of lost vegetation, the soil seed bank is a key element in plant community dynamics, enable plant populations to maintain their genetic variability and to survive in the adverse conditions and persist over time (Yohannis Teklu, 2014).

2.5. Species diversity, richness and evenness

2.5.1. Species diversity

Species diversity is measured by recording the number of species and their relative abundances (evenness or unevenness) of species within the sample or community (Kent, 2012). It is the functions species number (richness or abundance of species) and evenness with which the individuals are distributed among these species (species evenness or species equitability) (Spellerberg, 1991; Magurran, 2004). Measures of species diversity have been broadly used as indicators of ecosystem status and play a critical role in studies dealing with the assessment of the human impact on ecological systems (Leitner and Turner, 2001). Due to the biodiversity of any ecosystem is too complex to be comprehensively quantified, suitable indicators of biodiversity are needed. Thus, species richness and evenness appear as the most intuitive and simple parameter to measure biodiversity. One approach to measure species diversity is using indices commonly known as diversity indices. This helps to interpret the relative variation between and within the community and explain the underlying reason for such a difference (Kent, 2012).

2.5.2. Species richness

Species richness can refer to the number of species present in a given area without considering the number of individuals in each species (Hamilton, 2005). It is important to measure the number of species in a given site and can be expressed in a mathematical index to compare diversity between sites (Zerihun Woldu, 1985). Species richness is used to identify biodiversity hotspots and plays an important role in conservation planning (Magurran and McGill, 2011).

Measuring species richness helps for basic comparisons among sites and for addressing the saturation of local communities colonized from a regional source pool (Cornnell, 1999). Maximizing species richness is often an explicit or implicit goal of conservation studies (May, 1988) and current and background rates of species extinction are calibrated against the patterns of species richness (Simberloff, 1986).

2.5.3. Species evenness

Species evenness can be defined as the equitability or proportional abundances of species in a given ecosystem (Tuomisto, 2012). Diversity and equitability (evenness) of species in a given plant community are used to interpret the relative variation between and within the community and help to explain the underlying reason for such a difference (Kent, 2012). An ecosystem where all the species are represented by the same number of individuals has high species evenness, while an ecosystem where some species are represented by many individuals and other species are represented by very few individuals has low species evenness. The value evenness (J') ranges normally between 0 and 1; where 1 represents a situation in which all the species are equally abundant (Magurran, 1988).

2.6. Measures of species diversity

Understanding the processes that are responsible for diversity patterns at different geographical scales has been a vital role in vegetation ecology (Cody, 1993). Species diversity can be measured by alpha, beta and gamma diversity which enables us to understand the causes shaping patterns of diversity (Whittaker, 1972). Alpha diversity (α) refers to the diversity of species within a particular habitat or community. Beta diversity (β) is a measure of the rate and extent of change in species composition along an environmental gradient from one habitat to another. It is sometimes called habitat diversity since it represents differences in species composition between very different areas or environments and the rapidity of change of habitats (Kent, 2012). It calculates the number of species that are not the same/ in two different communities. Beta diversity has gained considerable value as a conservation tool by representing either species turnover in space or time or ecological connectivity. Gamma diversity (γ) is a measure of the overall diversity of the different ecosystems within a region (Whittaker, 1972).

Basically the concept of species diversity measurement was forwarded in various ways by different scholars. For instance, Whittaker (1972) considers species richness as a strong measure of species diversity. However, using species richness alone as a measure of diversity is criticized, because species richness is just one component of species diversity (Hurlbert, 1971; Sanjit and Bhatt, 2005). On the other hand scholars such as Magurran (1988) argue that species richness and the relative abundance (evenness or equitability) are important parameters to measure species diversity within the given community. Thus, the Shannon-Wiener and Simpson's indices of diversity, which combine species richness with relative abundance, are widely used to measure species diversity (Whittaker, 1972; Kent, 2012). Shannon index expresses the relative evenness or equitability of species, while Simpson's index gives weight to the dominant species (Whittaker, 1972).

2.7. Multivariate data analysis

Multivariate statistical methods are capable of analyzing more than one relationship at a time. Plant community data are multivariate in nature and their analysis is closely related to the development of multivariate techniques, i.e. methods of multivariate analysis to study the joint relationship of variables (Stephane *et al.*, 2008). Recently, wide varieties of multivariate techniques are available to study the complex nature of plant communities. Among the multivariate techniques for studying the complex nature of plant communities; Cluster analysis and Ordination analysis are the two main and basic techniques (Mueller-Dombois and Ellenberg, 1974; Whittaker, 1975).

2.7.1 Cluster analysis

Cluster analysis is exploratory data analysis tools, which aim at sorting different objects into groups in a way the composition of the group varies most between groups and varies least within groups (Anderson, 1965). Clustering needs dissimilarity matrix as an input and it builds a hierarchic tree where all observations are finally united at the root (ecologists usually draw this tree inverted or felled) (Zerihun Woldu, 2017). Cluster analysis encompasses several different classification algorithms, which seek to organize a given data set into homogeneous subgroups, or clusters. Methods for clustering items (samples or species) depend upon how similar (or dissimilar) the items are to each other. Similar items are treated as a homogeneous class or group, whereas dissimilar items form additional classes or groups (Tryon, 1939).

Cluster analysis can be classified into non-hierarchical or hierarchical. The non-hierarchical method is used when there is no particular advantage in the groups being arranged in a hierarchy, a non-hierarchical method of classification may be chosen (Gauch, 1962; Dingby and Kempton, 1987). In this case, species are arranged in clusters, bringing similar species together (Pielou, 1969) to optimize the structure of individual species. If homogeneity of species is of prime importance in the application process, the non-hierarchical techniques are the best fit. Hierarchical clustering is a clustering method when the classes themselves are classified into groups; the process is repeated at a different level to form a tree. Hierarchical classification methods can be further divided into agglomerative and divisive methods (van Tongeren, 1995; McCune and Grace, 2002). An agglomerative method is a bottom-up approach, where each observation starts in its own cluster and pairs of clusters are merged as one moves up the hierarchy. Agglomerative methods start with individual items and group them together in a series of steps (Dingby and Kempton, 1987), while divisive methods start with all the units as one group and proceed by repeatedly dividing groups into two until all the units are separate. Agglomerative clustering algorithms are used to construct a tree-like hierarchy, which implicitly contains all values of k (number of clusters). Ward's method is a special case of average linkage is distinct from all other methods because it uses an analysis of variance approach to evaluate the distances between clusters (van Tongeren, 1995)

2.7.2. Ordination analysis

Ordination is a collection of techniques, which transform the vector observations into a new set of vector observations. In contrast to cluster analysis that searches for discontinuities in the dataset, ordination extracts the main trends in the form of continuous axes (Zerihun Woldu, 2017). Ordination simply means arranging items along a single or multiple axis and is often used to seek and describe patterns. Ordination involves the arrangement of vegetation samples in relation to each other in terms of their similarity of species composition (species ordination) and/or their associated environmental controls (sample units ordination) (ter Braak and Prentice 1988; McCune and Grace, 2002). Ordination method is important to: i) summarizing plant community data and providing an indication of the true nature of variation within the vegetation of the study area, ii) enabling the distribution of individual species within different communities to be examined and compared and iii) providing summaries of variation within sets of vegetation samples which can then be correlated with environmental controls to define environmental gradients (McCune and Grace, 2002).

Ordination can be direct (Constrained) or indirect (Unconstrained). With direct gradient analysis, sample units (e.g., plots) are ordinate based on measured environmental factors in those sample units. The constrained ordination axes, therefore, correspond to the directions of the greatest data set variability that can be explained by the environmental variables (Austin *et al.*, 1994; Zerihun Woldu, 2017). These methods are therefore capable of testing the hypotheses about the influence of environmental factors on species composition directly. Generally, direct ordination is often performed using Canonical Correspondence Analysis (CCA) and Redundancy Analysis (RDA). RDA is the constrained form of PCA and is inappropriate under the unimodal model. CCA is the constrained form of CA (ter Braak and Prentice, 1988; Southwood and Handerson, 2000). For instance, Principal component analyses require linear relationships between variables and the normal distribution of variables (McCune and Grace, 2002). CCA differs from other ordination methods in that it incorporates the correlation and regression between floristic and environmental data within the ordination analysis itself (ter Braak and Prentice, 1988). PCA or RDA should be used if the beta diversity is small, or if the range of the samples covers only a small part of the gradient. A long gradient (heterogeneous datasets) has high beta diversity and this indicates that CA or CCA could be used (Legendre and Legendre, 2012).

Indirect ordination is performed in ordination methods like principal component analysis (PCA), principal coordinate analysis (PCoA**)**, correspondence analysis (CA) and multidimensional scaling and (NMDS) (Kent, 2012; McCune and Grace, 2002).

2.8. Soil properties and its role in plant diversity

2.8.1. Soil physical properties

Physical soil properties such as water holding capacity, permeability, soil drainage and its resistance to erosion are directly linked with the aggregation and pore space of the soil (Hingston, 1992). Stable aggregate exists between particles and the fine pores are able to hold moisture of the soil against gravity whereas the existence of coarse pores in the soil will permit the drainage of excess moisture which in turn improves the supply of oxygen to the root zone of the plant (Nirmal *et al.*, 2011). Physical assets of soil could be everlasting assets except altered due to harvesting processes, unstable agronomy and fires of woodland. Forest soil's physical assets include texture porosity, structure, density, temperature, aeration, movement and water retention (Burger *et al.*, 1994). The productivity and fertility of forest soil are affected by these properties that are determined for the comfort of root saturation, the water holding capacity and for easily uptake of water by plants, the volume of oxygen and other gases in the soil and the point of which water transfers horizontally and vertically over the soil. Physical assets of soil also affect the usual division of species of woodland trees progression and production of biomass of woodland through physical possessions of forest soil are mainly controlled by arrangement size, dispersal and soil particles (Schoenholtza *et al.*, 2000).

Physical properties of the soil are determined by soil texture, the minerals present in the soil and the amount of organic matter (Hilel, 1980). Particles that range in size from 0.05 to 2.0 mm are sands, 0.002 to 0.05 mm is considered as silt and the smallest particles are found in clay, with size less than 0.002 mm. Their abundance or scarcity affects every aspect of soil use. Settling rates of primary particles are based on the principle of sedimentation as stated by Sanchez (1976), that the larger the particle the more quickly sinks (settle) out of suspension, hence, most of the sand particles in the soil will settle to the bottom quickly. The silt and clay particles will take quite a bit longer time. Sandy soil particles fit together in a way that creates large pores so that infiltration rates and permeability to water are high and retain little water. In contrast, clay soil particles fit together in a way that creates small pores so that infiltration rate and permeability to water are low and retain much water in available forms and may be poorly drained. Therefore, soil made of clay particles will have more total pore spaces than sand soil particles. Soils textures such as loams are intermediate in porosity, water retention and drainage. Specific surfaces and cation exchange capacities of sands are low as compared to clays (Wakene Negassa, 2001; Ward, 2008).

2.8.2. Soil chemical properties

Discrimination of physical, chemical and biological properties of soil is very difficult because of their vivacious inter-linked with each other. The chemical properties of soil are directly affected on all those microbiological processes that can encourage the water holding capacity, nutrient cycling, water accessibility, pH buffering and leaching and ion exchange capacity of the soil. Chemical indicators of soil are the same for farming and woodland soils (Bockheim, 2015). Soil organic matter is also a major key chemical indicator for assessing soil quality and aggregate stability (Bockheim, 2015; Schaetzl and Thompson, 2015).

Soil chemistry determines the availability of nutrients, microbial growth, corrosively and stability of water. The chemistry of clays and humus determines soil chemical properties (Janssens *et al.*, 1998). Soil chemical properties such as electron conductivity, Cation exchange capacity, total organic matter, pH as well as the availability of important elements such as Nitrogen (N), Carbon (C), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) have a significant role in plant species diversity in a given ecosystem. Enhancing or diminishing these contents will bring a huge impact on species richness and dictating their physiognomic growth (Roem and Berendse, 2000; Rutherford and Westfall, 1994).

2.8.3. The impacts of soil on plant diversity

Discrimination of physical, chemical and biological properties of soil is very difficult because of their vivacious inter-linked with each other. The soil properties have a significant role in dictating the various determinants that directly affect plant species growth and diversity. Chemical indicators of soil are the same for farming and woodland soils (Bockheim, 2015). for instance, soil organic matter and other macro and micronutrients in the soil could have strong association with species growth and surviveal in a given ecosystem (Bockheim, 2015; Schaetzl and Thompson, 2015).

2.9. Ethnomedicine

2.9.1. The concept of ethnomedicine

Ethnomedicine is the knowledge that is generated over centuries by communities using plants, animals, mineral derivatives and is mostly orally transmitted for treatment purposes. It is a mixture of traditional healing practices (WHO, 2003). The knowledge on the application of traditional medicinal plants is called ethnomedicinal knowledge. Traditional societies around the globe are having their knowledge and cognitive on how plant and plant products are utilized and manage (Cotton, 1996). Ethnomedicinal knowledge involves traditional diagnosis, collection of raw materials, preparation of remedies and prescription to the patients (Farnsworth, 1994). The linkage between plants and human cultures is not restricted to the use of plants for food, clothing and shelter, however, it also includes their use for religious ceremonies, ornamentation and healthcare (Schunko and Vogl, 2010). Ethnobotanical studies are useful, for not only documenting, analyzing and disseminating indigenous knowledge of local people but also indicate the interaction between biodiversity and human society, including how biodiversity is valued in different societies and how it is influenced by human activities (Martin, 1995).

2.9.2. Medicinal plant species use in Ethiopia

Ethiopia is often quoted as one of the six countries of the world where about 60% of the plants are said to be indigenous with healing potential (Mirgissa Kaba, 1996). The traditions of using medicinal plants in Ethiopia have a long history and exercise widely in all areas to cure both human and animal disorders. The local people in the country endowed with medical lore and the population are relies on medicinal plants to improve their health (Dawit Abebe and Estifanos Hagos, 1991; Ermias Lulekal *et al.*, 2013). The application practice of medicinal plants in Ethiopia varies from one area or from community to community depending on the socio-cultural conditions of the different ethnic groups (Sikkerveer, 1990; Dawit Abebe and Ahadu Ayehu, 1993). It was estimated that about 80% of the Ethiopian population is dependent on traditional medicine, which essentially involves the use of plants (Dawit Abebe and Estifanos Hagos, 1991). This was associated with the cultural acceptability of healers and local pharmacopoeias, price fairness, easily accessible and effectiveness against several health problems (Tesema Tanto *et* *al*., 2003; Kebede Deribe *et al*., 2006). The other fact was due to the health care quality in developing counties like Ethiopia is largely below standard and inaccessible (Abbiw, 1996).

2.9.3. Ethnoveterinary medicine in Ethiopia

Ethiopia is one of the top ranking in African countries and among the first ten in the world in livestock resources which directly constitutes important sources of livelihood (Tafesse Mesfin and Mekonnen Lemma, 2001). However, the ethnoveterinary services are not as intensvely distributed as the production of livestocks. The exited limted ethnoveterinary centers are expense high cost, far and out of the reach of the Ethiopian farmers and pastoralists (Mirutse Giday *et al*., 2003; Tadesse Beyene, 2015). To overcome these problems, many people use traditional herbal medicines to treat their livestocks ailments. In Ethiopia, conventional veterinary services have been playing a paramount role in the control of livestock diseases. However, the demand and supply of the drug is still unbalanced. Thus, many Ethiopian people prefer using herbal medicines to cure the health of their livestock. Documenting of medicinal plants used to cure animals health and the associated indigenous knowledge alongside the education on the concept of ethnoveterinary would have a significant role in the management of livestock disease and improve the livelihood of community engaged on animal productions (Tafese Mesfine and Mekonnen Lemma, 2001).

2.9.4. Transfer of ethnomedicinal knowledge

The knowledge related to ethnomedicinal utilization and management in Ethiopia is transferred from generation to generation in the form of songs, proverbs, stories, folklore and other practices (Jansen, 1981). The indigenous knowledge is mostly is kept as a strict mystery. This is due to medicinal healers perceive, disclosing traditional medicine publicly as lose its curing capability. That is why the indigenous knowledge of medicine is restricted to few people (Amare Getahun, 1976; Dawit Abebe, 1986). Besides, the vast knowledge on ethnomedicine is not fully documented and most of the knowledge is conveyed from generation to generation orally. This system of knowledge transformation is vulnerable to loss (Amare Getahun, 1976; Getachew Addis *et al*., 2001). Beyond the poor documentation and knowledge transfer, loss of habitats of medicinal plants and overharvesting are other major threats of medicinal plants in the country

(Mirutse Giday *et al.*, 2003). Thus, there is a need of exhaustive documentation of such useful knowledge and utilization practices through ethnomedincal investigations.

2.9.4. Threats and conservation of medicinal plants in Ethiopia

More than 85% of the Ethiopian population resides in rural areas and their livelihood depends on natural resources that lead to prolonged resource depletion (USAID, 2008). The medicinal plants in Ethiopia like to other African counties are exposed to various challenges of sustainability due to either natural factors such as drought, bush fire, disease and pest outbreak or manmade factors including a rapid increase in population, the need for fuel, urbanization, timber production, over-harvesting, destructive harvesting, invasive species, commercialization, agricultural expansion and habitat destruction (Ensermu Kelbessa *et al.,* 1992). Such depletion and degradation are high threats to plants and plant habitats (IBC, 2005). Furthermore, medicinal plants are grown and found in unprotected areas that make the management action challenging (Dold and Cocks, 2002; Williams, 2004).

Conservation of medicinal plants can be achieved through *in situ* and *ex situ* means. The *in situ* conservation approach is implemented through growing of the medicinal plants in their natural habitat without facing adaptation difficulty. *Ex situ* conservation is the technique of conservation of all levels of biological diversity outside their natural habitats through different techniques like captive breeding, aquarium, botanical garden, and gene bank. It plays key roles in communicating the issues, raising awareness, and gaining widespread public and political support for conservation actions and for breeding endangered species in captivity for reintroduction (Mohammed Kasso and Balakrishnan, 2013; IBC, 2009). On another side, documenting the indigenous knowledge related to traditional medicinal plants as well as identifying and recording the medicinal plant species used to treat human and livestock disease has a significant role to conserve the medicinal plants (Mirutse Giday *et al.*, 2010).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location and topography

Hirmi woodland vegetation occurs in three districts (Tahtay Koraro, Medebay Zana and Asgede Tsimbla) of the Northwest Zone of Tigray National Regional State, Ethiopia. The area of Hirmi woodland vegetation is found at a distance of 1100 km North of Addis Ababa (Ethiopian capital) between $13^0 49'$ – $14^0 04'$ latitude and $38^0 14'$ – $38^0 25'$ longitude; with an elevation range between 1098-2002 m.a.s.l (Figure 2). The total area coverage of the study area is 30, 900 ha (Yilma Abebe, 2010; Agriculture and Natural Resource Bureau of North-Western Zone of Tigray Regional State (ANRBNWZT), 2017).

In the study area, there are two rivers, namely Hirmi and Keyhmeret, which drain and join Tekeze River after traversing through Hirmi woodland vegetation. The remnant vegetation has different types of patches. The largest part of the study area with a moderate and steep slope is covered by dense mixed species of *Combretum* and *Terminalia* with seldom *Acacia* species. The lower altitude and flat slopes are mainly covered by species of *Acacia* and *Ziziphus.* The hilly part of the northern and northwestern part of the study vegetation is dominantly covering by species of *Olea europaea* subsp. *cuspidata*, *Acacia abyssinica* and *Croton macrostachyus* (Gerben, 2013).

Figure 1. Partial view of Hirmi woodland vegetation

Inside the vegetation, there are a number of faunas including Leopard (*Panthera pardus*), Bush Pig (*Potamochoerus larvatus*), Wild Cat (*Felis silvestris*), Jackals (*Canis aureus*), Warthog (*Phacochoerus africanus*), babons (*Papio*) and various kinds of birds (Gerben, 2013; Kindeya Gebrehiwot *et al*., 2016). In the lower altitude, the western and eastern part of the study area, human settlements and expansion of farming agriculture were dominantly observed which encroaches to the natural vegetation. Thus, the numbers of wildlife as well as plant species, are decreasing from time to time as a result of observed disturbances (ANRBNWZT, 2017).

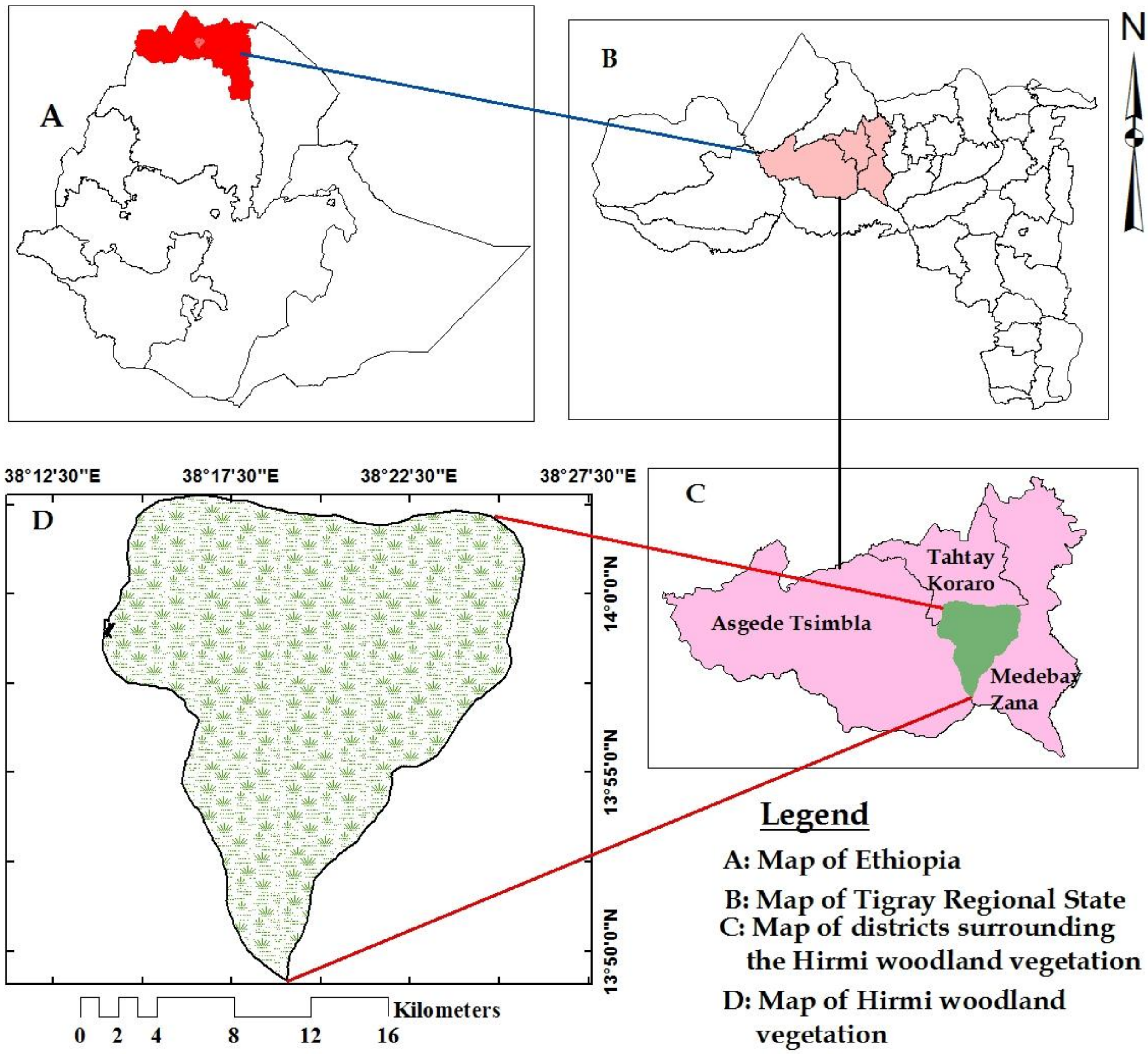


Figure 2. Map of Ethiopia showing Tigray Regional State, the study districts and Hirmi woodland vegetation

3.1.2. Geology and soil

Volcanic activities during the tertiary period resulted in the extrusion of huge quantities of flood lavas that occurred in a series of layers called the 'Trap series' in the region. Various rock types including rhyolites, trachytes, tuffs and ignimbrites compose the Trap series, but basalts are the major components and they constitute the major rock types of the study area (Mohr, 1971). The dominant soil types around the study vegetation are Vertisols, Cambisols, Lepitosols and Luvisols (Virgo and Munro, 1978). According to a study conducted by Tsehaye Gebrelibanos and Mohammed Assen (2013), the spatial variation of topsoil properties of the study area is associated with slope and vegetation types. According to their findings, sandy and silt soil types were dominant at the lower altitude and the flat to moderate slopes, while clay soil type was found in the upper altitudes of the study area. They were found that the soil depth was shallow and eroded at the steep area whereas relatively fertile and deep soil was found in the flat and moderate slope of the study areas. Generally, the soils of the study area belong to three textural classes. Most of the soil samples fall in the sandy loam textural classes while a few of them are clay loam and loam (Figure 3 and Appendix 3).

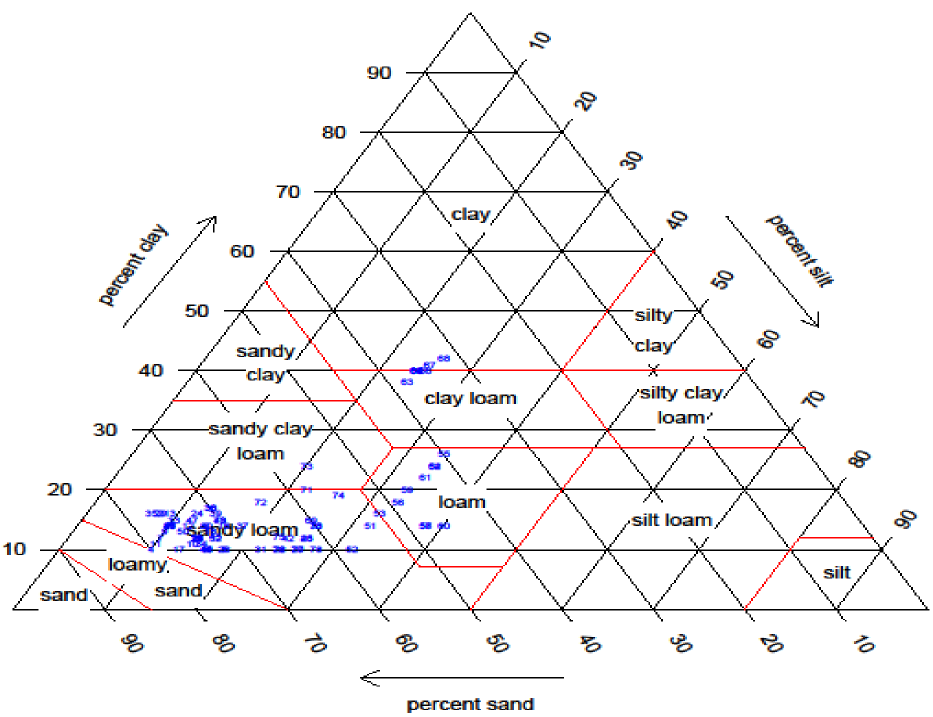


Figure 3. Soil textural triangle of the sampling plots in the study area

3.1.3. Climate

The metrological data of twenty years (1998-2017) was taken from Endabaguna, which is the nearest station to the study area (NMSA, 2018). Meteorological data analysis revealed that the study area has a minimum and maximum monthly mean temperature of 13.1 °C and 31.9 °C, respectively. As indicated in the climate diagram (Figure 4), the study area receives a unimodal mean annual rainfall of about 888 mm/year from May to September and dry from October to April. The highest rainfall was recorded in August whereas the lowest precipitation was recorded in February.

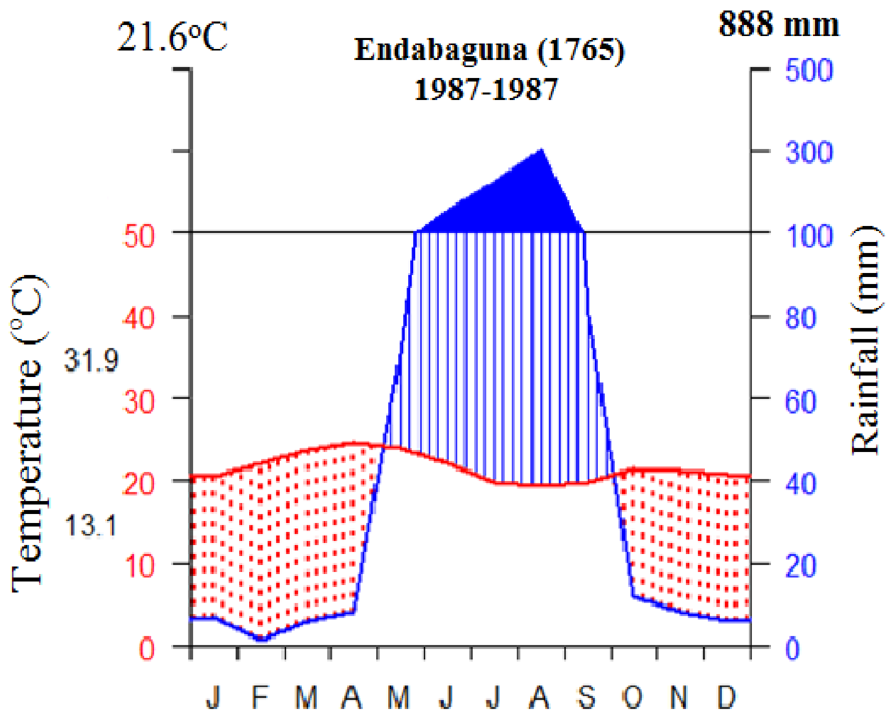


Figure 4. Climate diagram of the study area

3.1.4. Natural vegetation

Hirmi woodland vegetation is part of the Tigray Floristic Region (TU) (Friis *et al.*, 2010). The vegetation type is characterized as *Combretum - Terminalia* woodland and wooded grassland and *Acacia-Commiphora* woodland and bushland (Friis *et al.*, 2010; MEF, 2015). The *Combretum-Terminalia* woodland and wooded grassland is the predominant vegetation type with *Acacia* species around the flat and moderate slope of the study area. Around the Endabaguna Mountains and hills (west to the study area with elevation > 1900 m.a.s.l), a small patch of Dry evergreen

Afromontane forest and grassland complex (DAF) were found (Figure 5). *Olea europaea* subsp. *cuspidata* and *Acacia abyssinica* were among the characteristic species in this patch of vegetation. In the 1960's the study area was covered with densely stocked natural vegetation including various species of *Acacia*, *Terminalia*, *Combretum*, *Albiza*, *Ficus* as well as species like *Oxythenanthera abyssinica*, *Ziziphus mucronata*, *Ziziphus spina-christi*, *Ximenia americana*, *Adansonia digitata*, *Boswellia papyrifera*, *Euclea racemosa*, *Diospyros abyssinica* and *Diospyros mespiliformis* (MEF, 2015; Kindeya Gebrehiwot *et al*., 2016). The land use land cover dynamics study conducted by Tsehaye Gebrelibanos and Mohammed Assen (2015) in the Hirmi woodland vegetation and surrounding watersheds showed that currently the study area is covered with degraded remnant vegetation patches. The 58.1% of the area was covered by woody plant species, 18.7% by grassland and degraded land and 23.2% by cultivated and rural settlement. According to their findings (Tsehaye Gebrelibanos and Mohammed Assen, 2015), the vegetation cover of Hirmi is declining from time to time due to agricultural expansion, rural settlement, grazing and habitat degradation. For instance, the grassland coverage reduced sharply from 18.7% in 1964 to 11.3% in 2006 and the shrubland from 50.6% to 42.6%. However, the land use land cover dynamics of the cultivated and resettlement were enhanced by 10.5% in 42 years.

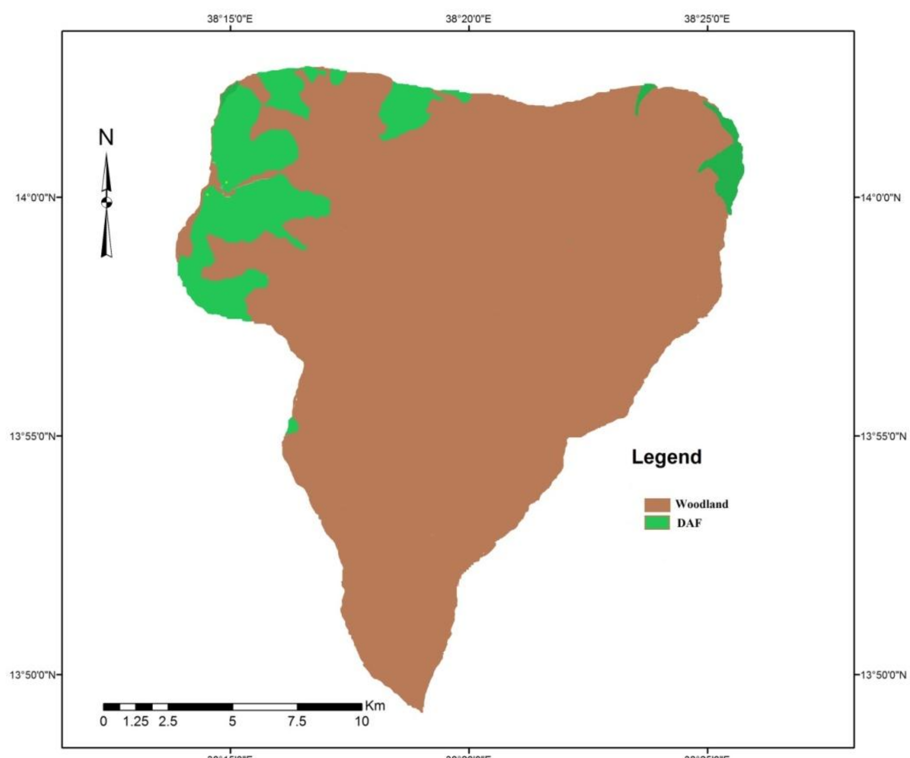


Figure 5. Vegetation potential of the study area

3.1.5. Socioeconomics and demography

According to CSA (2007), the total population of the three study districts where the vegetation stretched was 329,638. The majority of the inhabitants in these districts are agrarians. Teff was the main food crop grown in the area followed by barley, finger millet and maize. About 91% of the farmers own livestock, predominantly cattle and goats. The inhabitants use both crops and livestock as a source of cash income. Few of them also enhance their income sources by selling incense gum, charcoal and firewood.

Tahtay Koraro district has a total population of 68,989, of whom 34,477 are men and 34,512 women. The district has a population density of 35.6 people per square kilometre. About 97.7% of the population are Orthodox Christianity and 2.2% of them are Muslims. Of those 68.9%, rural dwellers whereas 31.13% are urban dwellers. The second district, Medebay Zana has a total population of 125,028, out of which 61,977 are men and 63,051 women. Of these, 8.4% are urban inhabitants and the rest are rural dwellers with a population density of 46.6 people per square kilometre. The majority of the inhabitants practice Orthodox Christianity (97.8%), while the remaining are Muslim (CSA, 2007). The third district where Hirmi woodland vegetation laid was the Asgede Tsimbla. Tekeze River boundaries in the south part of the district. The total population in the district was 135,621, of whom 69,143 are men and 66,478 women. The majority (92.5%) of the population are rural dwellers. The district's population density is 48.9 people per square kilometre. The majority of the inhabitants have practice Orthodox Christianity (97.5%), while 2.5% of the population are Muslim. About 99.5% of the inhabitants in all districts are Tigrigna speakers.

3.2. Data collection method

3.2.1. Ecological data collection methods

3.2.1.1. Vegetation data collection

Following a reconnaissance survey in August 2017, data was collected in three field trips i.e. February to March 2018; September to October 2018 and January 2019. Vegetation data were collected from a total of 80 plots along 10 transects laid systematically following the sampling approach as described by Mueller-Dombois and Ellenberg (1974). Each of the plots were laid at every 50 m altitudinal drop along the transect lines. The distance between each transect was within the range of 500-700 m apart. For the collection of woody species, plots of 25 m x 25 m (625 m^2) were laid. Herbaceous species were recorded in a 2 m x 2 m (4 m^2) subplot inside each main plot, four from each corner and one at the center.

Information required for the vegetation structure (DBH, height, frequency and density) and regeneration status were recorded. Woody species with a height of ≥ 2 m and DBH ≥ 2 cm were considered as trees or shrubs whereas these with height 1-2 m and height ≤ 1 m were considered as saplings and seedlings respectively (Feyera Senbeta and Demel Teketay, 2001; Tuxill and Nabhan, 2001; Zerihun Tadesse *et al*., 2018). Coppicing woody plants were not considered as tree or shrub rather it was treated as the presence of disturbance. DBH is used to compute the basal area of trees or shrubs. On the other hand, the relative dominance of species is calculated from the basal area of trees or shrubs. The Importance Value Index (IVI) was computed from the summation of relative frequency, relative density and relative dominance. The height of woody plants was measured using a calibrated bamboo stick. For those species taller than the calibrated bamboo stick, it was estimated visually. Species cover-abundance in each sample plot was estimated visually in the field and later transformed into the (1-9) Van der Maarel (1979) ordinal scales. The scales are described as follows: 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% and9 >75%. Data required for the regeneration status of the study vegetation was recorded by counting the number of saplings and seedlings of woody species from the main plot laid for the herbs.

Plant specimens were collected, pressed, dried during the data collection period and brought to the National Herbarium (ETH), Addis Ababa University for identification and verification by using the various volumes (volume 1-8) of the Flora of Ethiopia and Eritrea (FEE). An attempt was also made to record the vernacular names of species encountered in the study during collection whenever possible.

3.2.1.2. Environmental data collection

A terrain variable that affects the plant species diversity including altitude, slope and soil parameters (texture, pH, Electrical conductivity (EC), Cation Exchange Capacity (CEC), soil organic matter (SOM), total Nitrogen (N) and available phosphorus (P)) were recorded for each sample plot laid for vegetation.

- **Altitude**: were measured using Garmin GPS72.
- **Slope**: were measured using Suunto Pm-5/66 Pc Opti Clinometer
- **Soil samples**: were taken from five points (four from each corner and one from the center) at a depth of 0 – 30 cm in the main plot laid for vegetation data collection. These samples were mixed to form a composite sample and then about one kilogram of the sample was taken for analyses in Shire Agricultural Research Center, Soil Laboratory Department. The soil samples were air-dried by spreading on plastic trays crushed and sieved with a mesh size of 2 mm to remove root particles and other organic debris before the laboratory analyses. Subsequently, the following soil physical and chemical properties were analyzed:
  - **Soil texture:** the soil texture was measured using the hydrometer method following the method of Landon (1991).
  - **pH**: The soil pH was measured using 1:2.5 soil to water ratio mixture.
  - **Electrical conductivity (EC)**: EC was determined by soil water suspension and reading was taken using conductivity/TDS/salinity/resistivity conduct-meter following the method of Sahlemedhin Sertsu and Taye Bekele (2000).
  - **Soil cation exchange capacity (CEC)**: Soil cation exchange capacity (CEC) was determined by the summation method of the exchangeable bases and exchange acidity estimated titrimetrically by distillation of ammonium (Chapman, 1965).
  - **Soil organic matter (SOM)**: Measurements of soil organic matter were done through Walkley-Black wet digestion method (Walkley and Black, 1934).
  - **Total Nitrogen (N)**: The availability of total nitrogen in soil samples was analyzed using the three technical steps (digestion, distillation and titration) as described by Black (1965).
  - **Available phosphorous** (avP): Bray's method was used to analyze the availability of phosphorus in the soil sample (Bray, 1945).

3.2.1.3. Disturbance factors sampling

Various disturbance signs were recorded as present or absent in the sampled plots. The magnitude of disturbance was rated from 0 to 4 based on visible signs of vegetation disturbance parameters including cutting, debarking, grazing, fire and charcoal production signs following Gebremedhin Hadera (2000) and Feyera Senbeta *et al.* (2007). Values were coded as follows:

- 0: no any disturbance.
- 1: if anyone of the above-mentioned factors was present (slightly disturbed).
- 2: if any two of the above-mentioned factors were present (moderately disturbed).
- 3: if any three of the above-mentioned factors were present (highly disturbed).
- 4: if all of the above-mentioned and other associated natural factors such as tree stumps and landslide/degradation, were present (extremely disturbed).

Rating was also done by estimating visually for the intensity of each disturbance factors from 1-4.

3.2.1.4. Soil seed bank sampling

Based on Tsehaye Gebrelibanos and Mohammed Assen (2015) land-use dynamics study, there are five land-use types in the study area. The vast extent was covered by shrubland followed by grazing land, bare/fallow land, cultivated land and forest. A land use type used for cultivation has no/minimum role in the restoration process, due to the frequent and uncontrolled disturbances (Wade *et al.*, 2007). Thus, soil seed bank sample from the cultivated land of the study area was excluded and the samples were taken from shrubland, grassland, forest and bare land.

In every land use type, a plot of 15 m x 15 m was laid purposely following the method used by Li *et al.* (2017). Subsequently, about one kilo of soil seed bank samples were collected using a labeled metal rod and spoon from five points covering 15 cm x 15 cm (one at the center and the other four at the corners of the main plot) and four separate layers namely; Litter (0 cm), first layer (1 - 3 cm), second layer (3 - 6 cm), third layer (6 - 9 cm), following Feyera Senbeta and Demel Teketay (2002) and Tefera Mengistu *et al.* (2005). Accordingly, a total of 128 soil samples (4 layers x 4 land-use types x 8 sample points each) were taken via cotton bags and transported to the Ethiopian Biodiversity Institute (EBI) greenhouse site for germination of the seeds through spreading on plastic trays. The samples were taken during the dry season (February) and within a short period of time to avoid seed rain and temporal variations, respectively.

The soil samples were first sieved (Dainou *et al.*, 2011) with a mesh size of 2 mm to avoid sands. Seeds with diameter > 2 mm were retrieved and then re-deposited in the final sieved soil samples. The plastic trays were perforated at the bottom and plugged with cotton to facilitate proper drainage without losing soil. The seedling emergence method was employed to identify and counting emerged seedlings. Every five days all seed trays were checked for seedlings. Some species have emerged after two weeks. The identified seeds were removed from the tray to avoid nutrient competition with other species (Small *et al.*, 2010). Watering of the seed trays was done every day to keep moist and the positions of the seed trays were changed every week to avoid differences in light exposure (Esmailzadeh *et al.*, 2011; Toledo and Ramos, 2011). For those seedlings difficult to identify, transplants were made to continue their growth by transferring and maintaining them in another tray inside the greenhouse until the seedlings reached for identification following Zhang *et al.* (2017). This germination experiment lasted nine months (March – November 2018). Each plant specimens were pressed, collected and identified using Flora of Ethiopia and Eritrea.

3.2.2. Ethnomedicinal Data Collection

3.2.2.1. Site selection

Ethnomedicinal data were collected from the three districts where the Hirmi woodland vegetation falls. Totally there are 12 Kebeles (small administrative units in Ethiopia) surrounding the vegetation. Out of these six (6) Kebeles relatively closest to the vegetation i.e. Kelakil and Adi-Gidad (from Tahtay Koraro district), Adi-Shankur and Menfig (from Medebay Zana district), Bete-Marya and Badnako (from Asgede Tsimbla district) were selected. In these Kebeles there are 2,066 households (ANRBNWZT, 2017).

3.2.2.2. Selection of informants

A total of 335 informants (Table 1) were taken using Cochran's (1977) formula as follows:

$$\mathbf{n = \frac{N}{1 + N(e)^2}}$$

Where, n = sample size; N = total number of households in all 6 Kebeles (i.e. 2,066); e = maximum variability or margin of error 5% (0.05).

Informants were selected through gender stratified random sampling for the general informants and purposive sampling approaches for the key informants (Alexiades, 1996). A total of 20 key informants which includes traditional healers and knowledgeable persons (3 - 4 from each of the study Kebeles) were selected with the help of elderly people and local administrators. As described by Umulisa (2012), informants from each Kebeles were identified and computed from the formula below:

$$\text{Informants from each kebele} = \frac{\text{No. of HH x toal No. of informants}}{\text{Total No. HH}}$$

Where; No. = Number, HH= Householders

Table 1. Number of households and informants in the districts bordering Hirm vegetation

Name of District	Name of Kebele	HH	General informants	Key informants	Total informants	Gender	
						M	F
Tahtay Koraro	Kelakil	382	58	4	62	33	29
	Adi-Gidad	371	57	3	60	31	29
Medebay Zana	Adi-Shankur	320	49	3	52	28	34
	Menfig	315	47	4	51	25	26
Asgede Tsimbla	Bete-Marya	345	53	3	56	30	26
	Badnako	333	51	3	54	27	27
Total		2,066	315	20	335	174(51.9%)	171(48.1%)

3.2.2.3. Methods of data collection

Ethnobotanical data related to the traditional way of medicinal plant utilization and the associated indigenous knowledge was collected from the study area by means of a semi-structured interview from the selected informants (Figure 6). The semi-structured interviews were applied synergistically with field walks, observation and discussions. The field walks and observations are mainly important to collect the voucher specimens of the medicinal plant species with the help of the informants and local field assistants as well as to observe and discuss techniques of harvesting or patterns of plant distribution (Cunningham, 2001). The interviews and discussions were conducted using the local language (Tigrigna) as indicated in the English version in Appendix 8.

Focus group discussion was carried out with an average number of five informants in each Kebele to prove the reliability of the data collected through semi-structured interviews as recommended by Alexiades (1996). The group discussion includes knowledgeable and elder informants (recommended by the local inhabitants and Kebele administrations), guards of the Hirmi vegetation, male and female households. Traditional healers also participated in some of the discussions. This method was used to record information related to the mode of collection, preparation, utilization, conservation attempts and supposed threatening factors of the medicinal plants.

Figure 6. Different approaches used for ethnobotanical data collection

3.2.2.4. Ethical consideration

Before the ethnobotanical data collection, formal written permission was obtained from the Northwest Zone of Tigray Administration to each of the districts in the study area to create a workable environment between informants and the researcher. The objective of the study was explained briefly and clearly for the informants and Kebele administrators. Subsequently, everything was made clear and the informants were told about the purpose and benefit of the study and they understood the value of the research. The local peoples and Kebele administrators verbally declared that they support the study and understood that the research will have a significant role in the present and future generation healthcare system. The selected informants were also given personal consent voluntarily to be an interview and share their perceptions and knowledge for the investigator. Thus, ethnomedicinal data were collected based on a comprehensive participation, friendly interactions and the willingness of informants.

3.3. Data analysis

3.3.1. Species accumulation curve

To evaluate the effectiveness of the species estimators and to examine the degree of species sampling, species accumulation curve was plotted using R software. Species accumulation curve is a graph used to estimate and examine the number of species expected in the sample collections (Foggo *et al.*, 2003). Data on species numbers in an ecosystem is dependent on sample size and the existence of various plant communities. The species accumulation can increase as the number of sample sites increases. However, the species accumulation curve for an adequately sampled study area would level off before the total number of sampling plots is attained. Thus, the species accumulation curve allows estimating the expected number of new species that may be encountered for a given additional sampling effort (Zerihun Woldu, 2017).

3.3.2. Multivariate analysis

3.3.2.1. Classification

Cluster analysis is a multivariate technique that is widely used to group a set of observations based on their attributes (McCune and Grace, 2002). Hierarchical clustering methods start with individual items (vegetation samples) and group them (form community) in a series of steps (Dingby and Kempton, 1987). In this study Agglomerative hierarchical clustering using Ward's method (via dissimilarity measures) was performed to classify the vegetation into plant community types using R version 3.6.1 (R Development Core Team, 2019). Ward's method is favored because it uses an analysis of variance approach to evaluate the distances between clusters that minimize the error formed in the sampling steps (McCune and Grace, 2002). A sharp bend in the plot could be a good indication to decide the number of clusters in the data (Zerihun Woldu, 2017). The clusters were cut-off subjectively at a height where a clearly distinguished classes supported by the field observation of the author. The identified community types were refined in a synoptic table where species occurrences were summarized as synoptic cover-abundance values (van der Maarel *et al.*, 1979). The tree or shrub species with higher synoptic values in that specific community were used to name the community types. In each plant community type, the synoptic values of each species were further tested to find significant indicator values of the species performed in R using package labdsv (R Development Core Team, 2019).

3.3.2.2. Ordination

Species response along environmental gradient can be determined either by linear or unimodal model. The linear response model includes principal component analysis (PCA) or Redundancy Analysis (RDA) while the Unimodal response includes Correspondence analysis (CA) or and Canonical Correspondence Analysis (CCA). Deterended Correspondence Analysis (DCA) helps to decide whether to use unimodal or linear method based on the length of the first axis. If the length is > 4 and data are heterogeneous, unimodal method should be used. If the length is < 3 and data are homogeneous, linear methods should be used (Lepš and Šmilauer, 2001). The plant communities' species composition and abundance have a complex and long relationship with environmental determinants. Unimodal model is more close to reality in analysis for such ecological data (Zerihun Woldu, 2017). Thus, CCA was used to correlate the identified plant community types with the selected environmental and disturbance factors because the first axis in the DCA was 7.13 and used heterogeneous environmental datasets. Besides, CCA is preferable due to it is explanatory variables by line length and directions that express the correlation between the variables (Kent, 2012; Zerihun Woldu, 2017). Accordingly, the recorded plant species from all sample plots were correlated with selected environmental variables (altitude, slope, sand, silt, clay, pH, Electrical conductivity, Cation Exchange Capacity, soil organic matter, total Nitrogen and available phosphorus) and disturbances.

3.3.3. Species diversity analysis

Basically, plant diversity analysis is used to obtain a quantitative figure of plant variability in a given area. Diversity combines two quantifiable measures: the number of species within the community (species richness) and equal/unequal representation of species within the community (species evenness) (Mueller-Dombois and Ellenberg, 1974). Species richness, Shannon diversity and Shannon evenness were computed using the free statistical software R (R Development Core Team, 2019). Species richness is usually expressed as a number of species per sample unit or community (Whittaker, 1972). Shannon diversity index (H') is calculated from the equation:

$$\mathbf{H' = -\sum_{i=1}^{s} Pi\ ln\ pi}$$

Where: H' = Shannon-Wiener Diversity Index; pi = the proportion of individuals or the abundance of i^{th} species expressed as a proportion of total cover in the sample and ln = log base (natural logarithms). The values of Shannon diversity index is usually found to fall between 1.5 and 3.5 and rarely reaches 4.5 (Kent, 2012; Zerihun Woldu, 2017).

The Shannon evenness index (J) was calculated from the ratio of observed diversity to maximum diversity using the equation:

$$\boldsymbol{J = \frac{H'}{Hmax} = \frac{H'}{lns}}$$

Where, *J* = evenness; *Hmax = lnS; H'* = is the Shannon-Wiener diversity Index; *S* = is the total number of species in the sample. The value of J ranges normally between 0 and 1. The higher value of evenness index (1 or tends to 1) shows the more equally or evenly distribution of species within the given area (Magurran, 1988).

3.3.4. Floristic similarity analysis between clusters

Sorensen's similarity index was used to assess the degree of floristic similarity between plant communities. It is preferred because it gives weight to species that are common to the sample plots rather than to these only occur in either sample plot (Kent, 2012). The Sorensen's similarity index is calculated from the equation:

$$\mathbf{Ss = \frac{2a}{2a + b + c}}$$

Where Ss = Sorensen's similarity coefficient, a = the number of species common to both plant community types, b = the number of species present in one of the plant community type to be compared and c = the number of species present on the other plant community type. The similarity coefficient value ranges from 0 (complete dissimilarity) to 1 (totally similar).

3.3.5. Vegetation structure analysis

Diameter at Breast Height (DBH), height, vertical structure, basal area, density, frequency and Importance Value Index were computed to determine the vegetation structure.

3.3.5.1. Diameter at Breast Height (DBH)

In each plots, DBH of trees and shrubs with ≥ 2 cm thick was measured at about 1.3 m from the ground using a measuring tape. For tree/shrub species, that branch at breast height or below, DBH of each branch was measured separately and the average was taken and then treated as a single individual for the basal area calculation. This technique is easy, quick, inexpensive and relatively accurate. There is a direct relationship between DBH and basal area (Kent, 2012).

3.3.5.2. Vertical structure

Vertical structure of the woody species was analyzed using the classification scheme of the International Union for Forestry Research Organization (IUFRO) (Lamprecht, 1989). The IUFRO classification scheme classifies the vertical structure of woody species into three stories. These are upper, for the tree/shrub height > 2/3 of the top height; middle, for the tree/shrub height between 1/3 and 2/3 of the top height and lower; for the tree/shrub height < 1/3 of the top height.

3.3.5.3. Basal area (BA) and relative dominance

Basal area of a species was computed from diameter at breast height (d) as follows:

$$\mathbf{BA = \pi\left(\frac{d}{2}\right)^2}$$

First, all measurements were in square centimeter, latter it was converted into m^2 per hectare. The basal area is used to calculate the dominance of species. Relative dominance is the percent calculation of basal area of single species per the total basal area of all species.

3.3.5.4. Frequency

Frequency is defined as the probability or chance of finding a species in a given sample plot and was computed using:

$$\text{Frequency} = \frac{\text{Number of plots where a species occur}}{\text{Total plots examined}} \text{ X } 100$$

The higher the frequency, the more important the plant is in the community.

3.3.5.5. Density

Density refers to the count of individuals per unit area and was computed using:

$$\text{Density} = \frac{\text{Total number of stems of a given species}}{\text{sample size in hectare}} \text{ X } 100$$

3.3.5.6. Importance Value Index (IVI)

Importance value index is useful to compare the ecological significance of species and helps to measure conservation priority among groups of species (Kent, 2012). The Importance Value Index is the cumulative value of the three parameters (i.e. relative frequency, relative density and relative dominance), calculated using the following formula:

$$\text{IVI} = \text{Relative frequency(RF)} + \text{Relative dominance(RDO)} + \text{Relative density (RD)}$$

Where,

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a single species}}{\text{Frequency of all species}} \text{ X } 100$$

$$\text{Relative density (RD)} = \frac{\text{Density of a single species}}{\text{Total density of all species}} \text{ X } 100$$

$$\text{Relative dominance (RDO)} = \frac{\text{Basal area of a single species}}{\text{Basal area of all species}} \text{ X100}$$

3.3.6. Regeneration status

The regeneration status of woody species was assessed by employing the total count of all seedlings and saplings within the main sample plot in relation to mature woody species following the techniques in Khan *et al.* (1987) modified by Lysenko *et al.* (2008) as described below:

- ✓ **good regeneration status**: when the density of seedlings > density of saplings > density of trees/shrubs.
- ✓ **fair regeneration status**: when the density of seedlings > density of saplings < the density of trees/shrubs.
- ✓ **poor regeneration status**: when the density of saplings > density seedlings, however, the density of saplings may be <, > or = the density of mature trees/shrubs.
- ✓ **not regenerating**: if it survives only in the adult stage.
- ✓ **newly regenerating**: if it is presented only in the seedling stage.

Accordingly, the regeneration status was analyzed by calculating the density of seedlings, saplings and adult trees/shrubs per the sample area as the following:

$$\text{Density of seedling/sapling} = \frac{\text{the number of seedling/sapling}}{\text{area of sample in a hectare}}$$

3.3.7. Analysis of soil seed bank

The composition, density and vertical distribution of the emerged seedlings from the sampled soil seed bank were computed. The number of seedlings recovered from similar layers and land use types were combined and then converted to provide the density of seedlings/m^2. The density of seedlings of each layer and land use types were also compared following Eyob Tenkir (2006) and Yohannis Teklu (2014). Jaccard's coefficient of similarity (JCS) (Jaccard, 1901) was used to analyze the similarity between soil seed bank compositions among different land use types.

$$\mathbf{Sj} = \frac{\mathbf{a}}{\mathbf{a + b + c}}$$

Where Sj = Jaccard similarity coefficient

a = Number of species common to both layers

b = Number of species unique to layer b

c = Number of species unique to layer c. The coefficient has a value from one to zero, where one indicates complete similarity and zero complete dissimilarity.

3.3.8. Ethnomedicinal data analysis

3.3.8.1. Descriptive statistics

Descriptive statistical method such as percentage and frequency was employed to analyze the useful information gathered on medicinal plants reported by local people including plant type, methods of preparation, route of application, disease treated, part and growth form used, threats and conservation methods (Alexiades, 1996). Data on informants' background and medicinal plants in the districts were entered into Excel spreadsheet software (Microsoft Corporation, 2010) and prepared for statistical analysis. The indigenous knowledge dynamics on traditional medicinal plants among the informants (men and women; young and elder age group; literate and illiterate; single and married; Christian and Muslim; key and general informants) was computed using a t-test on SPSS (Ver. 22) programs.

3.3.8.2. Preference ranking and direct matrix ranking

Preference ranking is a system of ranking of lists or groups of plants in order of the first choice of importance across a community (Martin, 1995). In this study, preference ranking was used to determine the level of local communities' preference for ranking of most preferable medicinal pant used to cure both human and animal illness. Accordingly, 10 key informants were purposively selected to rank the most preferable medicinal plants against mostly cited illness by the informants as described by Alexiades (1996).

Direct matrix ranking is a system of ranking items in which instead of arranging a series of objects on one characteristic, the informant was requested to order them by considering several attributes one a time i.e. it draws explicitly upon multiple dimensions (Martin, 1995). The direct matrix in this study was used to order seven threatened medicinal plant species with multipurpose uses by the selected 10 key informants. As it is described by Martin (1995), direct matrix ranking method was employed to score the use diversity and selected informants were asked to assign use values (5 = best, 4 = very good, 3 = good, 2 = less used, 1 = least used and 0 = not used)

3.3.8.3. Informant Consensus Factor (ICF)

The calculation of the informant consensus factor (ICF) was used to test homogeneity on the informant's knowledge in choosing certain medicinal plants against a given ailment. ICF is important to select ailment categories where there is consensus on the use of plants among the informants and to identify species with particular importance in culture. The factor provides a range of 0 to 1, where a high value acts as a good indicator for a high rate of informant consensus. Informant consensus factor (ICF) was computed after the reported traditional remedies and corresponding diseases were grouped into 12 and 5 categories of human and livestock ailments, respectively. This was computed as; Number of use citations for each disease category (n_{ur}) minus the number of times species used (n_t), divided by the number of use citations in each category minus one (Heinrich *et al.*, 1998).

$$\mathbf{IFC} = \frac{\mathbf{nur - nt}}{\mathbf{nur - 1}}$$

CHAPTER FOUR

4. RESULTS

4.1. Floristic Composition

A total of 201 plant species (Appendix 1) belonging to 163 genera in 66 families were recorded and identified from the study area. Of the identified families 36 (54.6%) of them were represented by single species while the remaining 30 families were represented by two or more species. The highest number of species was recorded for the families Fabaceae (28 species, 13.9%) and Poaceae (21 species, 10.5%) followed by Asteraceae (12 species, 6%), Lamiaceae (11 species, 5.5%), Combretaceae, Euphorbiaceae, Moraceae (7 species each, 3.5%), Solanaceae (6 species, 3%), Rubiaceae (5 species, 2.5%) and Anacardiaceae, Apiaceae, Cucurbitaceae, Vitaceae (4 species each, 2%). Regarding the growth form; herbs (103 species, 51.2%) were the most abundant followed by shrubs (52 species, 25.9%), trees (43 species, 21.4%) and lianas (3 species, 1.5%).

Out of the total collected species, 171 species were recorded from the sample plots. The remaining plant species were medicinal plant species and were collected from the vegetation but outside of sampling plots (7 species) and cultivated areas homegardens and farmlands (23 species).

4.2. New species records to the floristic region

Based on the flora area (Ethiopia and Eritrea), Hirmi woodland vegetation is located in the Tigray floristic region (TU). A total of 17 species belonging to 12 genera and 13 families were recorded from the study vegetation as new records to Tigray floristic region (TU). This accounts for 10% of the total recorded species from the study area. Of these, herbs were represented by a high number of species, 9 (53%), followed by shrubs and trees (4 species, 23.5% each). The family Asteraceae has the highest number of species (3 species, 23.1 %%), followed by Combretaceae and Fabaceae (2 species, 15.4% each). The remaining 10 families were represented by single species each (Table 2).

Table 2. List of plant species as new record for Tigray floristic region (TU)

(T = tree, H = Herb, S = Shrub andHC = Herbaceous climber)

No.	Species name	Family	Growth form
1	*Acacia nilotica*	Fabaceae	T
2	*Ageratum conyzoides*	Asteraceae	H
3	*Antherotoma naudinii*	Asteraceae	H
4	*Brassica carinata*	Brassicaceae	H
5	*Buddleja cordata*	Loganiaceae	S
6	*Commelina benghalensis*	Commelinaceae	H
7	*Desmodium repandum*	Fabaceae	H
8	*Elaeodendron buchananii*	Celastraceae	S
9	*Eugenia bukobensis*	Myrtaceae	S
10	*Galiniera saxifraga*	Rubiaceae	T
11	*Hyparrhenia cymbaria*	Poaceae	H
12	*Sida cordifolia*	Malvaceae	H
13	*Tagetes minuta*	Asteraceae	H
14	*Terminalia laxiflora*	Combretaceae	T
15	*Terminalia macroptera*	Combretaceae	T
16	*Trachyspermum ammi*	Apiaceae	H
17	*Ziziphus mucronata*	Rhamnaceae	S

4.3. Endemic species and their IUCN status

Out of the total plant species identified from the study area, 8 (4%) species were found to be endemic and 2 species (1%) were near-endemic to Ethiopia according to the Flora of Ethiopia and Eritrea. Of these *Acacia venosa*, *Albizia malacophylla*, *Aloe elegans*, *Bidens macroptera*, *Lippia adoensis*, *Pennisetum glaucifolium*, *Phragmanthera macrosolen* and *Urtica simensis* were endemic and *Combretum hartmannianum* and *Combretum rochetianum* were near-endemic species. Based on the IUCN criteria of threat level one species (*Acacia venosa*) was recorded as endangered, while three species (*Albizia malacophylla, Combretum hartmannianum* and *Combretum rochetianum*) were designated as vulnerable (Table 3).

Table 3. Endemic and nearly endemic species (to the flora of Ethiopia and Eritrea) recorded from the study area, their IUCN status and geographical distributions (IUCN category: EN = Endangered, LC = Least Concern, NE= Not Evaluated, VU Vulnerable; Endemicity: ED = endemic, NE = near endemic)

No.	Species Name	Family	Endemicity	Growth form	Local name	IUCN category
1	*Acacia venosa*	Fabaceae	ED	S	Kentib	EN
2	*Aloe elegans*	Aloaceae	ED	S	Ere	LC
3	*Albizia malacophylla*	Fabaceae	ED	T	Turmi	VU
4	*Bidens macroptera*	Asteraceae	ED	H	Gelgelemeskel	NE
5	*Combretum hartmannianum*	Combretaceae	NE	T	Sebea	VU
6	*Combretum rochetianum*	Combretaceae	NE	T	Afekumo	VU
7	*Lippia adoensis*	Verbenaceae	ED	S	Keskese	LC
8	*Phragmanthera macrosolen*	Loranthaceae	ED	S	Dikala lihay	NE
9	*Pennisetum glaucifolium*	Poaceae	ED	H		NE
10	*Urtica simensis*	Urticaceae	ED	H	Tsehaytu	NE

4.4. Plant Community types and description

Five plant community types were identified from the agglomerative hierarchical cluster analysis based on the abundance data of the species (Figure 7). Two or three woody species with relatively high synoptic and significant indicator values in the group were used to name the corresponding communities (Table 4). The descriptions of the community types identified from the vegetation under study are given below:

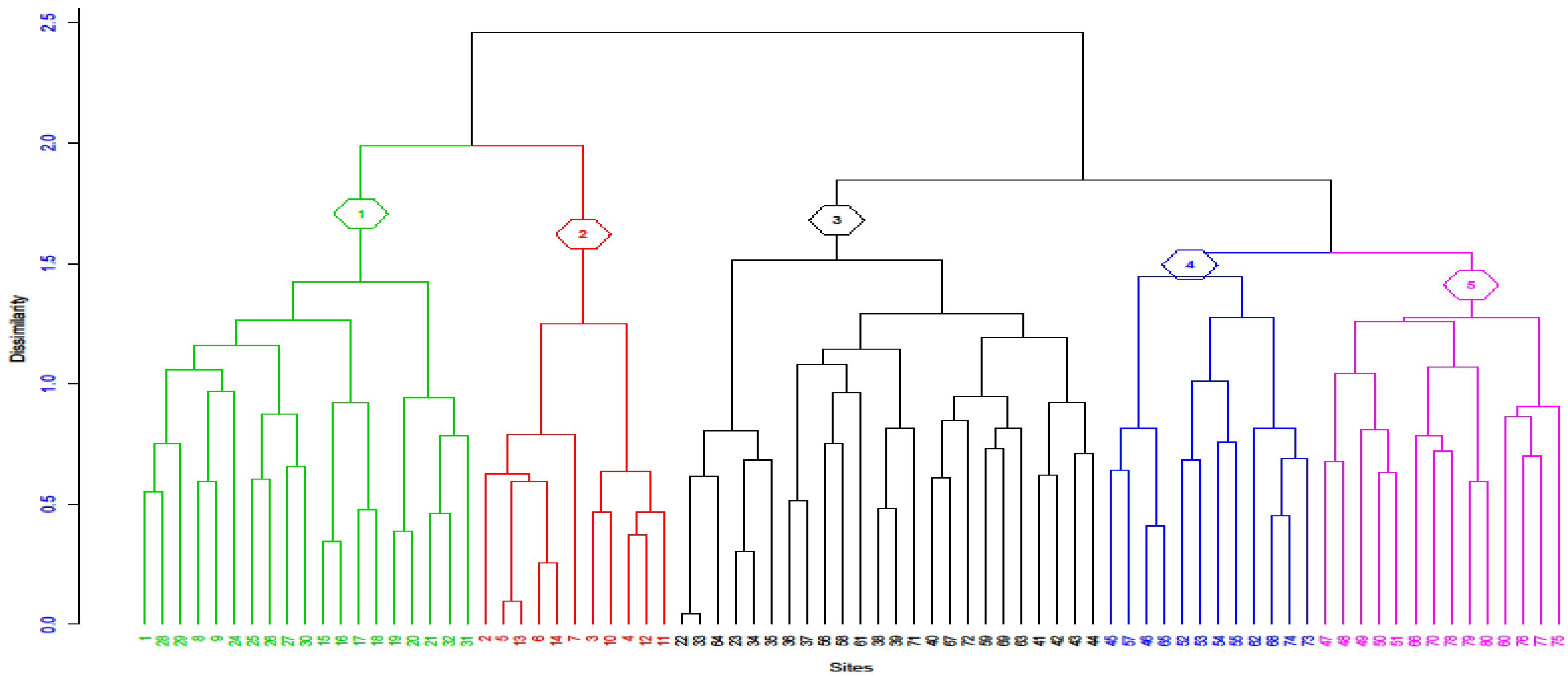


Figure 7. Dendrogram showing plant community types

The plot code and the arrangement of the plots along the dendrogram from left to right are as follows: (C1= *Ziziphus mucronata - Acacia polyacantha;* C2 = *Combretum hartmannianum - Terminalia macroptera - Oxytenanthera abyssinica;* C3 = *Anogeissus leiocarpa - Ozoroa insignis;* C4 = *Euclea racemosa - Acacia abyssinica;* C5 = *Dodonaea angustifolia- Flueggea virosa)*

Table 4. Synoptic values and P - value of species in each community type

Community number community size	C1 19	C2 11	C3 24	C4 12	C5 14	P-value
Ziziphus mucronata	**3.37**	0.27	0.21	0	0	**0.004**
Acacia polyacantha	**3.21**	0.1	0	0	0.14	**0.001**
Bidens pilosa	2.11	0.2	1.5	0.67	0	0.12
Achyranthes aspera	1.89	0	0.17	0	0	0.012
Ziziphus spina-christi	1.74	0.91	0.22	0	0	0.045
Trifolium campestre	1.84	0	0	0.33	0	0.6
Chamaecrista mimosoides	1.68	0	0.33	0	0	0
Dichrostachys cinerea	1.26	0.78	0	0	1.36	0
Combretum hartmannianum	0.84	**5.64**	0.92	0	0	**0.01**
Terminalia macroptera	1.32	**4.09**	0.42	0	0.1	**0**
Setaria megaphylla	0.84	4	0.33	0	0	0
Oxytenanthera abyssinica	0	**3.91**	0	0	0	**0**
Oplismenus burmannii	0.63	3.27	0.33	0	0	0
Ficus ingens	1.58	2.64	0	0	0	0.615
Lonchocarpus laxiflorus	1.11	2	0	0	0	0.245
Acanthospermum hispidum	0.84	1.09	0.33	0	0.29	0
Anogeissus leiocarpa	1.01	2.64	**2.96**	0.04	0.11	**0**
Ozoroa insignis	0	0.88	**2.79**	0	0.76	**0**
Bidens macroptera	0.42	0	2.33	1.33	0.86	0.38
Guizotia scabra	0.21	0	2.12	0.33	0.86	0.45
Terminalia laxiflora	0	0.65	1.46	0	0	0
Vangueria madagascariensis	0	0	1.17	0	0	0.23
Rhus retinorrhoea	0.32	0	0.58	0	0	0
Euclea racemosa	0	0	0.21	**3.17**	1.26	**0**
Acacia abyssinica	0	0	0.35	**2.83**	1.21	**0**
Galiniera saxifraga	0	0	0.42	2.25	0.79	0.01
Acokanthera schimperi	0.37	0	0.59	2.08	0	0
Acacia seyal	0	0	0.75	1.83	1.21	0
Balanites aegyptiaca	0.11	0	0	1.75	0	0.81
Mimusops kummel	0.26	0	0.42	1.5	0	0.11
Acacia lahai	0	0	0.25	1.42	0.79	0
Dodonaea angustifolia	0	0.1	0	0	**3.71**	**0.01**
Flueggea virosa	1.68	0.37	0	0	**1.71**	**0.02**
Hyparrhenia cymbaria	0	0	0	0	1.71	0.612
Capparis tomentosa	0.21	0	0.21	0	1.07	0.16
Arthraxon micans	0	0	0.17	0	1.43	0
Dactyloctenium aegyptium	0	0	0.1	0	1.14	0
Combretum adenogonium	1.11	0	0	0	0	4.23
Stereospermum kunthianum	0.26	0	0	0	0	0.84

1. *Ziziphus mucronata - Acacia polyacantha* community type

The community was found in altitudinal ranges of 1170-1565 m.a.s.l. It is situated on a flat to moderate slope ranging from 2-30%. At the lower altitudes of the community, high disturbance signs including cutting, debarking, grazing were observed. *Stereospermum kunthianum* and *Combretum adenogonium* were among the characteristic tree species. Other tree species present in the community include *Acacia polyacantha*, *Ficus ingens*, *Terminalia macroptera* and *Lonchocarpus laxiflorus* whereas *Ziziphus mucronata*, *Ziziphus spina-christi*, *Flueggea virosa* and *Dichrostachys cinerea* were the dominant species in the shrub layer. The field (herb) layer was dominated by *Bidens pilosa*, *Achyranthes aspera*, *Chamaecrista mimosoides* and *Trifolium campestre*. About 20 medicinal plant species were recorded in this community. Of these *Stereospermum kunthianum, Acacia polyacantha, Combretum adenogonium* and *Adansonia digitate* were the most commonly found and abundant species.

Figure 8. Dominant species in community one A) *Acacia polyacantha* B) *Ziziphus mucronata*

2. *Combretum hartmannianum - Terminalia macroptera - Oxytenanthera abyssinica* community type

This community was found within the altitudinal range of 1098-1300 m.a.s.l. Most plots of the community were situated on a moderate slope (12-30%). It is found around the edge of the woodland vegetation. It was the most disturbed community. This community type was dominated by *Combretum* and *Terminalia* species. The lowland bamboo (*Oxytenanthera abyssinica*) was the characteristic species for the community (Figure 9). The tree layer was dominated by *Combretum hartmannianum*, *Terminalia macroptera*, *Lonchocarpus laxiflorus, Anogeissus leiocarpa, Ficus ingens* and the shrub layers was dominated by *Dichrostachys cinerea* and *Ziziphus spina-christi*. *Setaria megaphylla*, *Oplismenus burmannii* and

Acanthospermum hispidum were also commonly found in the field layer. This community harbored 18 medicinal plant species. *Achyranthes aspera, Acacia polyacantha, Gardenia ternifolia* and *Grewia ferruginea* were among the medicinal species found in this community.

Figure 9. The dominant *Oxytenanthera abyssinica* population in community two

3. *Anogeissus leiocarpa- Ozoroa insignis* community type

This community was found within an altitudinal range of 1400-1840 m.a.s.l. with an average slope of 41%. This community type is found near to the center of the study vegetation. It is relatively less disturbed and species-rich community harboring 100 species. The tree layer was dominated by *Anogeissus leiocarpa, Ozoroa insignis andTerminalia laxiflora* whereas the shrub layer was dominated by *Vangueria madagascariensis* and *Rhus retinorrhoea* and *Acokanthera schimperi. Bidens macroptera, Guizotia scabra, Bidens pilosa* and *Oplismenus burmannii* were among the dominant species in the field layer. This community comprised the highest number (25 species) of medicinal plant species. Of these *Anogeissus leiocarpa, Boswellia papyrifera, Capparis tomentosa* and *Datura stramonium* were found abundantly.

4. *Euclea racemosa - Acacia abyssinica* community type

This community type is found in a wider altitudinal range (1405 - 2002 m.a.s.l) and on gentle to steep slopes (8-75%). At the upper altitudes (1980 – 2002 m) of the community type, plant species that belong to the DAF vegetation type including *Acacia abyssinica, Olea europaea* subsp. *cuspidata, Acacia lahai* and *Phytolacca dodecandra* were recorded. The remaining plots found in the mid/and lower altitude were also entertained by various tree, shrub and herb species.

The tree layer was dominated by *Acacia abyssinica, Balanites aegyptiaca, Acacia lahai, Mimusops kummel* and *Acacia seyal.* The shrub layer was dominated by *Euclea racemosa, Galiniera saxifrage* and *Acokanthera schimperi.* In the field layer species including *Bidens macroptera, Bidens pilosa* and *Guizotia scabra* were dominant. About 22 medicinal plant species were recorded in this community. Species including *Croton macrostachyus, Phytolacca dodecandra, Jasminum abyssinicum* and *Olea europaea* were among the medicinal plant species abundantly found in the community.

5. *Dodonaea angustifolia - Flueggea virosa* community type

This community occurs at altitudes from 1285 to 1790 m.a.s.l with slopes extending from 0-45%. Various disturbance signs (cutting, grazing and fire) were recorded in most of the sampled plots (Figure 10). *Hyparrhenia cymbaria* was the characteristic species for the community. In the elevated and moderate slopes of the community, two single shrubby species (*Dodonaea angustifolia* and *Flueggea virosa*) were recorded with high densities. Although the community is dominated by shrub layers including *Dodonaea angustifolia, Flueggea virosa, Eucle racemosa, Dichrostachys cinerea* and *Capparis tomentosa,* there were also few tree species including *Acacia seyal, Acacia lahai* and *Ozoroa insignis* in the tree layer. The field layer was dominated by *Arthraxon micans, Bidens macroptera, Dactyloctenium aegyptium* and *Guizotia scabra.* This community harbored a total of 20 medicinal plant species. *Cissus petiolate, Zehneria scabra, Dodonaea angustifolia* and *Senna singueana* were the most abundant medicinal plant species found in this community.

Figure 10. Dominant species of community five (A = *Dodonaea angustifolia*, B = *Eucle racemosa*) and various distrubances signs (C= cutting, D = grazing, E= degradation)

4.5. Ordination

CCA ordination was employed to examine the effect of environmental variables and disturbances (Table 5) on the patterns of variation in the floristic composition. Altitude, slope, soil physical and chemical properties (soil texture, pH, Electrical conductivity, available phosphorus, soil organic matter, total Nitrogen and Cation Exchange Capacity), as well as disturbance factors (tree cutting, debarking, grazing, firing and charcoal production), were investigated with respect to their association to plant community types. The permutation test result revealed that environmental variables including altitude, slope, disturbance, soil organic matter, total Nitrogen, sand and silt soil type were found significantly associated with the identified five community types (Table 5).

Table 5. The result of permutation test for environmental variables

Variable	Df	Sums of Sqs	Mean Sqs	F.Model	R2	Pr(>F)
Altitude	1	2.9544	2.95439	8.8283	0.09389	0.001 ***
Slope	1	0.8343	0.83433	2.4931	0.02652	0.001 ***
PH	1	0.4476	0.44763	1.3376	0.01423	0.143
EC	1	0.3280	0.32803	0.9802	0.01043	0.487
P	1	0.4002	0.40020	1.1959	0.01272	0.254
SOM	1	0.5772	0.57715	1.7246	0.01834	0.034 *
N	1	0.5788	0.57875	1.7294	0.01839	0.031 *
CEC	1	0.2915	0.29146	0.8709	0.00926	0.620
Sand	1	1.1337	1.13366	3.3876	0.03603	0.001 ***
Silt	1	0.5411	0.54108	1.6169	0.01720	0.049 *
Clay	1	0.3468	0.34679	1.0363	0.01102	0.409
Disturbance	1	0.6099	0.60985	1.8224	0.01938	0.024 *
Residuals	67	22.4216	0.33465		0.71259	
Total	79	31.4649			1.00000	

Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘’ 1

* = Environmental variables with significant value; df= degree of freedom, R^2=; coefficient of determination (ranges from 0-1), Pr= Significant value; Sqs=square

The Eigenvalue of axis one was 0.94 and the second axes was 0.24. Gradients of altitude, slope, silt and soil organic matter were positively correlated with the first axis and negatively correlated with the second axis. Disturbance, sand and total Nitrogen were positively correlated to the second axis and negatively correlated to the first axis. Community 4 was found at higher altitudes whereas communities 1 and 2 were found at lower altitudes. Communities 3 and 4 were found at the steep slopes with least disturbances whereas communities 1 and 2 were situated at the relatively flat slope with high disturbances. Community 5 was reflated mainly by the gradient of silt soil.

Total nitrogen, disturbances and sand soil were positively correlated with community types 1 (*Ziziphus mucronata - Acacia polyacantha*) and 2 (*Combretum hartmannianum - Terminalia macroptera - Oxytenanthera abyssinica*). Community type 3 (*Anogeissus leiocarpa - Ozoroa insignis*) was found dispersed in the biplot implying they were influenced by various factors. However, soil organic matter, slope and silt have a strong positive correlation to the community type when compared with other factors. Disturbance was negatively correlated with community 3. Community 4 (*Euclea racemosa - Acacia abyssinica*) was mainly correlated with altitude, silt and slope whereas the sand, disturbances and total Nitrogen were negatively correlated with the community. Community 5 (*Dodonaea angustifolia - Flueggea virosa*) was positively correlated with silt and disturbance and negatively correlated with sand (Figure 11).

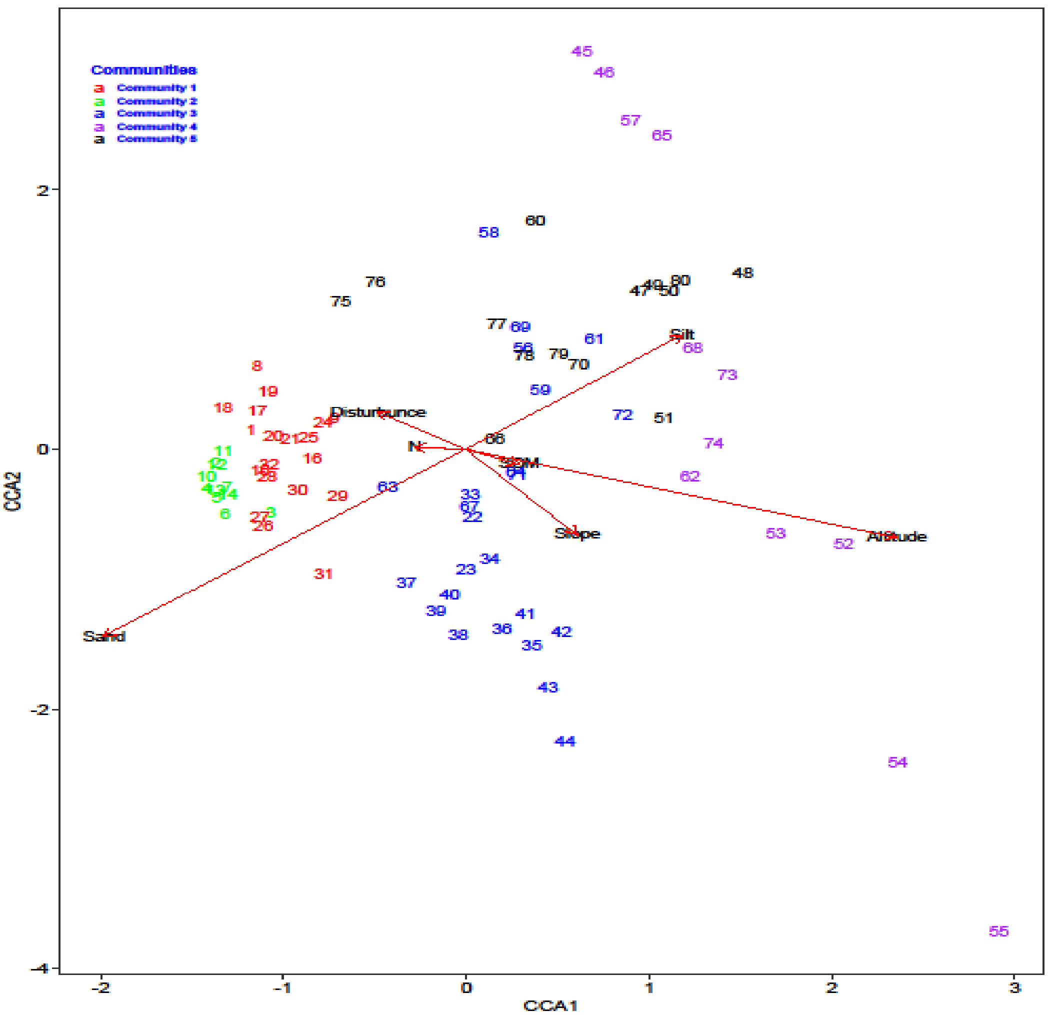


Figure 11. CCA biplot of environmental variables and sampling plots

4.6. Species richness, evenness and diversity of the five communities

Shannon diversity index and evenness of the identified five community types are summarized in Table 6. In terms of the actual number of species per community, community 3 (*Anogeissus leiocarpa* - *Ozoroa insignis*) was found the most species-rich (100 species) followed by community 4 (*Euclea racemosa* - *Acacia abyssinica*) and community 5 (*Dodonaea angustifolia* - *Flueggea virosa*) which comprises 75 species each. Community 2 (*Combretum hartmannianum* - *Terminalia macroptera* - *Oxytenanthera abyssinica*) was the most species poor (40 species) community. Similarly, community 3 had the highest species diversity (H'= 4.21) while community 2 had the lowest diversity (H'= 3.25)**.** In terms of evenness, community 4 had the highest evenness index (0.95) and community 2 and 3 had the lowest evenness of species (0.90 each) when compared with the other community types.

Table 6. Shannon-Wiener Diversity and Evenness indices of the five communities

Community types	Elevation (m)	Species richness (S)	Shannon-Wiener Diversity Index (H`)	Shannon's Evenness index (J)
1	1170-1565	64	3.83	0.93
2	1098-1300	40	3.25	0.90
3	1400-1840	100	4.21	0.90
4	1405-2002	75	4.07	0.95
5	1285-1790	75	3.96	0.93

4.7. Species composition similarities between plant communities

Sorensen's similarity coefficient was used to compare the floristic composition similarity among the five community types (Table 7). The similarity coefficient of plant communities ranged from 0.1 to 0.58. The highest floristic similarity was exhibited between community 1 and 2 (0.58). The least floristic similarity was between community 2 and 4 (0.1). The community types with the highest species similarity (1 & 2) shared 40.4% of the total species while those with the least species similarity (2 & 4) shared 11.7% of the total species.

Table 7. Pair wise comparison of Sorensen's similarity coefficient between the five plant communities

Community	C1	C2	C3	C4	C5
C1	1	-	-	-	-
C2	0.58*	1	-	-	-
C3	0.32	0.27	1	-	-
C4	0.21	0.1**	0.43	1	-
C5	0.23	0.23	0.54	0.38	1

(C= community; * = Communities with high similarity, ** = communities with least similarity)

4.8. Vegetation structure

4.8.1. DBH distribution

Tree and shrub species (height ≥ 2 m and DBH ≥ 2 cm) were classified into eight DBH (cm) classes: 2 -10; 10.1 - 18; 18.1 - 26; 26.1 - 34; 34.1 - 42; 42.1 – 50; 50.1 - 58 and > 58 cm. As the DBH class size increased, the number of individuals was found gradually decreasing towards the successive higher DBH classes (Figure 12). *Sterculia setigera, Ficus vasta, Adansonia digitata* and *Ficus ingens* were found to be the dominant large-sized trees. *Anogeissus leiocarpa, Ziziphus mucronata, Combretum hartmannianum* and *Terminalia macroptera* were among the species that contributed high cumulative proportion of DBH (> 21% of the total), whereas *Buddleja cordata*, *Clerodendrum myricoides* and *Otostegia fruticosa* contributed the least to the total DBH (<0.06% of the total DBH).

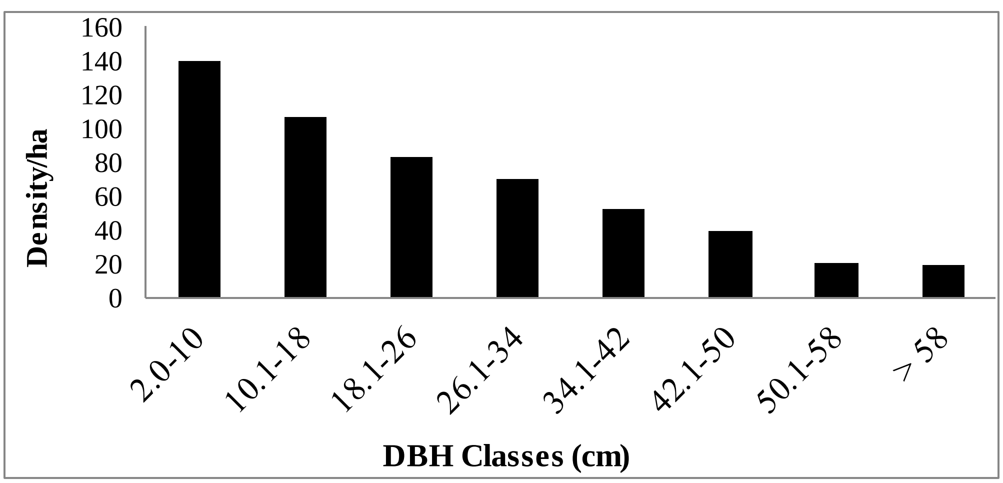


Figure 12. DBH class distributions of trees and shrubs

4.8.2. Height class

Individuals of woody species with height > 2 m and DBH ≥ 2 cm were classified into seven height classes and the density of each were calculated. The first two height classes accounted 73% of the total height class while the remaining five classes accounted for only 27% of the total height class. The cumulative height class of the study vegetation has an inverted J-shape which means there is a decline in the density of woody plants with increasing height classes (Figure 13).

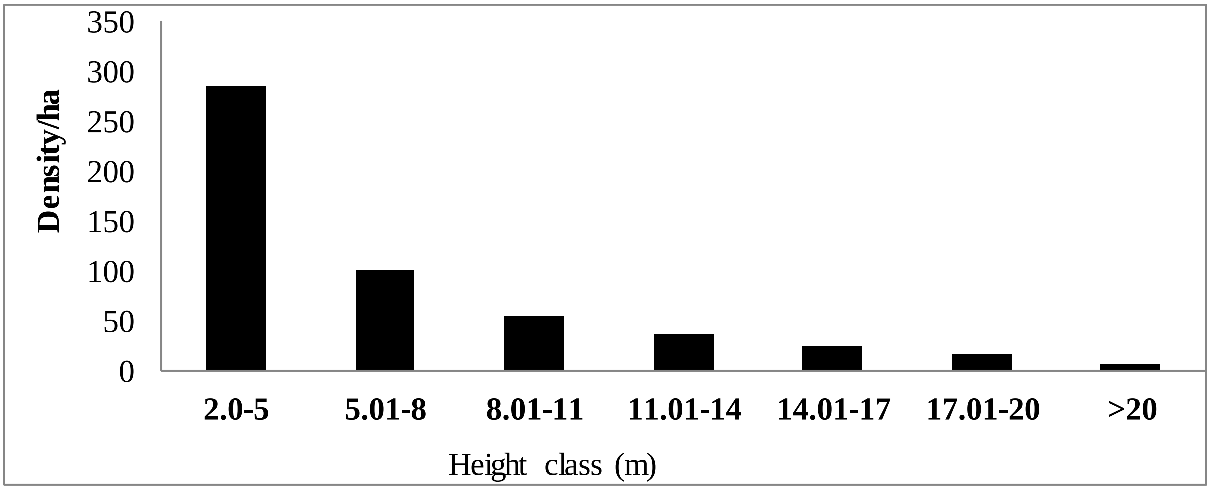


Figure 13. Height class distribution of woody species

4.8.3. Vertical stratification

The tallest tree observed in the Hirmi woodland vegetation was 25 m high. According to the IUFRO classification scheme (Lamprecht, 1989), woody species with height > 16.6 m are included under the upper story while woody species having heights between 8.3 - 16.6 m were included in the middle story. Woody species with height < 8.3 m are grouped within the lower story. The cumulative vertical stratification shows that the numbers of species decreased gradually towards the upper story. About 65.2% of the species were in the lower story followed by middle (28.6%) and upper (6.2%) stories. The most dominant woody species in the lower story were: *Acokanthera schimperi, Calpurnia aurea, Dichrostachys cinerea, Dodonaea angustifolia, Flueggea virosa, Maytenus arbutifolia* and *Ximenia americana*. Woody plants in the middle story were: *Albizia malacophylla, Ziziphus mucronata, Entada abyssinica, Diospyros mespiliformis* and *Euclea racemosa*. Species including *Acacia albida, Diospyros abyssinica, Combretum hartmannianum, Stereospermum kunthianum, Acacia abyssinica, Anogeissus* *leiocarpa, Combretum adenogonium, Ficus vasta, Sterculia setigera* and *Terminalia macroptera* were among the species categorized in the upper story. However, the species in the category 'upper story' could also found in the middle and lower story in the form of small tree, saplings and seedlings.

4.8.4. Density of woody species

The total density of woody species with DBH ≥ 2 cm was 528.4 stems/ha. As indicated in Table 8, only 10 species accounted for 40% of the total density. Among these, *Dodonaea angustifolia* accounts for the highest density (31.2 stems/ha or 5.9%) followed by *Flueggea virosa* (29.2 stems/ha or 5.5%), *Diospyros mespiliformis* (28 stems/ha or 5.3%), *Anogeissus leiocarpa* (25.8 stems/ha or 4.9%) and *Ziziphus mucronata* (18 stems/ha or 3.4%). The remaining woody species altogether accounted for 59.6% of the total density.

Table 8. Density and percentage contribution of ten woody species

Species name	Density /ha	%
Dodonaea angustifolia	31.2	5.9
Flueggea virosa	29.2	5.5
Diospyros mespiliformis	28	5.4
Anogeissus leiocarpa	25.8	4.9
Ziziphus mucronata	18	3.4
Combretum hartmannianum	18	3.4
Maytenus arbutifolia	18	3.4
Ximenia americana	16	3
Acokanthera schimperi	14.4	2.7
Acacia polyacantha	12.8	2.4
Total density of 10 species $\mathbf{h^{-1}}$	211.4	40

4.8.5. Basal area (BA)

The total basal area of Hirmi woodland vegetation was 14 m^2/ha. More than 50% (7.1 m^2 /ha) of the total basal area was contributed by ten large-sized and abundant tree species which are *Anogeissus leiocarpa, Acacia polyacantha, Combretum hartmannianum, Terminalia macroptera, Ziziphus mucronata, Terminalia laxiflora, Diospyros abyssinica, Ficus ingens, Ozoroa insignis* and *Diospyros mespiliformis* (Table 9).

Table 9. Basal area (BA) (m^2 /ha) of most dominant woody species

Species Name	**BA (m^2/ha)**	**% BA**
Anogeissus leiocarpa	1.5	10.4
Acacia polyacantha	0.9	6.2
Combretum hartmannianum	0.8	5.9
Terminalia macroptera	0.8	5.6
Ziziphus mucronata	0.6	4.1
Terminalia laxiflora	0.6	4.1
Diospyros abyssinica	0.7	4
Ficus ingens	0.5	3.5
Ozoroa insignis	0.5	3.5
Diospyros mespiliformis	0.5	3.5
Total	**7.1**	**50.7**

4.8.6. Frequency

The frequency values of species were classified into five frequency classes as: 1-10%; 10.1-20%; 20.1-30%; 30.1-40% and > 40% (Figure 14). The frequency distribution of the woody species showed that higher proportions (59 %) of species were distributed in the first frequency class followed by a rapid decline in the distribution of species across successive higher frequency classes. *Anogeissus leiocarpa* was the most frequent species (40.5%), followed by *Terminalia macroptera* (28.5%), *Ziziphus mucronata* and *Combretum hartmannianum* (26.3% each) whereas *Acacia nilotica*, *Olea europaea* subsp. *cuspidata*, *Otostegia fruticosa*, *Phoenix reclinata*, *Phytolacca dodecandra* and *Syzygium guineense* were species with low frequencies (2.5% each).

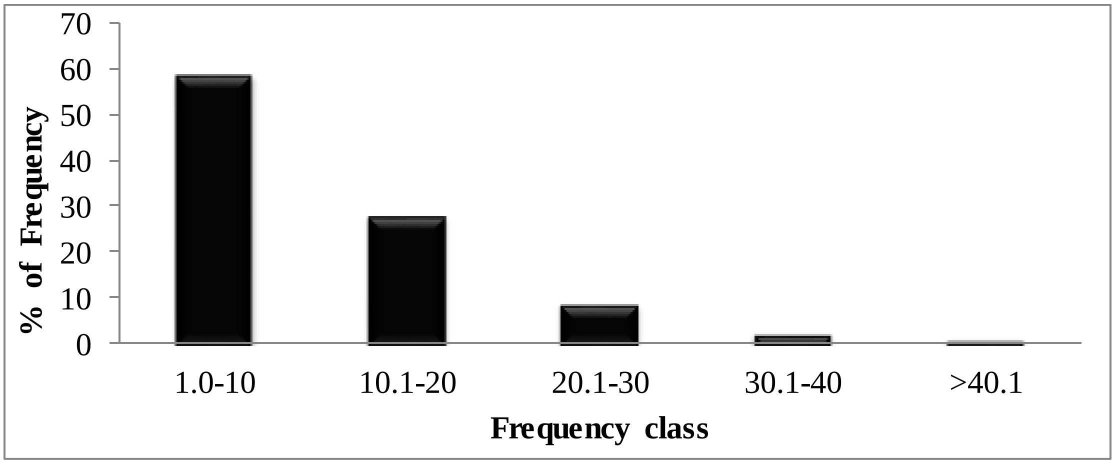


Figure 14. Frequency distribution of trees and shrubs

4.8.7. Importance Value Indices (IVI)

The importance value index of woody species in the study area ranged from 0.35 to 20.6 (Appendix 2). The first top ten woody species that contribute to 37.8% of the IVI in decreasing order were; *Anogeissus leiocarpa, Combretum hartmannianum, Ziziphus mucronata, Terminalia macroptera, Acacia polyacantha, Flueggea virosa, Dodonaea angustifolia, Diospyros abyssinica, Ozoroa insignis* and *Diospyros mespiliformis* respectively (Table 10). The remaining woody species accounted for 62.2% of the total IVI. Some of the species with the least IVI values were *Acacia nilotica, Buddleja cordata, Cordia africana, Olea europaea* subsp. *cuspidata, Otostegia fruticosa* and *Phytolacca dodecandra.*

Table 10. The top ten species with the highest IVI value (RF=Relative frequency, RD= Relative density, RDO= Relative dominance, IVI= Importance Value Index)

No.	Spp Name	RF	RD	RDO	IVI
1	*Anogeissus leiocarpa*	5	4.9	10.7	20.6
2	*Combretum hartmannianum*	3.2	3.8	6.1	13.1
3	*Ziziphus mucronata*	3.2	5.2	4.3	12.7
4	*Terminalia macroptera*	3.5	2.7	5.2	11.4
5	*Acacia polyacantha*	2.5	2.4	6.4	11.2
6	*Flueggea virosa*	2.3	5.5	1.9	9.7
7	*Dodonaea angustifolia*	1.5	5.8	2.2	9.6
8	*Diospyros abyssinica*	1.5	3.4	4.1	9.0
9	*Ozoroa insignis*	2.8	1.8	3.6	8.2
10	*Diospyros mespiliformis*	2.0	2.4	3.5	7.9
Total		**27.5**	**37.9**	**48.0**	**113.4**

4.9. Regeneration status of Hirmi vegetation

Regeneration status of Hirmi woodland was characterized by computing the density of seedlings, saplings and mature trees/shrubs (Appendix 4). The total density of seedlings, saplings and mature tree /shrub species were 2750 /ha, 3025 /ha and 528.4 /ha respectively, (Figure 15).

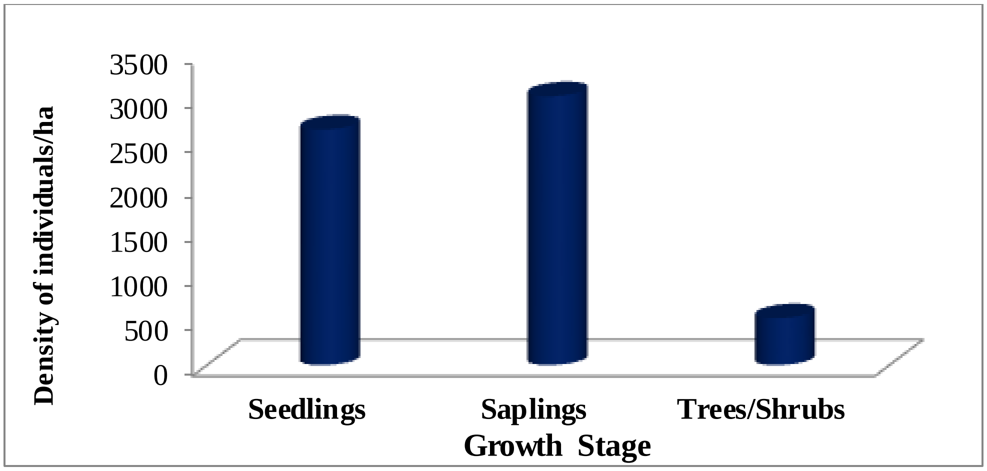


Figure 15. Densities (per hectare) of seedlings, saplings and trees/shrubs

The regeneration status of the woody species was categorized in three classes to prioritize conservation measurement. These are species with no seedlings, species with no saplings and species with no saplings and seedlings (Table 11). Twelve woody species were with no seedlings while 11 species were with no saplings. Besides, six species (*Acacia nilotica*, *Clerodendrum myricoides*, *Cordia africana*, *Justicia schimperiana*, *Phoenix reclinata* and *Phytolacca dodecandra*) had neither seedlings nor saplings.

Table 11. Classification of woody species in the different conservation priority classes

SN	species with the no seedlings	species with no saplings	species with no saplings and seedlings
1	*Acacia nilotica*	*Acacia nilotica*	*Acacia nilotica*
2	*Adansonia digitata*	*Buddleja cordata*	*Clerodendrum myricoides*
3	*Balanites aegyptiaca*	*Clerodendrum myricoides*	*Cordia africana*
4	*Clerodendrum myricoides*	*Cordia africana*	*Justicia schimperiana*
5	*Cordia africana*	*Ficus vasta*	*Phoenix reclinata*
6	*Croton macrostachyus*	*Justicia schimperiana*	*Phytolacca dodecandra*
7	*Erythrina abyssinica*	*Lannea schimperi*	
8	*Justicia schimperiana*	*Maerua angolensis*	
9	*Phoenix reclinata*	*Phoenix reclinata*	
10	*Phytolacca dodecandra*	*Phytolacca dodecandra*	
11	*Piliostigma thonningii*	*Sterculia setigera*	
12	*Rumex nervosus*		

4.10. Soil seed bank

4.10.1. Species composition of soil seed bank

A total of 58 plant species representing 51 genera in 22 families (Appendix 5) were recovered from the soil seed bank samples. Herbs were represented by the highest number of species i.e. 50 (86.2%), while shrubs and trees were represented by 5 (8.6%) and 3 (5.2%) species, respectively. *Croton macrostachyus, Diospyros mespiliformis, Syzygium guineense, Dodonaea angustifolia, Euclea racemosa, Jasminum abyssinicum, Rhus retinorrhoea* and *Woodfordia uniflora* were among the woody species recovered from the soil seed bank. The plant families with high species composition were Poaceae (19 species, 32.8%), Asteraceae (7 species, 12.1%), Fabaceae (5 species, 8.8%) and Lamiaceae (4 species, 6.9%) which accounting 60.6% of the total. The species composition in the different land use types ranged from 14 to 39. The highest species composition were found in the shrubland (39 species) followed by grassland (30 species) and forest (26 species), whereas the least species were recorded in soil seed banks taken from bare land (14 species).

Figure 16. Soil seed bank germination in EBI greenhouse

4.10.2. Species frequencies in the soil seed bank

The species frequencies in the sampled land-use types were different in their composition (Table 12). *Ageratum conyzoides, Oplismenus burmannii* and *Hyparrhenia rufa* were represented with high seedlings number (> 6 seedlings each), whereas species including *Jasminum abyssinicum, Leonotis ocymifolia, Oldenlandia herbacea, Plectranthus longipes, Rhus retinorrhoea, Tagetes minuta* and *Urtica simensis* were among the species represented with few seedlings (1 seedling each) in the sample taken from the forest. Regarding the soil seed bank sample taken from the shrubland, seedlings of woody species including *Woodfordia uniflora, Rhus retinorrhoea* and *Dodonaea angustifolia* were dominant which accounted for 13 (40.3%), 12 (37.5%) and 8 (25%) respectively. In contrast, species such as *Bidens macroptera, Oldenlandia herbacea* and *Spermacoce sphaerostigma* were represented with few seedlings (1 seedling each) in the soil seed bank sampled from shrubland. About 46.9% of the total seedlings recovered in the soil seed bank sampled from the grassland were accounted by *Oplismenus burmannii* and the 21.9% were accounted by *Digitaria abyssinica*. On the other hand, *Jasminum abyssinicum, Pennisetum glaucifolium, Plantago lanceolata, Satureja punctata, Snowdenia polystachya, Solanum americanum* and *Tagetes minuta* were represented by single seedling in the grassland soil seed bank. Bare land has the least total species in contrast to other land use types. The relative frequent species in the bare land were *Harpachne schimperi* 5 (15.6%), *Trifolium campestre* 4 (12.5%), *Dodonaea angustifolia* 2(6.3%) and *Eleusine africana* 2 (6.3%); whereas *Galinsoga parviflora*, *Setaria pumila* and *Tagetes minuta* were reprented by single individual seedling.

Table 12. Species with high and least frequencies in the soil seed bank of different LUT (LUT = Land use types)

LUT	Species with high seedlings frequency	Frequency (%)	Species with least seedlings frequency	Frequency (%)
Forest	*Ageratum conyzoides*	8 (25)	*Jasminum abyssinicum*	1(3.25)
	Oplismenus burmannii	8(25)	*Leonotis ocymifolia*	1(3.3)
	Hyparrhenia rufa	6(18.8)	*Oldenlandia herbacea*	1(3.3)
	Achyranthes aspera	5(15.6)	*Plectranthus longipes*	1(3.3)
	Galinsoga parviflora	5(15.6)	*Rhus retinorrhoea*	1(3.3)
	Euclea racemosa	4(12.5)	*Tagetes minuta*	1(3.3)
	Diospyros mespiliformis	3(9.4)	*Urtica simensis*	1(3.3)
shrubland	*Woodfordia uniflora*	13(40.3)	*Chloris pycnothrix*	2(6.3)
	Rhus retinorrhoea	12(37.5)	*Setaria pumila*	2(6.3)
	Pennisetum glaucifolium	11(34.4)	*Syzygium guineense*	2(6.3)
	Galinsoga parviflora	9(28.1)	*Trifolium campestre*	2(6.3)
	Dodonaea angustifolia	8(25)	*Bidens macroptera*	1(3.1)
	Tagetes minuta	8(25)	*Oldenlandia herbacea*	1(3.1)
	Pilea tetraphylla	7(21.9)	*Spermacoce sphaerostigma*	1(3.1)
Grassland	*Oplismenus burmannii*	15 (46.9)	*Jasminum abyssinicum*	1(3.1)
	Digitaria abyssinica	7(21.9)	*Pennisetum glaucifolium*	1(3.1)
	Arthraxon micans	6(18.8)	*Plantago lanceolata*	1(3.1)
	Cenchrus ciliaris	6(18.8)	*Satureja punctata*	1(3.1)
	Chloris pycnothrix	6(18.8)	*Snowdenia polystachya*	1(3.1)
	Dactyloctenium aegyptium	6(18.8)	*Solanum americanum*	1(3.1)
	Digitaria intecta	6(18.8)	*Tagetes minuta*	1(3.1)
Bare land	*Trifolium campestre*	4(12.5)	*Galinsoga parviflora*	1(3.1)
	Dodonaea angustifolia	2(6.3)	*Setaria pumila*	1(3.1)
	Eleusine africana	2(6.3)	*Tagetes minuta*	1(3.1)

4.10.3. Soil seed bank density and habitat types

The total density of seedlings from all land use types and layers (down to 9 cm) were 3,116.7 seedlings / m^2 (Table 13). Shrubland has the highest seedling density (1,266.6 seedlings / m^2) followed by forest (1,141.7 seeds/m^2) and Grassland (619.4 seedlings/m^2). The least densities of seedlings were found in the sample taken from bare land (88.9 seedlings /m^2).

Table 13. Vertical density of seedlings of soil seed bank taken from different land use types

Land use types	Density				
	Litter	1-3	3-6	6-9	Total density of LUTs
Shrubland	625	401.4	170.8	69.4	1,266.7
Forest	620.8	345.8	125	50	1,141.7
Grassland	358.3	186.1	54.2	20.8	619.4
Bare land	48.6	22.2	15.8	2.8	88.9
Total	1,652.7	955.5	365.8	143	**3,116.7**

In all land use types, the total density of species was inversely proportional to the depth (Figure 17). The litter layer had the highest species density (1652.7 seedlings / m^2), succeeding with first layer (955.5 seeds / m^2), second layer (365.8 seedlings / m^2) and third layer (143 seedlings / m^2). The seeds of species recovered only from the litter layer were *Crotalaria goreensis, Crotalaria onobrychis, Eragrostis tef, Plantago lanceolata, Leonotis ocymifolia* and *Harpachne schimperi*. Species including *Desmodium repandum, Digitaria abyssinica, Hibiscus crassinervius, Nicandra physaloides* and *Oldenlandia herbacea* were found only in the first layer. *Dioscorea schimperiana* was recovered only from the second layer of the soil seed bank. There were no species recovered only from the third layer (6-9cm). However, the species recovered from this layer were also found in the other layers. Seedlings of woody species such as *Diospyros mespiliformis, Dodonaea angustifolia, Euclea racemosa, Syzygium guineense* and herb seedlings; *Ageratum conyzoides, Arthraxon micans, Bidens macroptera, Cyperus schimperianus, Digitaria intecta, Galinsoga parviflora, Guizotia villosa, Tagetes minuta, Trifolium rueppellianum* were found in all layers soil seed samples.

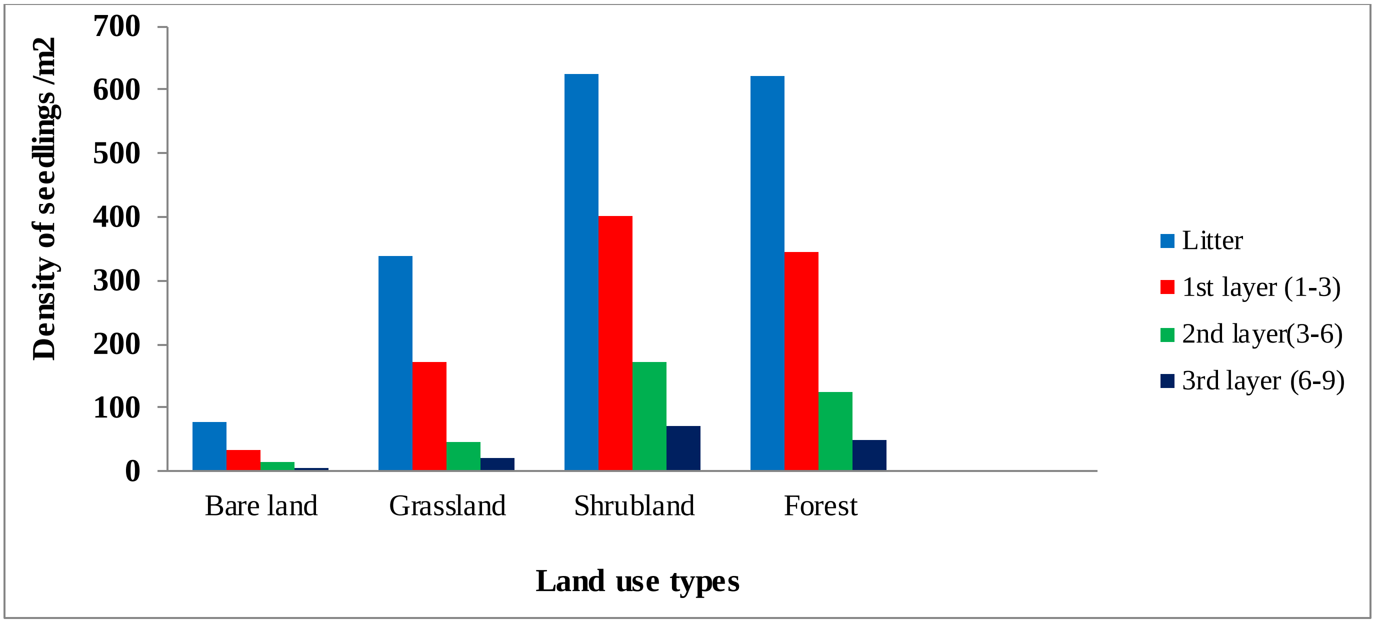


Figure 17. Density of seedlings across all vertical layers in the different land use types of the study area

4.10.4. Similarity of species composition among land use types

Based on the result of the Jaccarad's coefficient of similarity (Table 14), the species composition similarity between the soil seed bank of the four habitats were generally low (ranged from Sj: 0.15-0.35). The highest similarity was between the soil seed bank of forest and shrubland (Sj=0.35) while the least species similarity was between the soil seed bank taken from the forest land and bare land (0.15).

Table 14. Jaccard's coefficient of similarity in species composition of among the land use types

Land Use Types	Forest	Shrubland	Grassland	Bare Land
Forest	1	**0.35***	0.31	**0.15****
Shrubland	-	1	0.27	0.29
Grassland	-	-	1	0.27
Bare Land	-	-	-	1

* Highest Jaccard's coefficient of similarity; ** = least Jaccard's coefficient of similarity in the in communities of Hirmi woodland vegetation

4.11. Ethnomedicinal study

4.11.1. Diversity

A total of 85 medicinal plant species used to treat human and livestock ailments were collected and documented from the study area. These species belong to 78 genera in 47 botanical families. Among the families; the Fabaceae was the most species-rich with 9 species (10.6%) followed by Lamiaceae 7 (8.2%), Euphorbiaceae 6 (7.1%), Solanaceae 5 (5.9%), Asteraceae 3 (3.5%) and Cucurbitaceae 3 (3.5%). The remaining 30 (63.8%) and 11 (23.4%) plant families were represented by single and two species, respectively. Eighty-three medicinal plant species (97.6%) were used to treat human disease (Appendix 6) and 27 species (31.8%) were used to treat livestock ailments (Appendix 7). About 92.6% (25) of the medicinal plants used to treat livestock disease were also used to treat human ailments.

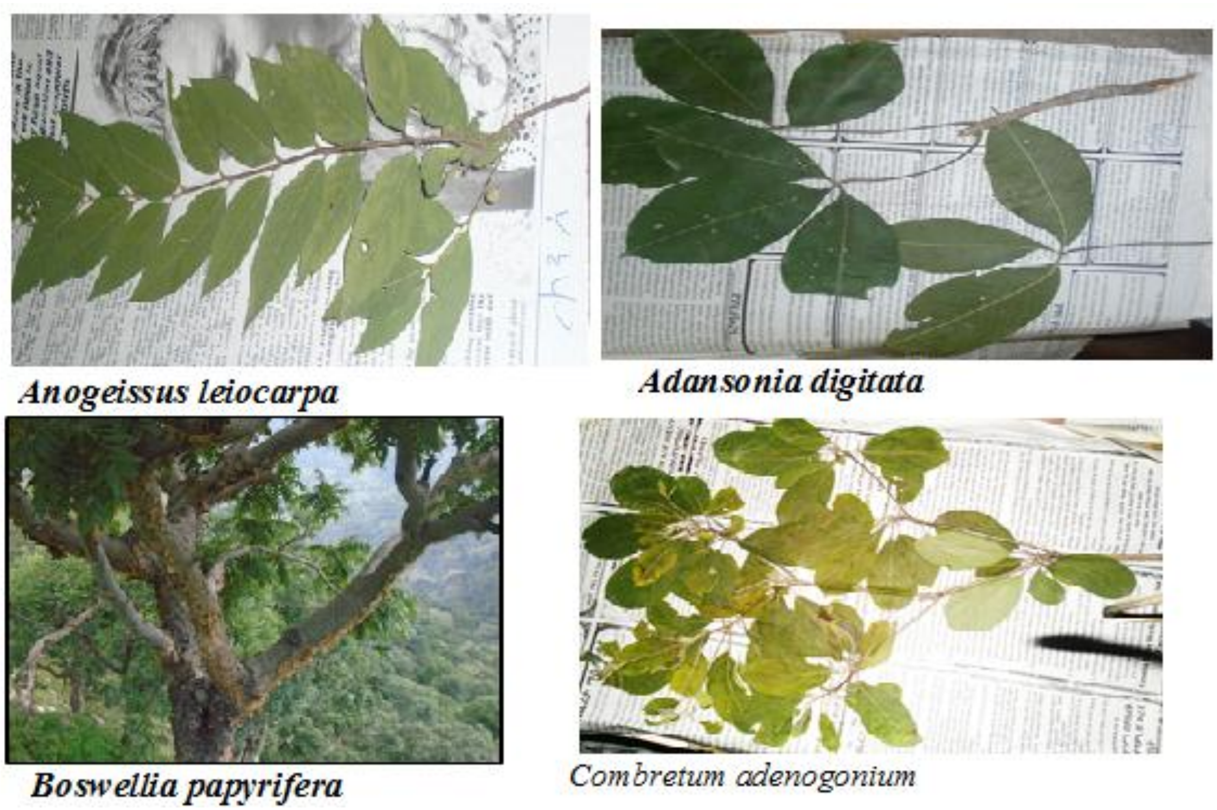


Figure 18. Some important medicinal plants in/from Hirmi woodland vegetation

4.11.2. Growth forms of medicinal plant species

Out of the total medicinal plants recorded from the study area, herbs comprised the largest category (34 species, 40%) followed by shrubs (30 species, 35.3%) and trees (21 species, 24.7%). Regarding the growth forms of medicinal plant species used to treat human ailments, herbs encompass 32 species (38.5%), shrubs comprised of 29 species (35%) and 22 species (26.5%) were trees. The most dominant growth forms of plants reported for treating livestock ailments were shrubs (14 species, 51.8%) followed by herbs (7 species, 25.9%) and trees (6 species, 22.2%)

4.11.3. Habitat of the medicinal plants

Communities in the study districts collect medicinal plants from their vicinity including cultivated land (homegardens and agricultural land) and the wild, mainly from the vegetation and common lands. The greater proportions of the medicinal plants (62 species, 72.9%) were collected from the wild environment (Hirmi vegetation). The remaining 23 (27.1%) species were collected from cultivated land. Almost all of the medicinal plants collected from the wild environment exist in the plots of the five community types in Hirmi woodland vegetation.

Regarding the medicinal plants used to treat human health, 61 (73.5%) species were collected from the wild environment whereas 22 (26.5%) species were collected from the cultivated land. Of the medicinal plants used to treat livestock diseases, 88.9% (24 species) were collected from the wild environment while 3 species (11.1%) were gathered from the cultivated land.

4.11.4. Plant parts used for medicine

The local inhabitants used different plant parts to prepare human and livestock remedies. About 14 plant parts were mentioned to prepare remedies to cure different ailments. Of these, the most common plant parts used for the preparation of remedies were leaves (33.1%) and roots (16.2%) followed by stem (12.5%), fruit (8.8%) and Bark (8.1%). The remaining plant parts used were described in the following Table 15.

Table 15. Used parts of medicinal plant species

Plant part used	Number of species used	Percent (%)
Leaf	45	33.1
Root	22	16.2
Stem	17	12.5
Fruit	12	8.8
Bark	11	8.1
Whole plant	7	5.1
Seed	4	2.9
Latex	4	2.9
Leaf and root	3	2.2
Leaf and bark	3	2.2
Young twig	3	2.2
leaf & fruit	2	1.5
Bulb	2	1.5
Rhizome	1	0.8

4.11.5. Modes of remedy preparation and application

Herbal medicines were prepared in diverse modes of preparation by the local people of the study area to treat both human and livestock ailments.

4.11.5.1. Modes of remedy preparation and application for human ailments

Twelve mode of remedies preparation and application to treat human disease were recorded in the study area (Figure 19).

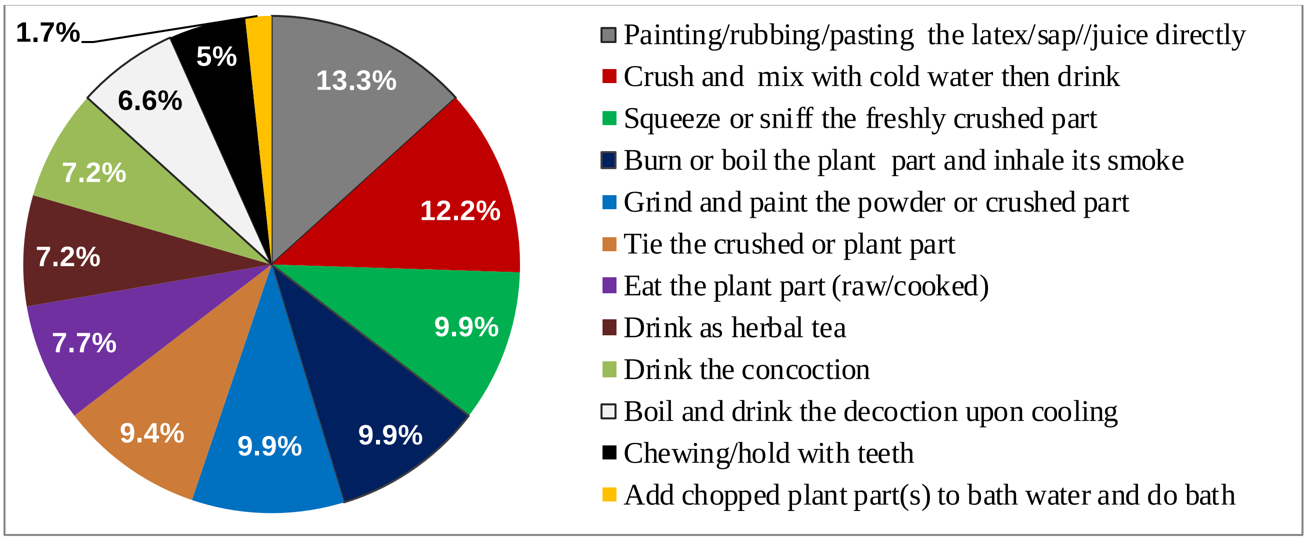


Figure 19. Methods of remedy preparation and application of medicinal plants used for human ailments

4.11.5.1. Modes of remedy preparation and application for livestock ailments

Eight (8) modes of remedy preparations and applications were detected to treat livestock ailments (Table 20).

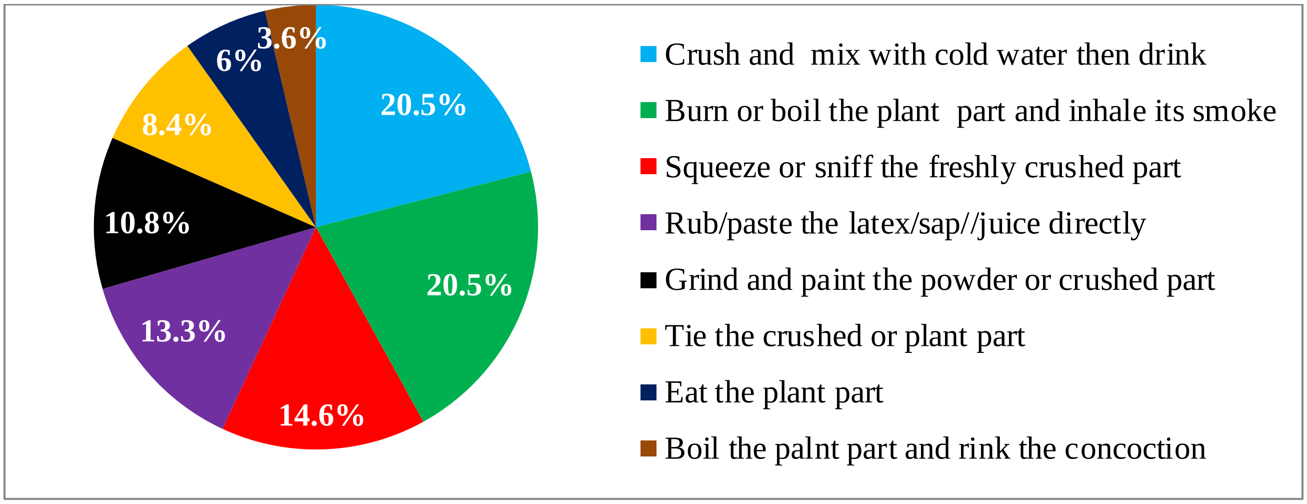


Figure 20. Methods of remedy preparation and application of medicinal plants used for livestock ailments

4.11.6. Dosages, antidotes and routes of remedy administration

There were inconsistent reports among the informants on the doses and measuring materials/ units for the medicinal plants that they use. However, estimated dosages were reported considering age, gender and pregnancy. Remedies were reported to be measured in coffee cups, water glasses, liters, handful or spoonful. Honey, water, milk and butter were the commonly used antidotes for herbal preparations in case they feel pains and for those species with adverse effects. However, none of the traditional healers and infromats reported any adverse side effects of the traditional medicinal plants. Few informants (4.5%) reported that few species including *Zingiber officinale, Datura stramonium* and *Phytolacca dodecandra* have temporal pain and body scars.

The six routes of administration for the medicinal plants reported in the present study were oral, dermal, nasal, optical and auricular. Of the routes of administration of remedies used against different human ailments in the traditional health care systems, oral application was the most common route of administration (84 preparations, 45.7%) followed by dermal (76 preparations, 41.3%), nasal (16 preparations, 8.7%), optical (5 preparations, 2.7%), tooth surface (2 preparations,1.1%) and auricular (1 preparation, 0.5%). Four routes of remedy administrations were commonly reported for livestock ailments. Of these the most common route of administration was via dermal (20 preparations, 54.1%) followed by oral (11 preparations, 29.7%), nasal (5 preparations, 13.5%) and optical (1 preparation, 2.7%) applications (Table 16).

Table 16. Routes of remedy administration (RA= Routes of Administration, NP= Number of preparations)

RA	RA for human		RA for livestock	
	NP	%	NP	%
Oral	84	45.7	11	29.7
Dermal	76	41.3	20	54.1
Nasal	16	8.7	5	13.5
Optical	5	2.7	1	2.7
Tooth surface	2	1.1	0	0
Auricular	1	0.5	0	0

4.11.7. Human and livestock ailments treated with medicinal plants

Seventy-one human ailments (Appendix 6) and 16 livestock ailments (Appendix 7) were identified as being treated with the use of medicinal plants recorded. Out of the reported human diseases, abdominal diseases were treated with the highest number of medicinal plants (12 species) followed by the evil eye, eye disease, headache, tooth disease/ache and wound which were all reported to be treated with 7 species each. Other ailments such as body swelling, blood pressure, evil spirits were mentioned to be treated with 6 species each and insect bite was reported to be treated by 5 species. Most (92.6%) of the medicinal plants used to treat livestock ailments were also used to treat different human diseases. Among the livestock ailments reported, skin diseases were treated via a high number of medicinal plants (7 species) prescriptions followed by that of wound (6 species), leech infection (4 species), ectoparasite (4 species) and anthrax (3 species). Species such as *Adansonia digitata, Citrus aurantiifolia, Phytolacca dodecandra, Plumbago zeylanica, Ricinus communis* were used to treat $\geq$ 5 ailments (Table 17).

Table 17. Plants prescribed for five or more disease types in the study area

Name species	Number of Diseased treated	Diseased treated
Adansonia digitata	6	Insect bite, poor drink appetite, Infant fever, stomachache, Infant diarrhea, Backbone ache
Citrus aurantiifolia	5	Cough, Headache, Tetanus, Blood pressure, Insect bite
Phytolacca dodecandra	6	Rabies, warts, Abortion, children's TB, Leech infection, Exo-parasite
Plumbago zeylanica	5	Tooth infection, stomach pain/diarrhea, skin swelling, ear problems, Evil sprit
Ricinus communis	5	Hemorrhoids, Wounds, dandruff, Giardiasis, amoebiasis

4.11.8. The most preferred medicinal plants to treat human ailments

According to the results of preference ranking (Table 18), the species most preferred for the treatment of abdominal disease (frequently reported human disease in the study area) are *Zehneria scabra, Plumbago zeylanica* and *Zingiber officinale.*

Table 18. Results of preference ranking of ten medicinal plants reported for treating abdominal disease (human ailments)

No.	**Medicinal plants**	**Informants labeled A to J**										**Total Score**	**Rank**
		A	B	C	D	E	F	G	H	I	J		
1	*Zehneria scabra*	7	3	8	8	10	7	9	10	10	10	**82**	**1st**
2	*Plumbago zeylanica*	9	2	9	7	4	10	10	9	9	8	**77**	**2nd**
3	*Zingiber officinale*	2	1	6	1	9	3	5	5	5	1	**72**	**3rd**
4	*Allium sativum*	10	8	7	6	3	9	8	4	8	9	**57**	**4th**
5	*Calpurnia aurea*	8	4	10	4	6	6	3	8	2	6	**53**	**5th**
6	*Datura stramonium*	5	7	2	9	2	4	7	6	6	5	**47**	**6th**
7	*Boswellia papyrifera*	6	9	1	10	1	8	2	7	1	2	**45**	**7th**
8	*Anogeissus leiocarpa*	1	5	4	5	5	5	4	2	7	7	**42**	**8th**
9	*Jasminum abyssinicum*	4	6	3	2	8	2	6	3	4	4	**38**	**9th**
10	*Gardenia ternifolia*	3	10	5	3	7	1	1	1	3	3	**37**	**10th**

4.11.9. Other uses of medicinal plants

The majority of the medicinal plant species used to treat both human and livestock were cited for one or more other uses in addition to the medicinal role. The proportion of medicinal plant species over different use categories is summarized in Figure 21.

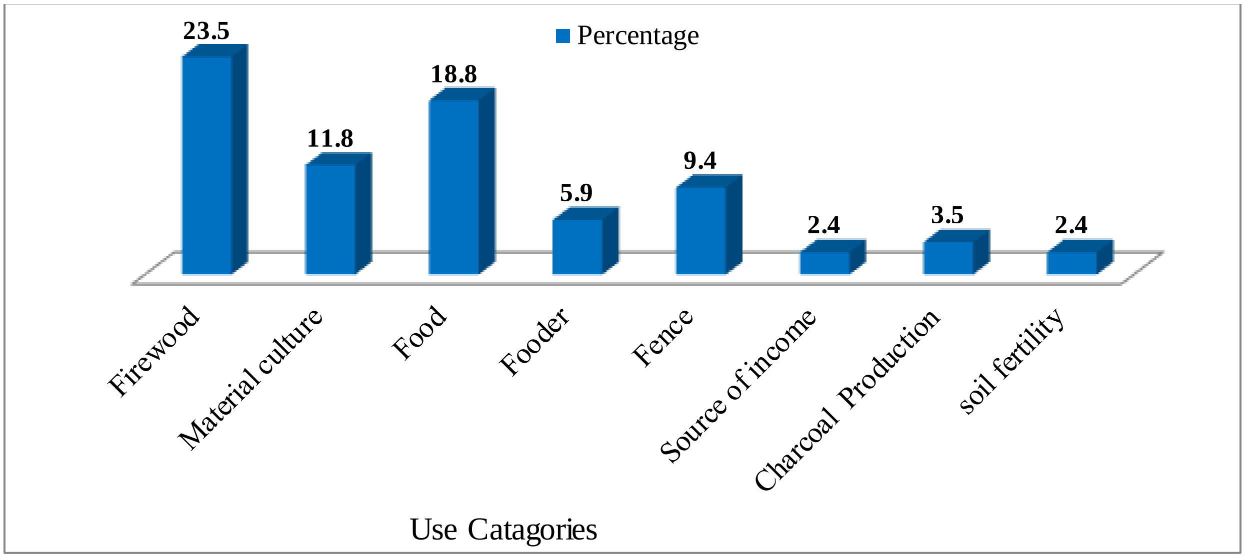


Figure 21. Other uses of medicinal plants in the study area

4.11.10. Source and transfer of indigenous knowledge on medicinal plants

About seven sources of indigenous knowledge on medicinal plants were reported (Table 19). Out of these, parents and grandparents were the main sources. The majority (> 80%) of the informants reported that the indigenous knowledge is transferred through oral secrecy from parents to one of the family members that fulfill their criteria. Other means of knowledge transfer reported include through friends or neighbors secretly.

Table 19. Sources of knowledge on the practice of traditional medicine

Source of knowledge	%
Parents	57
Grandparents	23.5
Friends	6.7
Neighbors	5.3
Husband/wife	4
Sister/Brother	2
Traditional healers	1.5

4.11.11. Threats to medicinal plants

The respondents distinguished more than two threats for the medicinal plants. Out of the eight recorded threats, the highest reported threats were overgrazing/browsing (20%), deforestation (19.1%) and expansion of agriculture (17.3%). Other reported threats were over-harvesting by humans (11.9%), lack of knowledge on the use and management (10.1%) of medicinal plants, drought (9.3%), firewood collection (6.9%) and charcoal production (5.4%).

4.11.12. Multipurpose plants

For the purpose of identification of plants that need conservation priority, ten key informants were requested to identify and rank seven threatened medicinal plant species with multipurpose uses. Accordingly, *Dodonaea angustifolia*, *Boswellia papyrifera* and *Gardenia ternifolia* were found as the most threatened species (Table 20).

Table 20. Direct matrix ranking of top seven multipurpose plants (Use category: MD = edicine; FW= fire wood; MC= Material culture; Fd= Fodder; Fe= Fence; CP = Charcoal Production)

Multipurpose medicinal plants	Use categories							
	FW	MC	MD	Fd	Fe	CP	Total	Rank
Dodonaea angustifolia	5	3	3	4	4	1	20	1st
Boswellia papyrifera	4	4	3	4	1	0	16	2nd
Gardenia ternifolia	5	4	2	4	0	0	15	3rd
Piliostigma thonningii	4	4	2	2	2	0	14	4th
Olea europaea subsp. cuspidata	4	5	1	0	2	1	13	5th
Adansonia digitata	5	5	2	1	0	0	13	5th
Clerodendrum myricoides	3	0	1	0	0	0	4	7th
Total Score	30	25	14	15	9	2	95	
Rank	1st	2nd	4th	3rd	5th	6th		

4.11.13. Management and conservation of medicinal plants by the local people

More than ten management and conservation techniques were reported from all respondents. Out of these, the six techniques that were highly cited by the respondents were; homegarden growing (24.2%), fencing (20.9%), plantation (17%), education (13.1%), efficient utilization (9.8%) and using alternative energy (8.4%). Few respondents 22 (6.6%) had no idea regarding the conservation methods of the medicinal plants.

4.11.14. Informant consensuses on most frequently used medicinal plants

4.11.14.1. Informant consensus on medicinal plants treating human ailments

Medicinal plants that are effective in treating certain diseases and are well known by community members also have higher informant consensus factor values. The 71 human diseases identified in the study area were grouped into 12 disease categories. As indicated in Table 21, the abdominal complaints related disease has the highest informant consensus value (0.95) whereas the category of diabetes and blood pressure scored the least informant consensus value (0.86).

Table 21. ICF values of traditional medicinal plants used for treating human ailments (ICF = informant consensus factor, n_{ur} = Number of use citation to each disease, category n_t = number of species used)

Diseases category	n_t	n_{ur}	ICF	Rank
Abdominal complaints related disease	12	206	0.95	1
Skeletal, bone disease, dental problem	7	98	0.94	2
Evil spirit, evil eye	8	120	0.94	2
Wound, External injuries/Sprain	8	119	0.94	2
Insect and snake bite	8	110	0.93	5
Problems of the respiratory system	9	114	0.93	5
Skin diseases, Ectoparasite	10	133	0.93	5
Eye disease	5	60	0.93	8
Headache	5	54	0.92	9
Fever, appetite loss, digestion problems	7	70	0.91	10
Elephantiasis, body swelling	7	48	0.87	11
Diabetes, blood pressure	4	23	0.86	12

4.11.12.2. Informant consensus of medicinal plants treating livestock ailments

The identified 16 livestock diseases were grouped into five major categories which were treated by the local medicinal plants in the study area (Table 22). The categories of dermal/skin disease and ectoparasite had the highest informant consensus factor value (0.89) followed by Wound (0.88), Problems of the Respiratory System (0.87), Leech infection (0.85) and Swelling/ Tumor (0.83).

Table 22. ICF values of traditional medicinal plants used for treating livestock ailments (ICF = informant consensus factor, n_{ur} = Number of use citation to each disease, category n_t = number of species used)

Diseases category	Nt	Nur	ICF	Rank
Dermal/skin disease, Ectoparasite	10	85	0.89	1st
Wound	9	70	0.88	2nd
Problems of the Respiratory System	7	48	0.87	3rd
Leech infection	5	28	0.85	4th
Swelling/ Tumor	4	19	0.83	5th

4.11.15. Distribution of indigenous knowledge on medicinal plants among the informants

There was a significant difference ($P < 0.05$) in the number of medicinal plants reported by young age groups (18-40 years) and elder age group (> 40 years), illiterate and literate informants, single and married informants, general and key informants (Table 23). High number of medicinal plants was reported by elders than younger age groups, illiterate than literate and key informants than general informants. Although gender and religion was not statistically exert a significant difference ($P > 0.05$) high numbers of medicinal plants were reported by men than women and Orthodox Christian followers than Muslims.

Table 23. Statistical test of significance, t-test, on the average number of reported medicinal plants among different informant groups (* = Significant difference (p<0.05)

Parameters	Informant groups	Number of respondents	Average ± SD	t-Value	P-value
Gender	Male	174	1.57 ± 0.5	2.9	0.15
	Female	171	1.38± 0.49		
Age	Youngster (18-40 years)	120	1.48± 0.50	-7.36	0.00*
	Elder (> 40 years)	215	1.89±0.32		
Educational status	Illiterate	256	1.52± 0.50	7.6	0.00*
	Literate	79	1.1 ±0.30		
Marital status	Single	112	1.52 ±0.50	-7.2	0.00*
	Married	223	1.91± 0.28		
Religion	Orthodox	307	1.24± 0.41	-2.3	0.22
	Muslim	28	1.14± 0.35		
Informants	General	315	1.0± 0.00	4.37	0.00*
	Key	20	1.16± 0.36		

CHAPTER FIVE

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. Discussion

5.1.1. Floristic composition and diversity of Hirmi woodland vegetation

About 95% of the study area was composed of *Combretum–Terminalia w*oodland and wooded grassland (CTW) and *Acacia-Commiphora* woodland and bushland (ACB) vegetation types. The remaining small part (approximately 5%) was Dry evergreen Afromontane forest and grassland complex (DAF) situated in the massifs and elevated parts. However, *Olea europaea* subsp. *cuspidata, Acacia abyssinica* and *Phytolacca dodecandra* were the only DAF characteristic species recorded in the study area. Furthermore, species including *Croton macrostachyus, Eulophia streptopetala, Erythrina abyssinica* and *Clematis simensis* were among the shared species between DAF and the woodland vegetation. The existence of different vegetation types in the study area could be due to: the habitat heterogeneity harboring different vegetation patches (Murphy and Lugo, 1986), altitudinal variations that bring changes in the availability of temperature and moisture (Tamrat Bekele, 1993; Körner, 2000) and disturbance factors that change the vegetation structure (Lyaruu *et al.,* 2000).

The species richness of the study vegetation is higher than that of woodland vegetation in Metema areas for which 87 species were recorded (Haile Adamu *et al.*, 2012) but the recorded species richness was less than that of the Ilu Gelan district *Combretum-Terminalia* mixed *Acacia Commiphora* woodland vegetation reported for 214 species (Zerihun Tadesse *et al*., 2018). The differences in species richness among these sites could mainly be attributed to the dissimilarities of the sites in terms of location, size of the vegetation, altitude and rainfall (Lovett and Wasser, 1993; Schmitt *et al*., 2013) as well as the degree of disturbances (Bongers *et al*., 2009). On the other hand, the species richness of the study area was equivalent to Dello Menna woodland vegetation with 171 species (Motuma Didita *et al*., 2010). This might associate with altitudinal similarities among the sites (Friis *et al*., 2010; Schmitt *et al*., 2013).

Regarding with growth form analysis, herbaceous species were abundant. This might be associated with the open canopy cover of the vegetation that enabled their free growth (Murphy and Lugo, 1986). Anthropogenic impacts such as exploiting plant products and selective cutting of trees (Ermias Lulekal *et al.,* 2008; Haile Yineger *et al.,* 2008a) and dominance of shrubby species in dryland area (Mulugeta Lemenih and Bongers, 2011) were also reported as responsible factors for dominant growth of herbaceous species in an area. More than half (54.5%) of the total recorded plant families were represented by single species which indicates the diversity of species in the study vegetation. High number of species were recorded in the families Fabaceae, Poaceae and Asteraceae confirming the fact that they are species-rich families in the Flora Ethiopia and Eritrea (Mesfin Tadesse, 2004). The successful dispersal mechanisms, the presence of different growth forms and better adaptation mechanisms to various environments contributes to the species richness in the family Fabaceae (Hedberg, 1964; McKey, 1994). Besides, Sprent (2001) stated that the unique feature for the adaptability and diversity of the family Fabaceae in a given ecosystem is due to the ability of nitrogen fixation even in rainfall erratic habitats (dryland areas). On the other hand, the presence of rich species in the families Poaceae and Asteraceae could be due to the diverse dispersal mechanisms (via insect, wind, bird and water) and pollination mechanisms (self & cross) (Hedberg, 1964; Hirsch *et al.,* 2012) and the ability to cope in association with other plant species (Levick *et al.,* 2015).

The compositions of new record species (about 10% of the total) to the floristic region implies the plant species from Hirmi woodland vegetation, North-Western Zone of Tigray Region were not exhaustively recorded and collected. The lack of access might be the factor for the inadequately surveyed of the floristic region or/and study area. Hence, this study has a significant input to enrich the documentation of the Flora of Ethiopia and Eritrea.

Out of the recorded endemic species, *Acacia venosa* has been included in the IUCN red list of Ethiopia and Eritrea as critically endangered (Vivero *et al.,* 2005) whereas *Albizia malacophylla, Combretum hartmannianum* and *Combretum rochetianum* are assessed as vulnerable species. This could be associated with the existing significant anthropogenic and livestock impacts as observed during the study survey. The dryland vegetation types (CTW, ACB and DAF) in Ethiopia are currently under strong environmental stress (Friis *et al.,* 2010). An ecosystem approach of biodiversity conservation and participatory forest management provides an opportunity to conserve large number of species that are rare and endemic (Ermias Aynekulu 2011; Mulugeta Lemenih and Bongers, 2011).

The Shannon diversity index and evenness of Hirmi woodland vegetation were 3.86 and 0.92 respectively. This depicts the vegetation has high species diversity with more even distribution of the species within the study plots. The observed topographic variation (elevation: 1098-2002 m and slope: 0-75%), different vegetation paths (CTW, ACB and DAF), community types could be contributed to the high species diversity and evenness (Friis *et al.*, 2010; Kent, 2012). In line with this analysis, Suratman (2012) reported that differences in terrain variables cause differences in the soils, water and microclimate conditions, which brings a significant impact on species diversity and adaptability. Magurran (2004) has also stated that species diversity and evenness in an area could be attributed due to the existed species richness in a given area. The Shannon diversity index and evenness value of the study area was higher than that of reported in other woodland areas such as Metema (H'= 3.55 and J=0.63; Haile Adamu *et al.,* 2012) and Arero-Borena (H' = 2.67 and J'=0.79; Wakshum Shiferaw *et al*., 2018). The variations in the level of climatic components and environmental gradients have a significant role for the variation of diversity and evenness (Maguran, 1988; Kharkwal *et al*., 2005).

5.1.2. Plant Communities

The existed high species diversity in the study vegetation forms different community types. Environmental factors such as altitude, slope and soil properties together with disturbance factors might contribute to the community formations (Whittaker *et al,* 2003). Both species dominance and indicator species are important to name the plant communities (Kent, 2012). Accordingly, the five plant communities are discussed here below:

Community types of *Ziziphus mucronata* - *Acacia polyacantha* and *Combretum hartmannianum* - *Terminalia macroptera* - *Oxytenanthera abyssinica* were comprised relatively least species compositions. The fact that the communities' location in/around the edge and flat slope of the study area (easily accessible by human and livestock) was the reason for the existing high disturbance which resulted in the least species richness. Besides, these community types have relatively open canopy, which encourages the growth of grasses and other herbaceous vegetation resulting in various levels of grazing intensity (Bongers *et al*., 2009; Goiteom Woldu *et al.,* 2019). High populations of *Ziziphus mucronata* and *Acacia polyacantha* mainly dominated for the *Ziziphus mucronata* - *Acacia polyacantha* community. The edibility of *Ziziphus mucronata'*s fruit and the versatile use of *Acacia* *polyacantha* (charcoal production, firewood, medicinal value and material culture) probably aggravate the disturbance in this community type. *Combretum hartmannianum - Terminalia macroptera - Oxytenanthera abyssinica* community was dominated by various species of *Combretum* and *Terminalia* including *Oxytenanthera abyssinica*. The local community used different timber products from *Combretum* and *Terminalia* species as well as *Oxytenanthera abyssinica* for different material cultures might be contributing to the observed disturbances. Kacholi (2014), Leul Kidane (2015) also reported similar findings.

Anogeissus leiocarpa - Ozoroa insignis community was found with the most species rich and diverse community. The location of the community in a steep slope (most of them > 40%) and far from the edge might contribute to less accessibility of the community type by humans and herbivores. This attributes to comprise relatively rich species and less signs of disturbances. This community also harbors relatively high number of medicinal plants. High species richness of the community contributes to the high species diversity and implies its conservational roles (Magurran, 2004). *Euclea racemosa - Acacia abyssinica* community was accompanied by the highest Shannon evenness index and second most species-rich and diverse. This could be associated with the high altitudinal difference (1405-2002 m.a.s.l.) between the plots of the community makes to harbor all representative sample plots and species from all altitudinal ranges. Altitudinal difference does not only influence the species richness and diversity but also affects the other determinants which play a significant role in species distribution and composition, including factors like soil texture, atmospheric pressure, moisture and temperature (Tamrat Bekele, 1994; Lovett & Wasser, 1993). Few species belong to the DAF vegetation types (*Olea europaea* subsp. *cuspidata*, *Acacia abyssinica* and *Phytolacca dodecandra*) were found in the elevated (>1980m) part of the community, i.e. in line with the study of Friis *et al*. (2010).

Dodonaea angustifolia - Flueggea virosa community was dominated by the population of *Dodonaea angustifolia, Flueggea virosa* and *Euclea racemosa*. However, there were extreme impacts such as selective harvest, firewood and charcoal production signs in most plots of the community. This is strongly associated with close vicinity to human settlement and Debrekerbe town that demands firewood and charcoal to satisfy their livelihood. The abundance of shrubs like *Dodonaea angustifolia* and *Euclea racemosa* in the extensive dry landmass of the Ethiopia area could be associated with human induced environmental degradations (Mulugeta Lemenih, 2011; Goiteom Woldu *et al.,* 2019). This is due to these species can easily adapt to degraded environments and harsh conditions (Reubens *et al.*, 2011). Thus, the dominance of these species in this community might be related to the observed various disturbance signs.

The distribution of various medicinal plant species in each community types of Hirmi woodland vegetation indicates the importance of the plant communities in harboring of various medicinal plants. Conservation of these plant community types gives an opportunity to rescue and use sustainably for the existed medicinal plants.

5.1.3. Species composition similarities between plant communities

The high similarity of species composition between community 1 (*Ziziphus mucronata* - *Acacia polyacantha*) and Community 2 (*Combretum hartmannianum* - *Terminalia macroptera* - *Oxytenanthera abyssinica*) was due to the fact that the plots of these communities were in adjacent and laid on similar topography. The lowest (1098 m.a.s.l) and highest elevation (2002 m.a.s.l) of the study vegetation were found in community 2 (*Combretum hartmannianum* - *Terminalia macroptera* - *Oxytenanthera abyssinica*) and 4 (*Euclea racemosa* - *Acacia abyssinica*), respectively. Thus, the least Sorensen's similarity coefficient was recorded between these communities. The higher number of shared species between communities might show that the plots of the two communities were found in a relatively similar environment and a narrow geographical distance whereas those communities reported for the least similarity of species composition reveals the high topographic differences between the communities (Condit *et al.*, 2002; Schmitt *et al.*, 2013).

5.1.4. Plant Communities and their relationship with the environment

The CCA analysis result showed that environmental variables including altitude, slope, silt, sand, soil organic matter, total Nitrogen and disturbances were associated with species compositions of plant communities in the Hirmi woodland vegetation. However, all the investigated environmental determinants exhibited different effects on the five identified communities. According to a study by Brinkmann *et al.* (2009), plant community has its distribution area specific to combination of various environmental variables. In ordination, an axis with high eigenvalue (tends to 1) implies the importance of the axis for species distribution (Legendre and Legendre, 2012). Axis 1 was with the highest eigenvalue (0.94) that is reflected mainly by altitude. This could be due to the fact that the continuous change of environmental determinants along the altitudinal gradient that directly influence the growth and development of plant species (Hedberg, 1964; Lovett and Wasser, 1993). Other studies in Ethiopia (Kumelachew Yeshitila and Tamrat Bekele, 2002; Haile Yeneger *et al.*, 2008b; Ermias Aynekulu, 2011) also states that the importance of altitude as a major determinant of vegetation distribution.

Ziziphus mucronata - Acacia polyacantha and *Combretum hartmannianum - Terminalia macroptera - Oxytenanthera abyssinica* community types experienced disturbances and were positively influenced by total Nitrogen and sand. The existences of anthropogenic and animal disturbances in these communities were due to the fact that plots of these communities were found very close to the human settlements and farmlands. Thus, the highest content of Nitrogen in these communities might be associated with the leaching of fertilizers (Peri *et al.,* 2019) from the nearby farmlands and frequently revealed animal manure (Zanine and Ferreira, 2015). Nitrogen content of the soil has been reported as a major factor limiting species growth and diversity (Brown, 2003). On the other hand, the highly aerated nature of sandy loam soil in these communities has an important role in the growth of plants (Prasad and Power, 1995). *Anogeissus leiocarpa - Ozoroa insignis* community was the most species rich community which was highly correlated with soil organic matter, silt and slope. The presence of high species richness in this community boosts the formation of litter or humus, which is the source of soil organic matter (Rasse *et al.*, 2006). As a result, this community was with high soil organic matter and with a moisture-holding capacity of the silt loam soil type favors for species growth (Baer *et al.*, 2003; Brown, 2003; O'Geen, 2006). The location of the community at steep slopes could be a factor for the existed less disturbances which is in line with studies conducted elsewhere in Ethiopia (Abiyou Tilahun *et al.,* 2011; Kflay Gebrehiwot *et al.,* 2019).

In the ordination axis, altitude was strongly correlated with *Euclea racemosa - Acacia abyssinica* community. The possible reasons for this result could be due to plots in this community were distributed at a high altitudinal range (1405 - 2002 m.a.s.l.). Furthermore, this community was found positively correlated with slopes but negatively correlated with total Nitrogen and disturbance. The observed very steep slope might be a factor for the formation of shallow soils and/or the erosion of the upper soil (rich Nitrogen content) and relatively impede from disturbances (Bongers *et al.*, 2009; Wang *et al.*, 2016). The community type *Dodonaea angustifolia - Flueggea virosa* was positively correlated with silt loam soil and impacted by various disturbances. Despite the existed silt loam type of soil contains a modest combination of sand, silt and clay particles that support the growth of virtually all forms of plant life (Sheunesu, 2018), the community was impacted by various disturbances and degradations. Only a population of few species mainly *Dodonaea angustifolia* and *Euclea racemosa* were abundant. This might be associated with the feature of these species to cope even with degraded, rocky and shallow soils (Tesfaye Bekele, 2000; Getachew Tadesse *et al.*, 2008).

5.1.5. Vegetation structure of Hirmi woodland vegetation

Vegetation structure of the study vegetation was analyzed by considering the growth form, height, DBH, density, basal area, vertical structure, frequency, Importance Value Index of the plant species.

Herbs and shrubs were the dominant growth forms in the study area. In northern Ethiopia, because of high anthropogenic disturbance, the natural forest patches are being converted into shrubland (Darbyshire *et al.*, 2003; Mulugeta Lemenih and Bongers, 2011). Such disturbances create gaps in the canopy and boost the growth of herbaceous species in the vegetation (Murphy and Lugo, 1986; Ermias Lulekal *et al.*, 2008; Haile Yineger *et al.*, 2008a).

The overall DBH and height class distribution showed an inverted J-shape distribution. The existence of a high number of species at the lower DBH and height classes was due to the dominance of a small-sized but large number of individuals including *Dodonaea angustifolia, Flueggea virosa, Maytenus arbutifolia, Acokanthera schimperi, Bersama abyssinica*, *Ziziphus mucronata* and *Ximenia americana*. The observed disturbance factors such as overharvesting of large-sized trees for their timber product could be the reason for the inadequate large statured trees (Gebremedhin Hadera, 2000; Zerihun Tadesse *et al.*, 2018). The *Combretum - Terminalia* species in Northern Ethiopia are under extreme exploitation because they are desirable for timber products by the local communities (Ensermu Kelbessa and Abenet Girma, 2011). On the other hand, in dryland regions, most of the plant species are short in height due to environmental and genetic factors (Newton, 2007). Similar findings were also reported in Abergele dry woodlands (Abeje Eshete *et al.*, 2011), Hallideghie wildlife reserve (Ahmed Endris *et al.*, 2017), Dawsura – Tembien woodlands (Goiteom Woldu *et al.*, 2019) and Ilu Gelan *Combretum-Terminalia* and *Acacia* vegetation (Zerihun Tadesse *et al.*, 2018).

Based on the Lamprecht (1989) vertical stratification scheme, the highest proportions of species were found concentrated in the lower story followed by the middle and upper story. The result might be associated with the abundance of shrubby and small-sized species in the study area. The poor moisture content in dryland regions can affect the physiognomy of plant species (Newton, 2007). According to Kent (2012), environmental determinants particularly precipitation can modify the vertical structure of the vegetation. Besides, the existing human/livestock disturbance can cause the replacement of large sized (height) woody species by small-sized species (shrubs) and regeneration of secondary young plants. This finding was in agreement with the study by White (1983), Abeje Eshete *et al.*, 2011), Mulugeta Lemenih and Bongers (2011) and Zerihun Tadesse *et al.* (2018).

The overall density of woody species was 528.4 stems per hectare. About 40% of the total density was covered by few (10) species including *Dodonaea angustifolia, Flueggea virosa, Diospyros mespiliformis, Anogeissus leiocarpa, Ziziphus mucronata, Combretum hartmannianum, Maytenus arbutifolia, Ximenia americana, Acokanthera schimperi* and *Acacia polyacantha* indicating the dominance of these species in the study vegetation. The present study area has relatively higher density than other woodland vegetation studied by Haile Adamu *et al.* (2012) in Metema areas, Ethiopia (18.8 stems/ha). However, it was less than the density reported for the woodland vegetation of the Borana lowland (3,149 stems/ha) (Gomedo Dalle, 2004), dry land vegetation of Welo (3,146 stems/ha) (Getachew Tadesse *et al.*, 2008) and Shai Hills dryland in Ghana (959/ha) (Swaine *et al.*, 1990). Such variations could be attributed to variations in topographic gradients, size of the woodlands, habitat preferences and the degree of anthropogenic disturbances (Whittaker *et al.,* 2003).

The total basal area of the study vegetation for plant species with DBH > 2 cm was 14 m^2/ha. More than 50% of the total basal area of the vegetation was contributed by ten large-sized tree species including *Anogeissus leiocarpa, Acacia polyacantha, Combretum hartmannianum, Terminalia macroptera, Ziziphus mucronata, Terminalia laxiflora*, *Diospyros abyssinica, Ficus ingens*, *Ozoroa insignis* and *Diospyros mespiliformis*. However, the numbers of the above tree species were far less than the shrubby species in the study area. An area dominated with shrub layers and small DBH individuals would have a small total basal area contribution in contrast to tree species (Murphy and Lugo, 1986; Mulugeta Lemenih and Bongers, 2011). Moreover, the size of woody species in dryland area are small in nature (Ahmed Endris *et al*., 2017; Moses *et al.*, 2020), which could be associated with ecological constraints (moisture deficit and high temperature) and/or anthropogenic disturbances (Debissa Lemessa, 2009). These factors might be contributed to the small basal area of the study vegetation. Thus, the basal area of the study area was less than the normal basal area value for virgin tropical forests in Africa (23-37 m2/ha) (Lamprecht, 1989). It was also less than Sire Beggo woodland (19.3 $m^{2/}$ha) (Abyot Dibaba, 2014) and *Combretum-Terminalia* mixed *Acacia* vegetation in Ilu Gelan district (18.96 $m^{2/}$ha) (Zerihun Tadesse *et al*., 2018). However, basal area of the study vegetation was greater than the basal area of other vegetation types such as Taltalle woodland (0.44 m^2/ha) (Debissa Lemessa, 2009) and Hallideghie wildlife reserve (0.99 m^2/ha) (Ahmed Endris *et al*., 2017). Such variations could be related to the variation of individual species in DBH and density among the study sites.

The frequency distribution of woody species showed that more than 59% of species were found in the lower frequency (frequency class 1). This indicates the heterogeneous species composition of the study vegetation (Lampriecht, 1989). *Anogeissus leiocarpa, Combretum hartmannianum, Terminalia macroptera, Ziziphus mucronata* and *Ziziphus spina-christi* were among the species with high frequency values whereas *Phoenix reclinata, Phytolacca dodecandra, Olea europaea* subsp. *cuspidata, Acacia nilotica andCordia africana* had small frequency values. Species with high frequency value indicates the relatively good distribution status and these with low value of frequency implies the rare/poor distribution status of the species in the vegetation imply the need of either *in situ/ ex situ* conservation approach (Zerihun Tadesse *et al.*, 2018). The frequency of a species always depends on factors that relate to habitat preferences, adaptation, degree of exploitation and availability of suitable environmental conditions for regeneration (Rey *et al.*, 2000).

In the study vegetation, *Anogeissus leiocarpa*, *Combretum hartmannianum*, *Ziziphus spina-christi*, *Terminalia macroptera*, *Acacia polyacantha*, *Flueggea virosa* and *Dodonaea angustifolia* were among the top ten species with the highest IVI value. The highest IVI values reflect the extent of dominance, occurrence and abundance of a given species in relation to other associated species as well as the ecological significance of a given species in an area (Kent, 2012). Of these species with high IVI *Anogeissus leiocarpa*, *Acacia polyacantha*, *Combretum hartmannianum* and *Terminalia macroptera* were used for various timber products, *Dodonaea angustifolia* and *Ziziphus spina-christi* used for their medicinal value whereas fruit of *Flueggea virosa* is edible by the local community. On the other hand, *Cordia africana, Olea europaea* subsp. *cuspidata*, *Otostegia fruticosa*, *Phytolacca dodecandra*, *Buddleja cordata* and *Acacia nilotica* were found rare and restricted to some sites of the study vegetation with least IVI score (< 0.5 each). The possible reason can be due to either these species require distinctive habitat/microclimate that favors their distribution or they are under selective harvesting for various uses. For instance, species including *Cordia Africana*, *Phytolacca dodecandra* and *Olea europaea* subsp. *Cuspidata* are prefered by the community for their medicinal values. The IVI of species ranged from 0.35 to 20.55. The variability of IVI values attributes to the conservation status of the species. Species found frequently and dominantly (higher IVI) require wise/sustainable conservation whereas those found rarely (low IVI) needs urgent conservation efforts. Species with high IVI in the present study were different from other woodland vegetation studied in Dello Menna woodland (Motuma Didita *et al.*, 2010), dry land vegetation of Welo (Getachew Tadesse *et al.*, 2008). However, there were some similarities with a species found in woodland vegetation of Metema and Abergele dry woodlands (Abeje Eshete *et al.*, 2011) and Dawsura-Temben (Goiteom Woldu *et al.*, 2019). These similarities or differences in species composition could be attributed to the geographical vicinity (Terborgh and Andresen, 1998; Whittaker *et al.*, 2003) as well as climate affinities (Schmitt *et al.*, 2013).

5.1.6. Regeneration status of Hirmi woodland vegetation

Information on the density of seedlings and saplings is always important to take conservation measures based on the regeneration status of plant species (Khumbongmayum *et al.*, 2006). In this study, the density of saplings was higher than the density of the seedlings and mature trees/shrubs. Accordingly, the regeneration status of the vegetation is categorized as poor following the assessment methods set by Khan *et al.* (1987). This might be associated with the observed human and livestock induced disturbance factors. Furthermore, the location of the study vegetation in a steep area leads to having a shallow soil depth, which may cause difficulties for the seedling germinations.

The land use land cover dynamics study conducted by Tsehaye Gebrelibanos and Mohammed Assen (2015) and Land use land cover mapping done by GIZ (2014) in or/and around Hirmi woodland vegetation indicated that human settlements around the present study area were restricted to mountainous landmasses before 50s years ago. However, the rapid human population growth from time to time imposed them to settle in lowland areas for the demand of large farmland as well as plant and plant products. Thus, the massive inhabitation of humans and livestock in these areas brought huge deforestations and environmental degradations, which could be caused for the poor regeneration of species. Vieira *et al.* (2007) also argued that disturbance factors such as logging increases canopy openness and decrease environmental humidity. However, seedlings favor humidity for their survival and growth. As a result, the overall regeneration status of woody species were poor and many species were represented with few or no seedlings or saplings. Moreover, species including *Acacia nilotica*, *Clerodendrum myricoides*, *Cordia africana*, *Justicia schimperiana*, *Phoenix reclinata* and *Phytolacca dodecandra* had no seedlings and saplings. This could be associated either with revealed frequent disturbance signs or other environmental determinates such as edaphic and climate factors. Studies conducted elsewhere in Ethiopia also shows that the dryland vegetation is characterized by poor and fluctuating patterns of regeneration status due to periodic disturbances such as grazing, fire and removal of trees (Dagnew Yebeyen, 2006; Getachew Tesfaye, 2008 Mulugeta Lemenih and Bongers, 2011). The poor regeneration status of species in a given ecosystem could be also associated with the habitat preference of the species (Whittaker *et al.,* 2003). Thus, the presence of species with no seedlings or/and saplings implies these species might be on the verge of local extinction and require imperative conservation measures and research programs focus on these species.

5.1.7. Soil Seed bank

5.1.7.1. Species composition in the soil seed bank

Soil seed bank study has a significant role to manage and restore or establish native species in a given vegetation (van der Valk and Pederson, 1989). The soil seed bank result depicted that land use types of the study area have variations in their species composition. High species compositions were recorded in the soil seed bank sampled from shrubland whereas the least species composition were recorded in soil seed bank samples taken from bare land. This might be associated with the absence or presence of standing vegetation in the vicinity and observed disturbance intensities (Reubens *et.al.,* 2007). The poor standing vegetation and degradations in bare land could be the factor for the least species composition in relation to other land uses (Wang, 2013).

The dominance of herbaceous species over woody species in the soil seed bank could be due to the smallness of the seeds of most herbs and their easy dispersal by different mechanisms (Yohannis Teklu, 2014). The ability of herbaceous seeds to resist disturbance factors (via easy incorporation into the soil) could also be the reason for the abundance of herbaceous seedlings in the soil seed bank (Demel Teketay, 2005b). In contrast, the seeds of woody species including *Syzygium guineense, Diospyros mespiliformis, Euclea racemosa* and *Rhus retinorrhoea* apparently had poor long-distance dispersal with large and recalcitrant nature of the seeds that easily rot, heavily predated, decompose rapidly before emerging a seedling (Rico-Gray and Garcia, 1992 and Eyob Tenkir, 2006). Besides, the poor regeneration potential of woody species in the dry area could probably be due to the existing overexploitation as well as the long dry season in the ecosystem (Demel Teketay and Granström, 1995). This means seeds in such areas require a long period of dormancy that contradicts with features of seeds of woody species (Shen *et al.*, 2007). The other possible reason might be woody plants use seed rain or coppicing from stumps, as alternative regeneration routes (Feyera Senbeta and Demel Teketay, 2002). About 32.8% of the total species recovered from the soil seed bank belongs to the family Poaceae. The abundance of the family Poaceae might be associated with the dominance of the family in the aboveground of Hirmi woodland vegetation, its ability to disperse itself in a wide range of ecosystems, ability to adapt to harsh conditions and ease of association with other populations (Levick *et al.*, 2015).

Regarding the vertical distribution of seedlings, the highest density was recorded in the litter layer and the least species density was found in the lowest layer (6-9 cm). The availability of organic nutrients which helps for the seed germination and recruitment favor (Rey *et al.,* 2000; Godefroid *et al,* 2006) as well as the intensity and quality of sunlight reaching (stimulate seed germination) of the upper soil layer could be the reasons to comprise high seed density (Facelli and Pickett, 1991). The ease of burial activity and dispersal diversity of herbaceous species has resulted in presence of high seedlings in the upper soil layers (Hedberg, 1964; Bekker *et al.*, 1997; Qiuyan *et al.*, 2011). Thus, seedlings of many herbs including *Crotalaria goreensis*, *Crotalaria onobrychis*, *Plantago lanceolata*, *Leonotis ocymifolia* and *Harpachne schimperi* were found only in the litter whereas that of *Desmodium repandum, Digitaria abyssinica, Hibiscus crassinervius, Nicandra physaloides* and *Oldenlandia herbacea* were confined to the first layer (1-3 cm). On the other hand, seedlings of few woody species including *Diospyros mespiliformis, Euclea racemosa* and *Syzygium guineense* were distrubuted in all soil layers. This might be due to the fact that seeds of these species possess a hard seed coat which enables them to remain inside the soil for an extended period of time until conditions become favorable for germination (Bekker *et al.*, 1998; Ferrandis *et al.*, 1999). In contrast to this result, a study by Lei *et al.* (2019) showed that seedling density increased with soil depth. This may be due to less probability of disturbance in the lower layers and the presence of more water and nutrients than in the upper soil. However, in drylands such as the present study areas, moisture and nutrient contents are a limiting factors (Thomas *et al.,* 2006), which imposes to have less density of seedlings in the lower soil layers.

In the case of land use types, shrubland and forest have the highest seedlings density. This might be due to the relative potential of the shrublands and forest to maintain moisture content as well as soil fertility which supports seedling growth (Koprdova *et al.*, 2010). On the other hand, the reason for the least species composition in the bare land could be the deficiency of soil nutrients and organic matter that support the growth of plant species (Snyman, 2003; Wang, 2013). This could emanate from the observed environmental degradation and man-induced disturbances.

5.1.7.2. Similarity in species composition among land use types

Out of 58 species recorded from the soil seed bank; *Oldenlandia herbacea, Jasminum abyssinicum, Setaria pumila, Syzygium guineense* and *Trifolium campestre* were found in all land use types of the study area. Probably, this would be in relation to seed longevity in the soil, their ability to resist different harsh environmental conditions and abundantly found aboveground (Halfiges, 1990; Feyera Senbeta and Demel Teketay, 2001). The Jaccard's coefficient of similarity exhibit, the highest similarity was between the seedlings that emerged in the soil seed banks sampled from forest and shrubland. This could be due to the existence of several above-ground species shared between both land use types. However, the least similarity between the seedlings restored from the forest and bare land indicates the variations of soil fertility and above-ground species in those land use types (Amiaud and Touzard, 2004; Snyman, 2003). Disturbance intensity could also be the factor for the similarity or variations of species composition among the study land use types (Mulugeta Lemenih and Demel Teketay, 2005; Eyob Tenkir, 2006; Yohannis Teklu, 2014).

5.1.7.3. Soil seed bank and its implication for rehabilitation and conservation

The presence and absence of viable seeds in soil is an important feature that implies the restoration potential of the plants to conduct conservation measurements (Demel Teketay, 2005b). In all land use types, seedlings of herbs were found abundant and at good regeneration potential. This indicates herbaceous vegetation has a better chance of recovery than woody species since it produces numerous seeds with great seed longevity and easily incorporate into soil (Alemayehu Wassie, 2007).

On the contrary, only a few (8) seedlings of woody species including *Croton macrostachyus, Diospyros mespiliformis, Dodonaea angustifolia, Euclea racemosa, Jasminum grandiflorum, Rhus retinorrhoea, Syzygium guineense* and *Woodfordia uniflora* appeared in the soil seed bank sampled from all land use types. This implies that woody species have poor regeneration potential and their restorations are not relying on the soil seed bank. This might be associated with the existence of various disturbances such as selective harvesting and grazing in the study area (Demel Teketay, 2005b; Reubens *et al.,* 2007). On the other hand, the least density of woody species in the seed bank is probably due to short viability and no dormancy features of the seeds (Demel Teketay and Granstrom, 1995). The large seed masses of woody species have the tendency to be easily rotten or germinate soon after seed fall (Daws *et al.,* 2005) could be the other reason factor for the poor restoration potential of woody species in the sampled soil seed bank. Similar findings were reported in other soil seed bank studies in Ethiopia (for example, Demel Teketay and Granstrom, 1995; Kebrom Tekle and Tesfaye Bekele, 2000; Feyera Senbeta and Demel Teketay, 2001; Mulugeta Lemenih and Demel Teketay, 2006; Yohannis Teklu 2014). Thus, planting of indigenous seedlings, preserving the standing woody species and setting an averting mechanism for those threats would be important for the restoration of woody species and species with limited seeds in the soil seed bank (Godefroid *et al.*, 2006; Eshetu Yirdaw, 2014). This is also operating for the land use type with poor seedlings density (bare lands) to overcome its poor regeneration potential.

5.1.8. Ethnomedicinal study

5.1.8.1. Ethnomedicinal plant Species

The ethnomedicinal study result showed that there are 85 medicinal plants used to treat various ailments. This indicates people in the study area have a tradition of using diverse plants as herbal medicine for themselves and their livestock. Ease of accessibility, economic, cultural acceptance and efficacy related aspects have played key roles for the people to rely on traditional medicine (Ermias Lulekal, 2014). The number of medicinal plants species recorded in the study area were higher than those reported elsewhere in Ethiopia such as in Aba'ala district (58 species; Misganaw Meragiaw, 2016), Asgede Tsimbila districts (68 species; Girmay Zenebe *et al.,* 2012), Gemad district (31 species; Kalayu Mesfin *et al.,* 2013), in and Around Alamata (16 species;

Gidey Yirga, 2010). However, it was less compared to studies conducted in Ankober (151 species; Ermias Lulekal, 2014), Central Zone of Tigray (129 species; Gebrekidan Abrha *et al.*, 2018), Kilte Awlaelo (114 species; Abraha Teklay *et al.*, 2013), South Omo (91 species; Ketema Tolossa *et al.*, 2013). The variation in the number of reported medicinal plants of the study area with other parts of the country, possibly associated with cultural use and perception difference among the study communities(Masika and Afolayan, 2003; Akhagba, 2017) as well as the variations of the plant used among different groups (Avocevou-Ayisso, 2011; Alemtshay Teka, 2020).

The families Fabaceae, Lamiaceae, Euphorbiaceae and Solanaceae comprise a high number of medicinal species in the study vegetation. These families are also with higher numbers of species that have wide geographical and habitat distribution in Ethiopia (Mesfin Tadesse, 2004). This result was in alignment with a study conducted in Asgede Tsimbila (Girmay Zenebe *et al.*, 2012), Erob and Gulomahda district (Tadesse Beyene, 2015), Debark district (Eskedar Abebe, 2011) and Seru district-Arsi Zone (Mengistu Gebrehiwot, 2010). Of the 68 medicinal plant species reported by Girmay Zenebe *et al.* (2012) in Asgede Tsimbila district, 40 (58.8%) of them were also used to treat human and livestock diseases in the present study area. This is because the selected Kebeles were in the vicinity of the present study area. This implies people found in a close locality or similar geographical locations possibly have a similar culture in using medicinal plants (Ososki *et al.*, 2007) and often exchange information on the most important plants and use similar herbal plants (Alemtshay Teka, 2020).

Herbs were the most prominent (40%) growth forms of medicinal plant species followed by shrubs (35.3%) reported to cure both human and livestock disease. This might be related to the abundance of herbs and shrubs in the vicinity of the community. This result concurred with other studies conducted in Ethiopia by Mirutse Giday *et al.* (2003), Gemedo Dalle *et al.* (2005) and Tadesse Beyene (2015). Regarding the source of the medicinal plant species, wild environments yielded more medicinal plant species (62 species, 72.9%) than cultivated fields (23 species, 27.1%). This implies the natural vegetation patches or the wild environments have a great role in harboring various medicinal plant species that support community health care. This is due to the fact that wild plants are abundant, grown freely with no human interference relative to those grown in/around agricultural areas and human dwellings. Related findings were reported elsewhere in Ethiopia by Fisseha Mesfin *et al.,* 2009, Mirutse Giday *et al.* (2009), Tesfaye Awas and Sebsebe Demissew (2009), Ermias Lulekal *et al.* (2013) and Beltran *et al.* (2014).

Out of the reported 12 plant parts used for remedial preparations, leaves were the foremost (34.9%) followed by roots (16.2%). The higher usage of leaves to prepare remedies from plants is due to their abundance, simple to collect and ease of their application (Dawit Abebe & Estifanos Hagos, 1991). Roots were the other plant parts frequently used to prepare a remedy by the local community. This was due to the fact that roots are hidden in the soil for a long time and not exposed to herbivores but available for the practitioners whenever they desire it, even during the long dry season especially in dryland areas like in the present study area. Studies conducted in other parts of Ethiopia by different researchers such as Mirutse Giday *et al.* (2009) and Getu Alemayehu *et al.* (2015) reported similar results. However, using root of medicinal plant species could seriously affect the survival of individual plants if special care is not given during the harvest. Using a limited amount of the root part of the medicinal plant and covering the remaining part with soil allows for the survival of the species and sustainable use (Ermias Lulekal *et al.,* 2013 and Moravec *et al.*, 2014).

Painting/rubbing/pasting the latex/sap/juice directly, crush the plant part and mix with cold water then drink and burn or boil the plant part and inhale its smoke are among the common remedy preparations and applications for both human and livestock disease. The mode of remedy preparation and application are managed according to the type of ailment, which they identify with reference to symptoms observed on either humans or livestock. Eskedar Abebe (2011), Kalayu Mesfin *et al.* (2013), Seyoum Getaneh and Zerihun Girma (2014) reported comparable ethnobotanical study results. The majority of the remedy preparation was in fresh form. This could be related to the belief that fresh remedies are expected to have high potency of capturing bioactive ingredients than dry remedies. This result is also in line with other ethnomedicinal studies elsewhere in the country (Bussmann *et al.,* 2006; Haile Yineger *et al.,* 2007; Getachew Addis *et al.*, 2009; Ermias Lulekal *et al.*, 2013).

The routes of administrations for remedies used against different human ailments in the traditional health care systems were mostly (45.7%) implemented internally through oral ingestion. This is due to the fact that the most frequent ailment in the study area was abdominal related diseases, thus medication is prescribed to ingest the herbal medicine. Regarding the route of remedy admirations for livestock ailments, the majority of them (54.1%) were implemented externally (dermal). This was associated with the frequently occurring external diseases in the study area including skin diseases, wounds and ectoparasites. Similar findings were reported in different parts of the country (Dawit Abebe, 1986; Haile Yineger *et al*., 2008a, Fisseha Mesfin *et al.,* 2009; Abraha Teklay *et al*., 2013; Mirutse Giday and Tilahun Teklehaymanot, 2013).

There were unstandardized and inconsistent doses of herbal preparations reported by traditional healers for any of the preparations used to treat human and livestock ailments in the study area. This attributes the variations in perception and culture of utilization among healers of the study area. The variation in quantity and unit of measurement was also noted in a study conducted elsewhere in Ethiopia (Abraha Teklay *et al.,* 2013). Though no adverse side effects were reported, unstandardized and unprescribed doses of herbal medicine could lead to serious health problems in patients (Hillenbrand, 2006; Abbiw, 1996). Lack of side effect reporting could relate to the fact that the healers are orienting their clients to keep the secret about the medicine since their livelihoods depend on the selling of remedies. Consequently, neither the healers nor the users were voluntary to state the side effects of these medicinal plants. However, respondents reported that honey, water, milk and butter were the commonly used antidotes for herbal preparations in case they feel pains and for these with adverse effects. This finding is consistent with reports elsewhere in the country (Mirutse Giday *et al*., 2010; Ermias Lulekal, 2014).

About 80% of the reported medicinal plants have more than one role (multipurpose) and 20% of them were used only for medicinal value. Of the other use types reported, firewood (23.5%), food (18.8%), material culture (11.8%) and fencing (9.4%) were frequently stated. Medicinal plants have different uses both in rural and urban areas (Bye and Linares, 1983). *Dodonaea angustifolia, Boswellia papyrifera* and *Gardenia ternifolia* were among the most threatened species for firewood and material culture. The multiple uses of these species could render them to high exploitation pressure. As a result, these species were hard to come across (even inside the Hirmi woodland vegetation) and are restricted to some sites of the study area. Other studies conducted in Ethiopia (Haile Yineger *et al*., 2007; Ermias Lulekal *et al.*, 2013 and Beltran *et al*., 2014) also showed that medicinal plants were exploited for non-medicinal value than medicinal purposes. Unless sustainable conservation practices are conducted by prioritizing these plants with the most important use value, there will be a high probability of extinction from the long-term uses.

5.1.8.2. Human and livestock ailments treated with medicinal plants

Seventy one human and 16 livestock ailments were treated by 85 medicinal plants in the study area. About 85 medicinal plants were used to treat 82 various human and livestock ailments in Erob and Gulomahda (Tadesse Beyene, 2015) and 68 ailments in Gimbi district (Etana Tolasa, 2007) which is less than the present findings. The type of the plant used, culture and perceptions toward the medicinal plant utilization varies from one area to the other (Masika and Afolayan, 2003). Some medicinal plant species in the study area including *Adansonia digitata*, *Citrus aurantiifolia*, *Phytolacca dodecandra*, *Plumbago zeylanica* and *Ricinus communis* were used to treat a large number of human and livestock ailments. This indicates that some human and livestock ailments have an opportunity to be treated by more than one plant species in the study area.

Of the reported human illness, abdominal diseases were treated using 12 different medicinal plants followed by other diseases including evil eye, eye disease, headache, tooth disease/ache and wound that were treated by the prescriptions of 7 various medicinal plants. The high diversity of medicinal plants used to cure abdominal diseases were for the encounter of frequent abdominal diseases reported in the study area. Regarding the livestock ailments, skin diseases were treated through a high number of medicinal plant (7 species) prescriptions. This was also associated with the high number of skin diseases reported in the study area. *Phytolacca dodecandra*, *Cissus petiolata* and *Nicotiana tabacum* were among the species used to treat the highest number of livestock ailments. These medicinal plants used to treat various livestock ailments were also mentioned in the study conducted by Mengistu Gebrehiwot (2010), Girmay Zenebe *et al.* (2012) and Gebrekidan Abrha *et al.* (2018).

5.1.8.3. Effectiveness of medicinal plants

The overall informant consensus was found to be high (0.86-0.95) which indicates the participants seem to have similar perceptions and knowledge on the nominated medicinal taxa. On the other hand, high informant consensus implies, few species are used by a large proportion of people, while a low value indicates that the informants disagree on the healing potential of taxa in the treatment for the category of disease (Canales *et al*. 2005). Of the human disease categories, the highest informant consensus value (0.95) was scored for the abdominal complaints related disease whereas the least informant consensus value (0.86) was scored for diabetes and blood pressure disease category. Concerning the livestock disease, the category of dermal/skin disease and ecto-parasite had the highest informant consensus factor value (0.89) whereas swelling/ tumor scored the least ICF value (0.83). The ICF score of these disease categories indicates the relative incidences of these diseases in the area. The score of the informant consensus factor is also a good indicator to identify plants of particular interest in the search for bioactive compounds. Accordingly, medicinal plants including *Zehneria scabra, Plumbago zeylanica, Zingiber officinale, Allium sativum, Calpurnia aurea, Datura stramonium, Boswellia papyrifera, Anogeissus leiocarpa, Jasminum abyssinicum* and *Gardenia ternifolia* were the most preferred human medicinal plant species to treat abdominal diseases which was the most frequently revealed ailments. The most favored species to treat a particular disease reflects its high efficacy in the study area, which requires further investigation for their pharmacological value. Trotter & Logan (1998) and Girmay Zenebe *et al.* (2012) also stated a similar suggestion.

5.1.8.4. Threats to and conservation practices of medicinal plants

Overgrazing, deforestation, expansion of agriculture, over-harvesting by humans, lack of knowledge on the utilization and management, drought, firewood collection and charcoal production were among the threats identified against medicinal plants. The intensity of these threats was not the same. Overgrazing, deforestation and expansion of agriculture were among the most serious threats to medicinal plants. The majority (> 85%) of the local people have engaged mainly in agricultural activities as well as livestock production (ANRBNWZT, 2017). Charcoal production was also the additional source of income for many people. Hence, these trends (agricultural expansion, livestock production and charcoal production) severely affect the medicinal plants in the study area. Such threats were also reported in other parts of the country (Etana Tolosa, 2007; Fisseha Mesfin *et al.*, 2009; Giday Yirga, 2010; Mersha Ashagre, 2011; Gebrekidan Abrha *et al.*, 2018; Leul Kidane *et al.*, 2018). The root causes of the entire threats for the plant species in the study area were rapid population growth that demands extensive agricultural and grazing land (Tsehaye Gebrelibanos and Mohammed Assen, 2015). The study conducted by Ensermu Kelbessa *et al.* (1992) stated that the rapidly growing population and poverty of the rural people could be the major causes for the overutilization of plant species as well as the whole biodiversity in Ethiopia. Furthermore, the traditional healers and parents keep the indigenous knowledge on the medicinal plants utilization and management secretly could be another possible threat to the medicinal plants and associated indigenous knowledge (Caniago and Siebert, 1998).

Conservation of local vegetation in the study area is not only significant for the medicinal value but also to sustain the associated knowledge and to get further benefits such as food, market value, material culture, fodder, wood and soil fertility. Thus, people in the study area practice different techniques to conserve medicinal plants. Out of these homegardening, fencing, plantation and education (awareness) were the most used mechanisms reported by the informants. These conservation approaches are mostly recommended as a guarantee for the continual survival of traditional medicinal plants for the coming generation (Cunningham, 2001). Despite, the local community uses the above conservation mechanisms, most of the medicinal plants were found in the wild environment which is out of their management scope and not reliable to rescue them. Hence, the local government should enforce the regulations regarding the utilization of natural resources particularly the plants for the sustainable use of medicinal plants. Side by side with this work, awareness creation should be taken up intensively.

5.1.8.5. Distribution of indigenous knowledge on medicinal plants among the informants

Gender had no significant difference ($P > 0.05$) in the reporting of medicinal plants in the study area. This indicates females in the study area are equally knowledgeable as males, which could be related to the exposure similarity toward the interaction with medicinal plants as well as equal opportunity in receiving indigenous knowledge from their parents. Other authors (Ermias Lulekal, 2014; Almeida *et al.*, 2010; Bisht *et al.*, 2006) stated similar reports. In contrast to this finding, a study conducted by Tilahun Teklehaymanot (2009) and Mirutse Giday *et al.* (2009) demonstrated that males have better knowledge than females which might be associated with the parents' preference to pass their indigenous medical knowledge more to their sons than to their daughters. The number of medicinal plants reported by different age groups showed a significance differences (P = < 0.05). The elder age groups of the community (age > 40 years old) reported a high number of medicinal plants than the young age groups (18 - 40 years old). This reveals the elderly age groups have more experience and knowledge about medicinal plant species than young age groups. A study by Silva *et al.* (2011) also states the knowledge and exposures of people increase with age. Livelihood modernizations including urbanization and the advent of formal education might be the other factors that affect youngsters' indigenous knowledge of medicinal plants.

The educational status of the community imparted a significant variation in the number of different medicinal plants reported. The illiterate people reported more than 76% of the medicinal plants. This indicates the illiterate people relatively have good knowledge of medicinal plant species whereas the literate groups rely on the modern health care system than on traditional medicinal plants use. Teferi Gedif and Hahn (2003), Tesfaye Awas and Sebsebe Demissew (2009), Ermias Lulekal *et al.* (2013) and Getu Alemayehu (2017), stated a similar report. The total numbers of medicinal plants reported by married people were higher than single informants. This might be due to the age difference between married people who were relatively elder (experienced) than single informants. A study conducted in Debre Tabor Town by Tezera Jemere *et al.* (2020) made similar conclusions. There was no significant variations shown between different religious followers, despite a higher number of medicinal plants (307 species) reported by Orthodox Christians than Muslim (28 species) followers. The other significant difference was between key and general informants. Though the numbers of key informants were less than the number of general informants, they all reported a higher number of medicinal plants. This could be associated with the lifelong experience and confidentiality (holding the medicinal secret) in using medicinal plants (Teferi Gedif and Hahn, 2003; Ermias Lulekal *et al.*, 2013; Tebkew Mekuanent *et al.*, 2015).

5.2. Conclusion

This study found that Hirmi woodland vegetation has a significant number of plant species with high diversity. The vegetation is dominated by mixed vegetation types that belong to *Combretum-Terminalia* woodland and wooded grassland and *Acacia-Commiphora* woodland and bushland with a small area of Dry evergreen Afromontane forest and grassland complex (DAF) in the higher altitudes. Topographic variation of the study area leads to the existence of heterogeneous vegetation types and high plant species diversity including medicinal plants. The presence of endemic and near endemic plant species, as well as newly recorded plant species to the Tigray floristic region (TU), indicate the high floristic biodiversity potential of the study area and further exhaustive botanical exploration would result in additional new records to the floristic region. Five community types namely: *Ziziphus mucronata - Acacia polyacantha, Combretum hartmannianum - Terminalia macroptera - Oxytenanthera abyssinica, Anogeissus leiocarpa - Ozoroa insignis, Euclea racemosa - Acacia abyssinica* and *Dodonaea angustifolia - Flueggea virosa* were identified. The canonical correspondence analysis (CCA) revealed that the plant community formations and patterns of plant distributions were mainly influenced by altitude, slope, disturbances, soil organic matter, total Nitrogen, sand and silt soil type.

The overall vegetation structure of Hirmi woodland vegetation showed that it is dominated by species with high density at the lower DBH classes and height. This could be due to the abundance/dominance of shrubby species such as *Dodonaea angustifolia, Flueggea virosa, Maytenus arbutifolia, Acokanthera schimperi, Bersama abyssinica, Ziziphus mucronata* and *Ximenia americana* and a few tree species as a result of overexploitation. The assessment for the regeneration status of species showed that the Hirmi woodland has a poor regeneration status, which was associated with the observed multiple disturbance factors (cutting, grazing, fire and charcoal production signs). As a result of these disturbances, there were plant species either with no seedlings, saplings, or both seedlings and saplings in the study vegetation. *Acacia nilotica, Clerodendrum myricoides, Cordia africana, Justicia schimperiana, Phoenix reclinata* and *Phytolacca dodecandra* were among the species found with no seedlings and saplings. This also possibly associated with the habitat preferences of these species to some restricted areas.

Out of the 58 species recovered in the soil seed bank taken from four land use types in the study area, herbs were found the predominant species (86.2%) both vertical and horizontal distributions over woody species (shrubs/trees). The possession of small size and numerous seeds as well as ease and diverse dispersal mechanisms of herbaceous species makes to be relatively successful in regeneration potential. Regarding the land use types, high numbers of species were recovered from shrubland whereas the least numbers of species were recovered from the bare land. This could be associated with variations in soil organic matter and the intensity of degradations among the land use types. Recovery of few (8) woody species in all land use types of the study area indicates soil seed bank is not reliable for the restoration of the woody species, thus other active restoration techniques and manipulation of disturbances need to be considered.

The ethnomedicinal survey showed that people in the study area used 85 medicinal species to treat 71 human and 16 livestock ailments. This could be related to easy access, perceived efficacy and cultural values attached to the plants. Of the recorded medicinal plants, 65.9% of them were found in Hirmi woodland vegetation. Herbs were the most used growth forms of medicinal plants since its ease to use and accessibility in their vicinity and the wild environments. The majority of the medicinal plants have multiple or more than one uses. This puts them into further exploitation. The most frequently revealed ailments for human and livestock in the study districts were abdominal diseases and skin diseases, respectively. Thus, more numbers of species were prescribed to treat these diseases. Overgrazing, deforestation and expansion of agriculture were the most proximate threats for medicinal plants. Consequently, some important medical species such as *Dodonaea angustifolia*, *Boswellia papyrifera* and *Gardenia ternifolia* were highly exploited and found rarely. To rescue these and other medicinal plants, local communities used various conservation techniques including homegardening, plantation, fencing and awareness rising. However, the level of awareness and commitment by inhabitants was variable on the use and management of medicinal plants. This brings a significant difference in reporting of medicinal plant use among the informants. Hence, the documentation of the vegetation resources and associated indigenous knowledge of the community has a significant role in the conservation of the study vegetation.

Generally, the study underscores the need of immediate conservation interventions by considering the identified significant environmental factors (altitude, slope, disturbance, soil organic matter, total Nitrogen, sand and silt soil type) associated with the species diversity, IUCN threat status, regeneration potential and/status and medicinal values of the species.

5.3. Recommendations

Based on the study findings the following recommendations are forwarded:

1. Human-induced disturbances are prevalent in the study area. Some endemic species were as vulnerable and assigned endangered status that is registered under the IUCN Red List categories. Hence, responsible conservation bodies including regional or/and federal agricultural research centers, Ethiopian Environment and Forest Research Institute, Ethiopian Biodiversity Institute and conservation NGOs shall take appropriate and immediate conservation measures in collaboration with the decision-makers to rescue these plant species and their habitats. The threatened (endangered and vulnerable) species requires *ex situ* conservation approach while the remaining species require *in situ* approach.
2. The presence of a significant number (17 species) of newly recorded plant species to the Tigray floristic region implies the need of exhaustive floristic survey mainly in the dryland areas which covers the largest landmass of the region for the full record of the floristic region.
3. The sign of disturbances including logging, wood collection, grazing and charcoal production signs were common in most community types. However, certain community types (i.e, *Ziziphus mucronata* - *Acacia polyacantha*, *Combretum hartmannianum* - *Terminalia macroptera* - *Oxytenanthera abyssinica* and *Dodonaea angustifolia* - *Flueggea virosa* communities) were seriously disturbed. Therefore, the federal and regional government should work with the local people around the study vegetation on how to balance their needs (including deducting the number of livestock, replacing biomass energy with electrical energy, solar energy and biogas) with the natural plant resources for its sustainable utilization.

4. The regeneration status of the study vegetation was poor and the future recovery of the indigenous plant species is at risk. Thus, the establishment of nurseries for the growth of plants with no seedlings (e.g. *Adansonia digitata, Croton macrostachyus, Justicia schimperiana, Rumex nervosus* and *Balanites aegyptiaca*), saplings (e.g. *Sterculia setigera, Ficus vasta, Lannea schimperi, Maerua angolensis* and *Buddleja cordata*) and both seedlings and saplings (*Acacia nilotica, Clerodendrum myricoides, Cordia africana, Justicia schimperiana, Phoenix reclinata* and *Phytolacca dodecandra*) should be given priority to enrich the natural regeneration process and rescue local extinction of the species.
5. The soil seed bank result from all land use types in the study area showed that the regeneration potential of the woody species were very limited and not reliable for their restorations. Hence, this study underscores the federal and regional governments in consultation or/and collaboration with the local community should implement the population enrichment and restoration approaches such as nursery-grown seedlings of indigenous woody species and plantations, direct seeding in the degraded lands and prevent selective cutting of the matured woody species.
6. Traditional healers and relevant professionals (found at regional and national levels) should provide education on how to use and manage the medicinal plants to their descendants by disseminating the required information and knowledge.
7. None of the traditional healers volunteered to tell the side effects of the traditional medicine. However, unstandardized and not scientifically prescribed doses of herbal medicine obviously would have health problems in patients. Hence, the phytochemical and toxicological investigations should further carry out by emphasizing on the more preferred and frequently used medicinal plant species (*Zehneria scabra, Plumbago zeylanica, Zingiber officinale, Calpurnia aurea, Boswellia papyrifera, Anogeissus leiocarpa, Jasminum abyssinicum* and *Gardenia ternifolia*) for their pharmacological value.
8. The local community around the study area has a strong linkage with plant resources. Hence, continuous awareness raising on ecosystem services and sustainable use of the study plant resources should be conducted to the local communities by the local government, conservation and research centers found in the county. The investigator of this study would also make efforts to this effect.

References

Abbiw, O.K. (1996). Misuses and Abuses in self-medication with Medicinal plants. The case of Erythrophelum in Ghana. **In**: *Biodiversity of African plants*. Kluwer Acadamic publisher, Netherlands. pp. 700 - 720.

Abeje Eshete, Stercka, F. and Bongersa, F. (2011). Diversity and production of Ethiopian dry woodlands explained by climate and soil-stress gradients. *Ecology and Management* **261(9):**1499-509

Abiyou Tilahun, Teshome Soromessa, Ensermu Kelbessa and Abyot Dibaba (2011). Floristic composition and community analysis of Menagesha Amba Mariam forest (egdu forest) in central shewa, Ethiopia. *Ethiopian Journal of biological science* **10**(2): 111-136.

Abraha Teklay, Balcha Abera and Mirutse Giday (2013). An Ethnobotanical Study of Medicinal Plants Used in Kilte Awulaelo District, Tigray Region of Ethiopia. *Journal of Ethnobiology* and *Ethnomedicin*e **9**(65):1-23.

Abyot Dibaba, Teshome Soromessa, Ensermu Kelbessa and Abiyou Tilahun (2014). Diversity, Structure and Regeneration Status of the Woodland and Riverine Vegetation of Sire Beggo in Gololcha District, Eastern Ethiopia. *Momona Ethiopian Journal of Science* (MEJS) **6**(1):70-96.

Abyot Yismaw, Birhanu Gedif, Solomon Addisu and Ferede Zewudu (2014). Forest cover change detection using remote sensing and GIS in Banja district, Amhara region, Ethiopia.

Ahmed Endris, Ali Seid and Addisu Asefa (2017). Structure and regeneration status of woody plants in the Hallideghie wildlife reserve, North East Ethiopia. *International Journal of Biodiversity and Conservation* **9**(6):200-211.

Akhagba, O. M. (2017). Cultural influence in the consumption of herbal medicine among Nigerian women: A theoretical exploration. *Miscellanea Anthropologica et Sociologica* **18**(3): 193–206.

Alemayehu Wassie, Sterck, F.J., Demel Teketay and Bongers, F. (2009). Effects of livestock exclusion on tree regeneration in church forests of Ethiopia. *Forest Ecology and Management* **257** (3): 765–772.

Alemtshay Teka, Zemede Asfaw, Sebsebe Demissew and Van Damme, P. (2020). Medicinal plant use practice in four ethnic communities (Gurage, Mareqo, Qebena andSilti), south central Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **16**(27):1-12.

Alexiades, M. (1996). Collecting ethnobotanical data: an introduction to basic concepts and techniques. In: *Selected Guidelines for Ethnobotanical Research: A Field Manual*, M.N. Alexiades (ed), The New York Botanical Garden, New York, pp. 53-94.

Almeida, C., Ramos, M., Amorim, E. and Albuquerque, U. (2010). A comparison of knowledge about medicinal plants for three rural communities in the semiarid region of northeast of Brazil. *Journa of Ethnopharmacol* **127** (3):674–684.

Amare Getahun (1976). Some common medicinal and poisonous plants in Ethiopia in folk medicine. Addis Ababa University, Ethiopia. http://ip.aaas.org/tekinde.

Amiaud, B. and Touzard, B. (2004). The relationships between soil seed bank, aboveground vegetation and disturbances in old embanked marshlands of western France. *Flora* **199**(1): 25-35.

Anderson, D.J. (1965). Classification and Ordination in Vegetation Science: Controversy over non-existent problem. *Journal of Ecology* 53 (2): 521-526.

Anonymous (1997). Ethiopia: National Conservation Strategy, Phase I Report. Ethiopian Environmental Authority, Addis Abeba.

ANRBNWZT (Agriculture and Natural Resource Bureau of North-Western Zone of Tigray Region), (2017). Conservation and management plan of natural resources and rural development of North-Western Zone of Tigray, Shire-Ethiopia.

Arponen, A. (2012). Prioritizing species for conservation planning. *Biodiversity and Conservation* **21**(4): 875–893.

Austin, M.P., Nicholls, A.O., Doherty, M.D. and Meyers, J.A. (1994). Determining species response functions to an environmental gradient by means of a b-function. *Journal of Vegetation Science* **5** (2): 215-228.

Avocevou-Ayisso, C., Avohou, T.H., Oumorou, M., Dossou, G., Sinsin, B. (2011). Ethnobotany of *Entadesma butyracea* in Benin: a quantitative approach. Ethnobotany Research and Applications **10**:151-166.

Awoyemi, O.K., Ewa, E.E., Abdulkarim, I.A. and Aduloju, A.R. (2012). Ethnobotanical assessment of herbal plants in southwestern Nigeria. *Academic research international* **2** (3): 50-57.

Baer, S.G., Blair, J.M., Collins, S.L. and Knapp, A.K. (2003). Soil resources regulate productivity and diversity in newly established tallgrass prairie. *Ecology* **84** (3): 724–735.

Bakker, J.P., Bos, A.F., Hoogveld, J. and Muller, H.J. (1991). The role of the seed bank in restoration management of semi-natural grasslands. Terrestrial and Aquatic Ecosystems: Perturbation and Recovery (ed. O. Ravera). pp. 449-455.

Bard, K.A., Coltorti, M. and Di-Blasi, M.C. (2000). The environmental history of Tigray (northern Ethiopia) in the middle and late Holocene: A preliminary outline. *African Archaeological Review* **17**(2):65-86.

Barnes, M. E. (2001). Seed predation, germination and seedling establishment of Acacia erioloba in northern Botswana. *Journal of Arid Environments*, *49*(3), 541-554

Bekker, R.M., Verweij, G.L., Smith, R.E.N., Reine, R., Bakker, R.P. and Schineider, S. (1997). Soil Seed Banks in European Grasslands: Does Land Use Affect Regeneration Perspectives. *Journal of Applied Ecollogy* **34**(5): 1293-1307.

Beltrán-Rodríguez, L., Ortiz-Sánchez, A., Mariano, N. A., Maldonado-Almanza, B., & Reyes-García, V. (2014). Factors affecting ethnobotanical knowledge in a mestizo community of the Sierra de Huautla Biosphere Reserve, Mexico. *Journal of ethnobiology and ethnomedicine*, **10**(1):1-19.

Bisht, A.K., A. Bhatt, Rawal, R.S. and Dhar, U. (2006). Prioritization and conservation of Himalayan medicinal plants: Angelica glauca Edgew. as a case study. *Ethnobotany Research and Applications* **4**:011-023.

Black, C.A, (1965). Methods of soil analysis. Part I, American Society of Agronomy. Madison,Wisconsin, USA. pp.1572.

Bockheim, J.G. (2015). The soil of Antarctica. World soil Book series, Springer International Publishing, Switzerland. pp.322.

Bongers, F., Poorter, L. and Hawthorne, W.D. (2009). The intermediate disturbance hypothesis applies to tropical forests, but disturbance contributes little to tree diversity. *Ecology Letters* **12**(8):798-805.

Borja, M.E. (2014). Climate change and forest natural regeneration in Mediterranean mountain areas. *Forestery Research* **3**(2): 1-2.

Bose, A. K., Weiskittel, A., Wagner, R. G., & Kuehne, C. (2016). Assessing the factors influencing natural regeneration patterns in the diverse, multi-cohort andmanaged forests of Maine, USA. *Journal of Vegetation Science* **27**(6):1140-1150.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total, organic andavailable forms of phosphorus in soils. *Soil Science* **59**(1):39-46.

Brinkmann, K., Patzelt, A., Dickhoefer, U., Schlecht, E. and Buerkert, A. (2009). Vegetation patterns and diversity along an elevational and a grazing gradient in the Jabal al Akhdar Mountain range of northern Oman. *Journal of Arid Environments* **73**(11):1035-1045.

Brooks, T.M., Mittermeier, R.A., Mittermeier, C.G. *et al*. (2002). Habitat Loss and Extinction in the Hotspots of Biodiversity. *Conservation Biology* **16**(4):909-923.

Brown, R.B. (2003). Soil Texture. University of Florida, Institute of Food and Agriculture Science. Available online: http://edis.ifas.ufl.edu/SS169.

Burger, J.A., Johnson, J.A., Andrews, J.E. and Torbert, J.L. (1994). Measuring mine soil productivity for forests. In: International Land Reclamation and Mine Drainage Conference on Reclamation and Revegetation Vol. 3. USDOI Bureau of Mines, Special Publication SP 06C-94. pp.48-56.

Bussmann, R. W., & Sharon, D. (2006). Traditional medicinal plant use in Loja province, Southern Ecuador. *Journal of Ethnobiology and Ethnomedicine* **2**(1): 1-11.

Bye, R.A. and Linares, E. (1983). The role of plants found in Mexican markets and their importance in ethnobotanical studies. *Journal of Ethnobiology* **3**(1):1-3.

Canales, M., Hemandez, T., Caballero, J., Romo de Viver, A., Avila, G., Duran, A. and Lira, R. (2005). Plants used by the people of San Rafael Coxcatlen, Puebla, Mexico. *Journal of ethnopharmacology* **97** (3):429-439.

Caniago, I. and Siebert, S.F. (1998). Medicinal plant ecology, knowledge and conservation in Kalimantan, Indonesia: *Economic Botany* **52**(3): 229-253.

Carey, D.D. and Watkinson, A.R. (1993). The dispersal and fates of seeds of winter annual grass *Vulpia ciliata*. *Journal of Ecology* **79**: 627-643.

CBD (1992). Convention on Biological Diversity. In:http://www.cbd.int/doc/legal/cbden. pdf. Anexed Februry11, 2006.

Central Statistical Agency (CSA) (2007). The 2007 population and housing census of Ethiopia: Statistical Report for Tigray Region. Addis Ababa.

Chapman, H.D. (1965). Cation exchange capacity. **In**: C.A. Black, L.E. Ensminger and F.E. Clark (Eds). Methods of soil analysis. *Agronomy*. **9**: 891-901.

Christoffoleti, J.P and Caetano, S.R. (1998). Soil seed banks. *Science and agriculture* **55:**74-78.

Clark, C.M. and Tilman, D. (2008). Loss of plant species after chronic low-level nitrogen deposition to prairie grasslands. *Nature* **451**(7179): 712–715.

Cochran, W. G. (1977). Sampling techniques (3rd ed.) New York: John Wiley and Sons.

Cody, L.M. (1993). Bird diversity components within and between habitats in Australia. **In**: Species diversity in ecological communities: Historical and geographical perspectives, University of Chicago Press, Chicago, USA. pp. 147-158.

Condit, R., Hubbell, S.P., Lafrankie, J.V., Sukumar, R., Manokaran *et al.* (2002). Species-area and species-individual relationships for tropical trees: a comparison of three 50-ha plots. *Journal of Ecology* **84** (4):549-562.

Cornell, H. V. (1999). Unsaturation and regional influences on species richness in ecological communities: a review of the evidence. *Ecoscience* **6**(3):303-315.

Cotton, C.M. (1996). Ethnobotany: Principles and Applications. John Wiley and Sons, New York. pp.412.

Crowley, W., Harrison, S.C., Coroi, M. and Sacré, V.M. (2003). An ecological assessment of the plant communities at Port Bán Nature Reserve in south-western Ireland. *Biology and Environment: Proceeding of the Royal Irish Academy* **103** (2): 69–82.

Cunningham, A.B. (2001). Applied Ethnobotany, People, Wild Plant Use and Conservation. WWF, UNESCO, Royal Botanical Gardens, Kew. Earthscan.

Dagnew Yebeyen (2006). Population status of *Acacia senegal* (linne) willd and its gum quality in the central Rift Valley of Ethiopia. MSc. thesis, Wondo Genet College of Forestry, Ethiopia.

Dainou, K., Bauduin, A., Bourland, N., Gillet, J. F., Feteke, F. and Doucet, J. L. (2011). Soil seed bank characteristics in Cameroonian rainforests and implications for post logging forest recovery. *Ecological Engineering* **37**(10):1499-1506.

Dalling, J.W., Swaine, M.D. and Garwood, N.C. (1997). Soil seed bank community dynamics in seasonally moist low land tropical forest, Panama. *Journal of Tropical Ecology* **13** (5):659-680.

Darbyshire, I., Lamb, H. and Umer, M. (2003). Forest clearance and regrowth in northern Ethiopia during the last 3000 years. *The Holocene* **13**(4): 537-546.

Dawit Abebe (1986). Traditional Medicine in Ethiopia: the Attempt Bering Made to promote it for Effective and Better utilization. *SINET: Ethiopian Journal of Science* **9**:61-69.

Dawit Abebe (2001). The role of medicinal plants in healthcare coverage of Ethiopia, the possible benefits of integration. **In**: *Proceedings of Workshop on Biodiversity*

Conservation and Sustainable Use of Medicinal Plants in Ethiopia, Medhin Zewdu, 191 Abebe Demissie (eds), Institute of Biodiversity Conservation and Research, Addis Ababa, Ethiopia, 28 April –May 2001. pp. 6-21.

Dawit Abebe and Ahadu Ayehu (1993). Medicinal Plants and Eenigmatic Health Practices of Northern Ethiopia. Addis Ababa, B.S.P.E. pp.511.

Dawit Abebe and Estifanos Hagos (1991). Plants as primary source of drugs in the traditional health practice of Ethiopia. **In**: Plant Genetic Resources of Ethiopia (Engles, J.M.M., Hawekes, G.M. and Melaku Worede (eds.). Cambridge University Press, Cambridge. pp.101-113.

Debissa Lemessa (2009).Woody plant species Diversity of Taltalle woodland (*Acacia*–*Commiphora* woodland Ecosystem), Oromia, Ethiopia. Forest Genetic Resources Conservation Department Institute of Biodiversity Conservation (IBC), Addis Ababa, Ethiopia.

Degafi Sileshi and Berhanu Abraha (2014). Assessment of Soil seed bank Composition of Woody Species in Hgumbirda National Forest Priority Area, Northeastern Ethiopia. *Momona Ethiopian Journal of Science* **6**(1):25-44.

Demel Teketay (2000). Vegetation Types and Forest Fire Management in Ethiopia. pp. 1-35. In MOA & GTZ (eds.) Proceedings of the Round Table Conference on Integrated Forest Fire Management in Ethiopia. Ministry of Agriculture (MOA) & Deutsche

Demel Teketay and Granstrom, A. (1995). Soil seed banks in dry Afromontane forests of Ethiopia. *Vegetation Science* **6**(6): 777-786.

Demel Teketay (2001). Deforestation, wood famine andenvironmental degradation in Ethiopia's highland Ecosystems: urgent need for action. *Northeast African Studies* **8(1)**:53-76.

Demel Teketay (2005a). Causes and consequences of dryland forest degradation in Sub-Saharan Africa. *Walia* **24**: 3-20.

Demel Teketay (2005b). Seed and regeneration ecology in dry Afromontane forests of Ethiopia: I. Seed production - Population structures. *Tropical Ecology* **46**(1): 29-44.

Digby, P.G.N. and Kempton, R.A. (1987). Multivariate Analysis of Ecological Communities: Population and Community Biology Series. Chapman and Hall, London.

Dold, A.P. and Cocks, M.L. (2002). The trade in medicinal plants in the Eastern Cape Province, South Africa. *South African Journal of Science* **98** (11): 589-597.

Duchok, R., Kent, K., Khumbongmayum, A. D., Paul, A. and Khan, M. L. (2005). Population structure and regeneration status of medicinal tree *Illicium griffithii* in relation to disturbance gradients in temperate broad-leaved forest of Arunachal Pradesh. *Current Science* **89** (4): 673-676.

EFAP (Ethiopian Forestry Action Program) (1994). *The Challenge for Development, Volume II*. Ethiopian Forestry Action Program, Addis Ababa, Ethiopia.

Emiru Brhane, Demel Teketay and Barklund, P. (2006). Actual and potential contribution of enclosures to enhance biodiversity of woody species in the dry lands of Eastern Tigray. *Drylands* **1**(2): 134-147.

Ensermu Kelbessa and Abenet Girma (2011). Forest types in Ethiopia; Status, Potential Contribution and Challenges. Forum for Environment, Addis Ababa Ethiopia. pp.158.

Ensermu Kelbessa and Sebsebe Demissew (2014). Diversity of vascular plant taxa of the flora of Ethiopia and Eritrea. Ethiopian. *Journal of Biological Sciences* **13**: 37 – 45.

Ensermu Kelbessa, Sebsebe Demissew, Zerihun Woldu and Edwards, S. (1992). Some threatened Endemic Plants of Ethiopia. **In**: Edwards, S. and Zemede Asfaw (eds). *The status of some plants in parts of tropical Africa*, NAPRECA, No. 2. Botany 2000, East and Central Africa. pp. 35-55.

Enoki, T. and Abe, A. (2004). Saplings distribution in relation to topography and canopy openness in an evergreen broad-leave forest. *Plan ecology* **173**(2):283-291.

Enright, N.J., Miller, B.P. and Akhtar, R. (2005). Desert vegetation and vegetation environment relationships in Kirthar National Park, Sindh, Pakistan. *Journal of Arid Environments* **61** (3): 397–418.

Ermias Aynekulu (2011). Forest diversity in fragmented landscapes of northern Ethiopia and implications for conservation. *Doctoral Dissertation*, University of Bonn.

Ermias Lulekal (2014). Plant Diversity and Ethnobotanical Study of Medicinal Plants in Ankober District, North Shewa Zone of Amhara Region, Ethiopia. PhD Dissertation. Addis Ababa University, Ethiopia.

Ermias Lulekal, Ensermu Kelbessa, Tamrat Bekele and Haile Yineger (2008). Plant species composition and structure of the Mana Angetu moist montane forest, Southeastern Ethiopia. *Journal of East African Natural History* **97**(2): 165-185.

Ermias Lulekal, Zemede Asfaw, Ensermu Kelbessa & van Damme, P. (2013). Ethnomedicinal study of plants used for human ailments in Ankober District, North Shewa Zone, Amhara Region, Ethiopia. *Journal of Ethnobiology & Ethnomedicine* **9**(1): 1-13.

Eskedar Abebe (2011). Ethnobotanical study on medicinal plants used by local communities In Debark wereda, North Gondar Zone, Amhara Regional State. MSc thesis in Biology (Botanical Science), Addis Ababa University, Addis Ababa.

Eshetu Yirdaw, Mulualem Tigabu, Mulugeta Lemenih, Mesele Negash and Demel Teketay (2014). Rehabilitation of Degraded Forest and Woodland Ecosystems in Ethiopia for Sustenance of Livelihoods and Ecosystem Services. *International union of forest research organizations* **32**:299-313.

Esmailzadeh, O., Hosseini, S.M. and Tabari, M. (2011). Relationship between soil seed bank and aboveground vegetation of a Mixed-deciduous Temperate Forest in northern Iran. *Agricultural Science Technology* **13** (3): 411-424.

Etana Tolosa (2007). Use, Treat and Conservation of Traditional Medicinal Plants by Indigenous people in Gimbi Wereda, Western Wellega, Ethiopia. M.Sc. Thesis, AAU, Ethiopia. pp. 1- 121.

Evans, J. (1992). Coppice forestry - an overview In: Buckley, G. P. (ed.) Ecology and Management of Coppice woodlands. Chapman and Hall, London. pp. 18-27.

Eyob Tenkir (2006). Soil seed bank study and natural regeneration assessment of woody species in Dodola dry afromountain forest and Bale Mountains. MSc thesis in Biology (Botanical Science), Addis Ababa University, Addis Ababa.

Facelli, J. and Pickett, S. (1991). Plant litter: its dynamics and effects on plant community structure. *Botanical Review* **57**(1): 1-25.

FAO (1996). Ethiopia: country report to the FAO international technical conference on plant genetic resource. Leipzig, Germany.

FAO (2005). State of the World's Forests. Deforestation Rate in Ethiopia, FAO, Rome.

Farnsworth, N.R. (1994). Ethnopharmacology and drug development**. In**: *Ethnobiology and the Search for New Drugs*. Wiley Chi Chester, Chicago, USA. pp. 42-59.

Feoli, E., Vuerich, L.G. and Zerihun Weldu (2002). Evaluation of environmental degradation in northern Ethiopia using GIS to integrate vegetation, geomorphological, erosion and socio-economic factors. *Agriculture, Ecosystems and Environment* **91** (3):313-325.

Ferrandis, P., Jose, M.H. and Juan, J.M. (1999). Effect of fire on hard-coated Cistaceae seed banks and its influence on techniques for quantifying seed banks. Plant Ecology **144**(1): 103–114.

Feyera Senbeta and Demel Teketay (2001). Regeneration of indigenous woody species in native and exotic tree plantations in central Ethiopia. *Tropical Ecology* **42**(2): 175-185.

Feyera Senbeta and Demel Teketay (2002). Soil seed banks in plantations and adjacent natural dry Afromontane forests of central and southern Ethiopia. *Tropical Ecology* **43** (2): 229-242.

Feyera Senbeta, Tadesse Woldemariam, Sebsebe Demissew and Denich, M. (2007). Floristic diversity and composition of Sheko forest, southwest Ethiopia. *Ethiopian Journal of Biological Science* **6(1):** 11-42.

Field, R., Hawkins, B. A., Cornell, H.V., Currie, D.J. *et al*. (2009). Spatial species-richness gradients across scales: a meta-analysis. *Journal of Biogeography* 36 (1): 132–147.

Fisseha Mesfin, Sebsebe Demissew and Tilahun Teklehaymanot (2009). An ethnobotanical study of medicinal plants in Wonago District, SNNPR. *Ethiopia Journal of Ethnobiology and Ethnomedicine* **5** (1):1-28.

Fitsum Hagos, John, P. and Nega Gebreselassie (1999). Land degradation in the Highlands of Tigray and Strategies for Sustainable Land Management. Socioeconomic and Policy Research Working Paper 25.

Foggo, A., Simon, D. R. and David, T. B. (2003). The net result: evaluating species richness extrapolation techniques for littoral pond invertebrates School of Biological Sciences, University of Plymouth, U.K. *Freshwater Biology* **48** (10):1756–1764.

Fortin, M.J. and Dale, M.R.T. (2005). Spatial analysis: a guide for ecologists. Cambridge University Press.

Fosberg, F. R. (1961). A classification of vegetation for general purposes. *Troical ecology* **2:**1-28.

Friis, I. (1992). Forests and forest trees of northeast tropical Africa: Their natural habitats and distribution patterns in Ethiopia, Djibouti and Somalia. Her Majesty's Stationery Office, London.

Friis, I. and Sebsebe Demissew (2001). Vegetation maps of Ethiopia and Eritrea. A review of existing maps and the need for a new map for the flora of Ethiopia and Eritrea. *Biologiske Skrifter* **54**:399-439.

Friis, I., Sebsebe Demissew and von Breugel, P. (2010). Atlas of Potential Vegetation of Ethiopia.The Royal Danish Academy of Science and Letters, Copenhagen.

Gaston, K.J. (2000). Global patterns in biodiversity. *Nature* **405** (6783): 220–227.

Gauch, H. G. (1962). Multivariate Analysis in Community Ecology. Cambridge, University Press. Cambridge.

Gebrekidan Abrha, Sibhatleab Hintsa and Gebrekiros Gebremedhin (2018). Indigenous knowledge based identification of medicinal plants in Central Zone of Tigray, North Ethiopia. *International Journal of Biodiversity and Conservation* **10**(6): 265-275.

Gebremedhin Hadera (2000). A study on the ecology and management of the Dessa forest in the northeastern escarpment of Ethiopia. M.Sc. Thesis, Addis Ababa University.

Gemedo Dalle (2004). Vegetation Ecology, Rangeland Condition and Forage Resources Evaluation in the Borana Lowlands, Southern Oromia, Ethiopia. Doctoral Dissertation. Georg-August University, Göttingen.

Gemedo Dalle, Maass, B. and Isselstein, J. (2005). Plant biodiversity and ethnobotany of Borana pastoralists of southern Oromia, Ethiopia. *Economic Botany* **59**(1):43-65.

Gerben van, E.k. (2013). Participatory Forest Management Socio-Economic Baseline Study. Assessment of the economic and social values of forests on rural households in and adjacent to SLMP project areas. Addis Ababa-Ethiopia.

Getachew Addis, Baskaran, R., Raju, M., Ushadevi, A., Zemede Asfaw *et al.* (2009). Effect of blanching and drying process on carotenoids composition of underutilized Ethiopian (*Coccinia grandis* L. Voigt) and Indian (*Trigonella foenum-graecum* L.) green leafy vegetables. *Journal of Food Process Preservation* **33** (6):744–62.

Getachew Addis, Dawit Abebe and Kelbessa Urga (2001). A survey of traditional medicinal plants in Shirka District, Arsi Zone, Ethiopia. *Ethiopian Pharmaceutical Journal* **19**:30-47.

Getachew Tadesse, Tamrat Bekele and Sebsebe Demissew (2008). Dryland woody vegetation along an altitudinal gradient on the eastern escarpment of Wolo, Ethiopia. *SINET: Ethiopia. Journal of Science* **31** (1): 43-54.

Getachew Tesfaye (2008). Ecology of regeneration and phenology of seven indigenous tree species in a dry tropical Afromontane forest, southern Ethiopia. PhD dissertation, Addis Ababa University, Addis Ababa, Ethiopia.

Getachew Tesfaye, Demel Teketay, Masresha Fetena and Erwin, B. (2010). Regeneration of seven indigenous tree species in a dry Afromontane forest, southern Ethiopia. *Flora* **205** (2): 135-143.

Getu Alemayehu (2017). Plant diversity and ethnobotany of medicinal and wild edible plants in amaro district of southern nations, nationalities and peoples region and Gelana district of Oromia Region, southern Ethiopia. PhD Dissertation Addis Ababa University, Ethiopia.

Getu Alemayehu, Zemede Asfaw and Ensermu Kelbessa (2015). Ethnobotanical study of medicinal plants used by local communities of Minjar-Shenkora District, North Shewa Zone of Amhara Region, Ethiopia. *Journal of Medicinal Plants Studies* **3**(6): 01-11.

Gidey Yirga (2010). Ethnobotanical Study of Medicinal Plants in and Around Alamata, Southern Tigray, Northern Ethiopia. *Current Research Journal of Biological Sciences* **2**(5): 338-344.

Girmay Zenebe, Mohammed Zerihun and Zewdie Solomon (2012). An Ethnobotanical Study of Medicinal Plants in Asgede Tsimbila District, Northwestern Tigray, Northern Ethiopia. *Ethnobotany Research & Applications* **10:**305-320.

GIZ (2014). Land use land cover mapping of participatory forest management (PFM) project areas and adjacent SLMP (Sustainable Land Management Program) watersheds in three regions of Ethiopia. Mekelle University, Ethiopia.

Godefroid, S., Phartyal, S.S. and Koedam, N. (2006). Depth distribution and composition of seed banks under different tree layers in a managed temperate forest ecosystem. *Acta Oecol* **29**(3): 283–292.

Goiteom Woldu, Negasi Solomon, Hadgu Hishe, Hailemariam Gebrewahid, Mewcha Amha and Emiru Birhane (2019).Topographic variables to determine the diversity of woody species in the exclosure of Northern Ethiopia. *Heliyon* **6** (1): 1-6.

Haile Adamu, Tamrat Bekele and Gemedo Dalle (2012). Plant community and ecological analysis of woodland vegetation in Metema Area, Amhara National Regional State, Northwestern Ethiopia. *Journal of Forestry Research* **23**(4): 599−607.

Haile Yineger, Delenasaw Yewhalaw and Demel Teketay (2008a). Ethnomedicinal plant knowledge and practice of the Oromo ethnic group in southwestern Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **4**(11): 1-10.

Haile Yineger, Ensermu Kelbessa, Tamrat Bekele and Ermias Lulekal (2007). Ethnoveterinary medicinal plants at Bale Mountains National Park, Ethiopia. *Journal of Ethnopharmacology* **112** (1): 55–70.

Haile Yineger, Ensermu Kelbessa, Tamrat Bekele and Ermias Lulekal (2008b). Floristic Composition and Structure of the Dry Afromontane Forest at Bale Mountains National Park. *SINET: Ethiopian Journal of Science* **31**(2): 103-120.

Halfiges Scholz, cited by Freitas (1990). Soil Seed Banks. Scientia Agricola. Vol. (55). Special Issue Piracicaba (1998), Brazil.

Hamilton, A.J. (2005). Species diversity or biodiversity? *Journal of Environmental Management* **75** (1): 89–92.

Harper, J.L. (1977).Population biology of plants. Academic Press, New York, NY, US.

Harrington, G.N., Irvine, A.K., Crome, F.H. and Moore, L.A. (1997). Regeneration of large-Seeded Trees in Australian Rainforest Fragments: A Study of higher-Order Interactions. pp. 292-303.

Hedberg, O. (1964). Features of Afroalpine plant ecology. *Acta Phytogeography Suecica* **49**:1-144.

Hegazy, A., El-Demerdash, M. and Hosni, H., (1998). Vegetation, species diversity and floristic relations along an altitudinal gradient in southwest Saudi Arabia. *Journal of Arid Environments* **38**: 3-13.

Heinrich, M., Ankli, A., Frei, B., Weimann, C. and Sticher, O. (1998). Medicinal plants in Mexico: Healers' consensus and cultural importance. *Social Science and Medicine* **47**(11):1859-1871.

Hillel, D. (1980). Fundamentals of soil physics.Harcourt Brace Jovanivich publisher, Academic press, Inc. San Diego. pp.413.

Hillenbrand, E. (2006). Improving Traditional-Conventional Medicine Collaboration: Perspectives from Cameroonian Traditional Practitioners. Nordic. *Journal of African Studies* **15** (1):1-15.

Hingston, F. (1992). Agroforestry for Soil Conservation: CAB International, Oxon, UK. 1989. Paperback. pp. 280.

Hirsch, B. T., Kays, R., Pereira, V. E., & Jansen, P. A. (2012). Directed seed dispersal towards areas with low conspecific tree density by a scatter-hoarding rodent. *Ecology Letters* **15**(12):1423-1429.

Hossain, M.K., Azad, A.K. and Alam, M.K. (1999). Assessment of natural regeneration status in a mixed tropical forest at Kaptai of Chittagong Hill Tracts (South) Forest Division. *The Chittagong University Journal of Science* **23**(1): 73–79.

Hurlbert, S.H. (1971). The non-concept of species diversity: a critique and alternative parameters. *Ecology* **52** (4): 577–586.

IBC (2005). National Biodiversity Strategy and Action Plan: Government of the Federal Democratic Republic of Ethiopia, Institute of Biodiversity Conservation, Addis Ababa, Ethiopia. pp. 1-77.

IBC (2009). Convention on BiologicalDiversity (CBD) Ethiopia's 4th country Report. Addis Ababa, Ethiopia.

IUCN (2020). The IUCN Red List of Threatened Species. Version 2020-3. Available at: http://www.iucnredlist.org. Accessed on 21 December 2020.

Jaganathan, G. K., Dalrymple, S. E. andLiu, B. (2015). Towards an understanding of factors controlling seed bank composition and longevity in the alpine environment. *The Botanical Review* **81**(1): 70-103.

Jansen, P.C.M. (1981). Spices, Condiments and Medicinal plants in Ethiopia, their Taxonomy and Agricultural Significance. Center for Agricultural Publishing and Documentation Wageningen, Netherlands. pp. 327.

Janssens, F., Peeters A., Tallowin, J.R.B., Bakker, J.P., Bekker, R.M., *et al.* (1998). Relationship between soil chemical factors and grassland diversity. Plant and Soil **202** (1): 69–78.

Kacholi, D.S. (2014). Edge-Interior Disparities in Tree Species and Structural Composition of the Kilengwe Forest in Morogoro Region, Tanzania. *ISRN Biodiversity* **2014:**1-8.

Kalayu Mesfin, Gebru Tekle and Teklemichael Tesfay (2013). Ethnobotanical Study of Traditional Medicinal Plants Used by Indigenous People of Gemad District, Northern Ethiopia. *Journal of Medicinal Plants Studies* **1**(4): 32-37.

Mohammed Kasso and Balakrishnan, M. (2013). Ex situ conservation of biodiversity with particular emphasis to Ethiopia. *International Scholarly Research Notices*.

Kebede Deribe, Alemayehu Amberbir, Binyam Getachew and Yunis Mussema (2006). A historical overview of traditional medicine practices and policy in Ethiopia. *Ethiopian Journal of Health Development* **20**(2): 127–134.

Kebrom Tekle and Tesfaye Bekele (2000). The role of soil seed banks in the rehabilitation of degraded hill slopes in southern Wello, Ethiopia. *Journal of Biotropica* **32**(1): 23-32.

Kent, M. (2012).Vegetation description and data analysis: a practical approach. 2nd ed. John Wiley & Sons, New York. pp. 414.

Ketema Tolossa, Etana Debela, Spiridoula Athanasiadou, Adugna Tolera, Gebeyehu Ganga and Jos GM Houdijk (2013). Ethno-medicinal study of plants used for treatment of human and livestock ailments by traditional healers in South Omo, Southern Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **9**(32):1-15.

Kflay Gebrehiwot, Sebsebe Demissew, Zerihun Woldu, Mekbib Fekadu, Temesgen Desalegn and Ermias Teferi (2019). Elevational changes in vascular plants richness, diversity anddistribution pattern in Abune Yosef mountain range, Northern Ethiopia. *Plant Diversity*: **41**(4): 220–228.

Khaine, I. and Woo, S.Y. (2015**)**. An overview of interrelationship between climate change and forests. *Forest Science and Technology* **11**(1):11–18.

Khan, M. L, Rai, J. P. N. and Tripathi, R. S. (1987). Population structure of some tree species in disturbed and protected sub-tropical forests of north-east India. *Acta Oecologia: Oecologia Applicata* **8**(2): 247-255.

Kharkwal, G., Mehrotra, P., Rawat, Y. S. and Pangtey, Y. P. S. (2005). Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. *Current Science* **89** (5): 873-878.

Khumbongmayum, A.D., Khan, M.L. and Tripathi, R.S. (2006). Biodiversity conservation in sacred groves of Manipur, northeast India: Population structure and regeneration status of woody species. *Biodiversity and Conservation* **15:** 2439-2456.

Kidane Georgis (2010). Agricultural based Livelihood Systems in Drylands in the Context of Climate Change. Inventory of Adaptation Practices and Technologies of Ethiopia. Food and Agriculture Organization of the United Nations, Rome. pp.57.

Kindeya Gebrehiwot (1997). Area enclosures as an approach in the management of dryland biodiversity: a case study in Tigray region, Northern Ethiopia. Paper presented at the workshop on Management of dryland biodiversity, Nairobi, Kenya.

Kindeya Gebrehiwot, Teklay Woldetensae, Emiru Birhane and Sarah Tewolde-Berhan (2016). Propagation Method of the Lowland Bamboo through Seed and Culm Cuttings in Hirmi natural forest, Tigray regional state- Ethiopia. *Journal of the Dry lands*. **6**(2): 513 – 518.

Kooch, Y., Jalilvand, H., Bahmanyar, M.A. and Pormajidian, M.R. (2009). Differentiation of ecosystem units of Caspian lowland forests and its relation with some soil characteristics.

Koprdova, S., Saska, P., Honek, A. and Martinkova, Z. (2010). Seed consumption by millipedes. *Pedobiologia* **54**(1): 31-36.

Körner, C. (2000). Why are there global gradients in species richness? Mountains may hold the answer. *Trends in Ecology and Evolution* **15**: 513 514.

Kreft, H and Jetz, W. (2007). Global patterns and determinants of vascular plant diversity. *PNAS* **104**(14):5925-5930.

Kumaraswamy, S. and Udayakumar, M. (2011). Biodiversity banking: a strategic conservation Mechanism. *Biodiversity and Conservation* **20** (6):1155-1165.

Kumelachew Yeshitila and Taye Bekele (2003). The woody species composition and structure of Masha-Anderacha forest, southwestern Ethiopia. *Ethiopian Journal of Biological Science* **2**(1): 31 – 48.

Lamprecht, H. (1989). Silviculture on the Tropics. Tropical forest ecosystems and their tree species – Possibilitiesand methods for their long term utilizations.

Lan, G., Getzin, S., Wiegand, T., Hu, Y., Xie, *et al.* (2012). Spatial distribution and interspecific associations of tree species in a Tropical Seasonal Rain Forest of China. *PLOS ONE* **7**(9):1-9

Landon, J.R. (1991). Tropical soil manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. pp .474.

Latham, R.E. and Ricklefs, R.E. (1993). Continental comparisons of temperate-zone tree species diversity. In: Species Diversity in Ecological Communities (Ricklefs RE, Schluter D, eds). University of Chicago Press, Chicago. pp. 294–314.

Legendre, P. and Legendre, L. (2012). *Numerical Ecology*. Third. Elsevier B.V., Amsterdam, The Netherlands.

Lei, J., Du, H., Duan, A., Zhang, J. (2019). Effect of Stand Density and Soil Layer on Soil Nutrients of a 37-Year-Old Cunninghamia lanceolata Plantation in Naxi, Sichuan Province, China. *Sustainability* **11**(5410): 1-20.

Leitner, W. and Turner, W.R. (2001).Measurement and analysis of biodiversity. In: Encyclopedia of biodiversity, Vol. 4, Levin S. A. (ed.), Academic Press, Princeton. pp. 123-144.

Lepš, J. and Šmilauer, P. (1999). Multivariate Analysis of Ecological Data. Faculty of Biological Sciences, University of South Bohemia Ceské Budejovice.

Leul Kidane (2015). Vegetation ecology and plant diversity of Hugumburda-Gratkhassu National Forest Priority Area, Northeastern Ethiopia: habitat fragmentation in time and space. PhD Dissertation. Addis Ababa University, Ethiopia.

Leul Kidane, Gebrecherkos Gebremedhin and Tadesse Beyene (2018). Ethnobotanical study of medicinal plants in Ganta Afeshum District, Eastern Zone of Tigray, Northern Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **14** (64): 1-19.

Levick, S., Setterfield, S., Rossiter-Rachor, N., Hutley, L., McMaster, D. and Hacker, J. (2015). Monitoring the distribution and dynamics of an invasive grass in tropical savanna using airborne LiDAR. *Remote Sensing* **7**(5):5117-5132.

Li, C., Xiao, B., Wang, Q., Zheng, R., Wu, J. (2017). Responses of Soil Seed Bank and Vegetation to the Increasing Intensity of Human Disturbance in a Semi-Arid Region of Northern China. *Journal of Sustainability* **9** (10): 1-13.

Li, Q., Yang, X., Soininen, J., Chu, C.-J., Zhang, J.-Q. *et al*. (2011). Relative importance of spatial processes and environmental factors in shaping alpine meadow communities. *Journal of Plant Ecology* **4** (4):249- 258.

Lovett, J.C. and Wasser, S.K. (eds.) (1993). Biogeography and ecology of the rain forests of eastern Africa. Cambridge University Press, Cambridge, UK.

Luzuriaga, A. L., Escudero, A., Olano, J. M. and Loidi, J. (2005). Regenerative role of seed banks following an intense soil disturbance. *Acta Oecologica* **27** (1): 57–66.

Lyaruu, H.V., Eliapenda S. and Backeus, I. (2000). Floristic, structural and seed bank diversity of a dry Afromontane forest at Mafai, central Tanzania. *Biodiversity and Conservation* **9** (2):241-263.

Lysenko, D., Dhanai, C., Singh, B., Chauhan, S., Todaria, N. and Khalid, M. (2008). Regeneration and tree diversity in natural and planted forests in a terai-bhabhar forest in Katarniaghat wildlife sanctuary, India. *Tropical Ecology* **49** (1): 53– 67.

Mace, G.M., Norris, K. and Fitter, A.H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology and Evolution* **27** (1): 19 –26.

Magurran, A. E. (1988). Ecological diversity and its measurement. Chapman and Hall, London.

Magurran, A.E. (2004). Measuring Biological Diversity. Blackwell Publishing, Oxford, UK. pp.256.

Magurran, A.E. and McGill, B.J. (2011). Challenges and opportunities in the measurement and assessment of biological diversity Biological diversity. Oxford University Press. pp. 1-7.

Martin, G.J. (1995). Ethnobotany. A People and plants conservation manual. Chapman and Hall, London. pp.268.

Masika, P.J. and Afolayan, A.J. (2003). An Ethnobotanical Study of Plants Used for the Treatment of Livestock Diseases in the Eastern Cape Province, South Africa. *Pharmaceutical Biology* **41** (1): 16-21.

May, R.M. (1988). How many species on earth? *Science* **241** (4872):1441-1449.

Mayaux, P., Holmgren, P., Achard, F., Eva, H., Stibig, H., Branthomme, A. (2005). Tropical forests cover change in the 1990s and options for future monitoring. *Philosophical Transactions of the Royal Society* **360** (1454):373–384.

McCune, B. and Grace, J.B. (2002). Analysis of Ecological Communities. MjM Software Design, Oregon, USA. pp.301.

McKey, D. (1994). Legumes and nitrogen: the evolutionary ecology of a nitrogen demanding lifestyle. Pages 211–228 in Advances in Legume Systematics, part 5, the nitrogen factor (J. I. Sprent and D. McKey, eds.). Royal Botanic Gardens, Kew, UK.

McLaren, K.P. and McDonald, M.A. (2003). Coppice regrowth in a disturbed tropical dry limestone forest in Jamaica. *Forest Ecology and Management* **180 (**3**)**: 99-111.

Meire, E., Frankl, A., DeWulf, A., Mitku, Haile, Deckers, J. and Nyssen, J. (2013). Land use and cover dynamics in Africa since the nineteenth century: Warped terrestrial photographs of North Ethiopia. *Regional Environmental Change* **13**(3):717–737.

Mengistu Gebrehiwot (2010). An ethnobotanical study of medicinal plants in Seru wereda, Arsi Zone of Oromia Region, Ethiopia. MSc. Thesis, AAU, Ethiopia.

Mersha Ashagre (2011). Ethnobotanical Study of Medicinal Plants used by Guji Agropastorialists in Bule Hora Wereda, Southeren Oromia, Ethiopia. MSc Thesis, AAU, Ethiopia.

Mersha Ashagre, Ensermu Kelbessa and Gemedo Dalle (2016). Ethnobotanical study of medicinal plants in Guji Agro-pastoralists, Bule Hora District of Borana Zone, Oromia Region, Ethiopia. *Journal of Medicinal Plants Studies* **4**(2): 170-184.

Mesfin Tadesse (2004). Asteraceae (Compositae). **In**: Hedberg, I, Friis, I.B. and Edwards, S. (eds.). *Flora of Ethiopia and Eritrea Volume 4, part 2.* The National Herbarium, Addis Ababa University, Ethiopia, Uppsala, Sweden.

Miles, L., Newton, A.C., DeFries, R.S., Ravilios, C., May, I. *et al.* (2006). A global overview of the conservation status of tropical dry forests. Journal of Biogeography **33** (3):491–505.

Million Bekele (2011). Forest plantations and woodlots in Ethiopia: African Forest Forum, 1.

Ministry of Agriculture (2003). A strategic plan for the sustainable development, conservation and management of the woody biomass resources (Final Draft). Woody Biomass Inventory and Strategy Planning Project Office, Addis Ababa.

Ministry of Environment and Forestry (MEF) (2015). Pilot Redd+ Sites Visit Report. Federal Democratic Republic of Ethiopia, Addis Ababa.

Ministry of Environment, Forestry and Climate Change (MEFCC) (2017). Ethiopia‟s Forest Reference Level Submission to the UNFCCC. Addis Ababa, Federal Democratic Republic of Ethiopia.

Mirgissa Kaba (1996). Utilization of plant medicine for the treatment of health problems. The case of Oromo District, Illubabor Zone, Western Ethiopia. *Ethiopian Journal Health Development* **10** (3): 161-162.

Mirutse Giday and Tilahun Teklehaymanot (2013). Ethnobotanical study of plants used in management of livestock health problems by Afar people of Ada'ar District, Afar Regional State, Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **9** (1): 1-8.

Mirutse Giday, Zemede Asfaw, Thomas Elmqvist and Zerihun Woldu (2003). An ethnobotanical study of medicinal plants used by the Zay people in Ethiopia. *Journal of Ethnopharmacology* **85** (1): 43-52.

Mirutse Giday, Zemede Asfaw and Zerihun Woldu (2010). Ethnomedicinal study of plants used in Sheko ethnic group of Ethiopia. *Journal of Ethnopharmacology* **132** (1):75-85.

Mirutse Giday, Zemede Asfaw, Zerihun Woldu and Tilahun Teklehaymanot (2009). Medicinal plant knowledge of the Bench ethnic group of Ethiopia: an ethnobotanical investigation *Journal of Ethnobiology and Ethnomedicine* **5** (1) 1-10.

Misganaw Meragiaw (2016). Wild useful plants with emphasis on traditional use of medicinal and edible plants by the people of Aba'ala, North-eastern Ethiopia. *Journal of Medicinal Plant and Herbal Therapy Research* **4** (1):1-16.

Mitku Haile and Kindeya Gebrehiwot (2000). Efforts to rehabilitate degraded lands: local initiative for planning resource management in Tigray. University of Trieste, Italy.

Mittermeier, R.A., Myers, N. and Thomsen, J.B. (1998). Biodiversity hotspots and major tropical wilderness areas: Approaches to setting conservation priorities. *Conservation Biology* **12**(3):516-520.

Mohr, P.A. (1971). The Geology of Ethiopia. Haile-Sellasie I Univ. Press, Addis Ababa.

Moses, N.S., Felix, N. A. and Townsend, P. (2020).Diversity, above-ground biomass andvegetation patterns in a tropical dry forest in Kimbi-Fungom National Park, Cameroon. *Heliyon* **6** (1): 1-12.

Motuma Didita, Sileshi Nemomissa and Tadesse Woldemariam (2010). Floristic and structural analysis of the woodland vegetation around Dello Menna, Southeast Ethiopia. *Journal of Forestry Research* **21**(4): 395-408.

Mueller-Dumbois and Ellenberg, H. (1974). *Aims and Methods of Vegetation Ecology*. John Willey and Sons, New York. pp.547.

Mulugeta Lemenih and Bongers, F. (2011). Dry Forests of Ethiopia and Their Silviculture. in the Tropics Springer, Berlin, Heidelberg. pp. 261-272.

Mulugeta Lemenih and Demel Teketay (2005). Effect of prior land use on the recolonization of native woody species under plantation forests in the highlands of Ethiopia. *Forest Ecology and Management* **218**(3): 60-73.

Mulugeta Lemenih and Demel Teketay (2006). Changes in soil seed bank composition and Density following deforestation and subsequent cultivation of a tropical dry Afromountane forest in Ethiopia. *Tropical Ecology* **47** (1): 1-12.

Mulugeta Lemenih and Habtetmeraim Kassa (2010). Socio-economic and environmental significance of dry land resources of Ethiopia and their development challenges.

Mulugeta Lemenih and Habtetmeraim Kassa (2011). Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia. Center for International Forestry Research Bogor, Indonesia. pp. 1-107.

Mulugeta Lemenih and Tadesse Woldemariam (2010). Review of forest, woodland and bushland resources in Ethiopia up to 2008. In: Ethiopian Environment Review. pp. 131-186 (Edwards, S., ed.). Forum for Environment Addis Ababa, Ethiopia.

Murphy, P.G. and Lugo, A.E. (1986). Ecology of tropical dry forest. *Annual Review of Ecology and Systematics* **17** (1):67-88.

Musse Tesfaye and Mesele Negash (2018). Combretum-Terminalia vegetation accumulate more carbon stocks in the soil than the biomass along the elevation ranges of dryland ecosystem in Southern Ethiopia. *Journal of Arid Environments* **155**: 59-64.

Muys, B., Kindeya Gebrehiwot, Aerts, R., Mitiku Haile and Deckers, J. (2006). Perspectives for the rehabilitation of dryland forests in Ethiopia. Journal of the Drylands **1**(2): 217-220.

National Metrological Service Agency (NMSA) (2018). Data of Rainfall and Temperature of 20 years (1998-2017). Addis Ababa, Ethiopia.

Nebiyu Abesha (2009). Domestic Energy Consumption and Deforestation in Harari region: Assessment of Students' Awareness and Views. Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Newton, A.C. (2007). Forest ecology and conservation: A handbook of techniques. Oxford University Press, Oxford, UK. pp. 454.

Nirmal, K. J., Patel, K., Kumar, R.N. and Kumar, B.R. (2011). Forest structure,diversity and soil properties in a dry tropical forest in Rajasthan, Western India. *Annual Forest Research* **54**(1):89-98.

Noss, R.F. (1999). Assessing and monitoring forest biodiversity: A suggested framework and indicators. *Forest Ecology and Management* **115** (3):135-146.

Nyssen, J., Unro, M.R.N., Mitiku Haile, Poesen, J., Descheemaeker, K., *et al.* (2007). Understanding the environmental changes in Tigray: a photographic record over 30 years. Tigray Livelihood Papers No. 3, VLIR – Mekelle University IUC Programme and Zala-Daget Project. pp.82.

O'Geen, A.T., Elkins, R. and Lewis, D. (2006). Erodibility of agricultural soils, with examples in Lake and Mendocino counties. Oakland: University of California Division of Agriculture and Natural Resources, Publication 8194. Available online: http://anrcatalog.ucdavis.edu

Oleg, E. (2012). Brief Odonata survey in North Ethiopia during heavy rainy season. *Journal of the International Dragonfly Fund* **56:** 1-54

Osem, Y., Zangy, E., Bney-Moshe, E., Moshe, Y., Karni, N., Nisan, Y. (2009). The potential of transforming simple structured pine plantations into mixed Mediterranean forests through natural regeneration along a rainfall gradient. *Forest Ecological Management* **259** (1): 14–23.

Ososki, A.L., Michael, Balick, J. and Daly, D.C. (2007). Medicinal plants and cultural variation across Dominican rural, urban and transnational landscapes. In traveling cultures & plants. *The Ethnobiology & Ethnopharmacy of Human Migrations* **7:** 14-39.

Pausas, J.G., Carreras, J. and Ferreira, A. (2003). Coarse-scale plant species richness in relation to environmental heterogeneity. *Journal of Vegetation Science* **14**:661-668.

Peri , P. L., Rosas, Y. M., Ladd, B., Toledo, S. et al.(2019). Modeling Soil Nitrogen Content in South Patagonia across a Climate Gradient, Vegetation Type andGrazing. *Sustainability* **11** (9): 1-15

Pichi-Sermolli, R.E.G. (1957). Una carta geobotanica dell'Africa Orientale (Eritrea, Etiopia. Somalia). *Webbia* **13** (1):15-132.

Pielou, E.C. (1966). Species diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical* Biology **10**(2): 370–383.

Pimm, L. and Raven, P. (2000). Extinction by numbers. Nature **403** (6772):843-845.

Prasad, R. and Power F. J. (1995). Nitrification Inhibitors for Agriculture, Health andthe Environment. *Advances in Agronomy* **54**:233-281

Purvis, A. and Hector, A. (2000). A review article on Getting the measure of biodiversity. Department of Biology and Centre for Population Biology, Imperial College, Silwood Park, Ascot, Berkshire SL5 7PY, UK.

Qiuyan, L., Haiyan, F. and Qiangguo, C. (2011). Persistent soil seed banks along altitudinal gradients in the Qilian Mountains in China and their significance for conservation management**.** *African Journal of Agricultural Research* **6** (10): 2329-234.

R Development Core Team (2019). R: A Language and Environment for Statistical Computing. URL. http://www.r-project.org/.

Rawat, U.S. and Agarwal, N.K. (2015). Biodiversity: Concept, threats and conservation. *Environment Conservation Journal* **16**(3):19-28.

Rasse, D.P., Mulder, J., Moni, C., Chenu, C. (2006). Carbon turnover kinetics with depth in an Ftench loamy soil. *Soil Science Society of America Journal* **70**(6): 2097-2105.

Reid, W.V. (1998). Biodiversity hotspots. *Tree* **13**(7):275-280.

Reubens, B., Heyn, M., Kindeya Gebrehiwot, Hermy, M. and Muys, B. (2007). Persistent Soil Seed Banks for Natural Rehabilitation of Dry Tropical Forests in Northern Ethiopia. *TROPICULTURA* **25**(4): 204-214.

Reubens, B., Moeremans, C., Poesen, J., Nyssen, J., Tewoldeberhan, S. *et al.* (2011). Tree species selection for land rehabilitation in Ethiopia: from fragmented knowledge to an integrated multi-criteria decision approach. *Agroforestry systems* **82**(3), 303-330.

Rey, P.J., Julio, M. and Alcantara, M. (2000). Recruitment dynamics of a fleshy-fruited plant (*Olea europaea*): Connecting patterns of seed dispersal to seedling establishment. *Journal of Ecology* **88**(4): 622-633.

Rico-Gray, V. and Garcia, J. G. (1992). Vegetation and soil seed bank of success ional stages in tropical low Land deciduous forest. *Journal of Vegetation Science* **3**(5): 617-624.

Roem, W.J. and Berendse, F. (2000). Soil acidity and nutrient supply ratio as possible factors determining changes in plant species diversity in grassland and heathland communities. *Biological Conservation* **92** (2): 151-161.

Rosenzweig, M. L. (1995). Species diversity in space and time. Cambridge University Press, Cambridge.

Rutherford, M. C. andWestfall, R. H. (1994). Biomes of southern Africa: an objective categorization. National Botanical Institute. pp.31-51.

Sahlemedhin Sertsu and Taye Bekele (2000). Procedures for soil and plant analysis. National Soil Research Centre, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia. pp.110.

Sanchez, P.A. (1976). Properties and management of soils in the tropics. JohnWiley and Sons, Inc., New York, USA. pp.618.

Sanjit, L. and Bhatt, D. (2005). How relevant are the concepts of species diversity and species richness? *Journal of Biosciences* **30**(5): 557-560.

Schaetzl, R.J. and Thompson, M.L. (2015). Soils: Genesis and Geography, 2 Edition, Cambridge University Press, New York, USA. pp. 795.

Schmitt, C.B. Feyera Senbeta, Tadesse Woldemariam, Rudner, M. and Denich, M. (2013). Importance of regional climates for plant species distribution patterns in moist Afromontane forest. *Journal of Vegetation Science* **24** (3): 553–568.

Schoenholtza, S.H., Van Miegroetb, H. and Burgerc, J.A. (2000). A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. *Forest Ecology and management* **138** (3): 335-356.

Schunko, C. and Vogl, C.R. (2010). Organic farmers' use of wild food plants and fungi in a hilly area in Styria (Austria). Journal of Ethnobiology and Ethnomedicine **6**(17): 1-14.

Sebsebe Demissew, Cribb, P. and Rasmussen, F. (2004). Field Guide to Ethiopia Orchids. Kew Field Guide, Royal Botanic Gardens, Kew.

Sebsebe Demissew, Mengistu Wondafrash and Yilma Dellellegn (1996). Ethiopia's natural resources base. In: Sue Edwards (ed) Important Bird Areas of Ethiopia: A first Inventory. Ethiopian Wildlife and Natural History Society, Addis Ababa.

Seyoum Getaneh and Zerihun Girma (2014). An ethnobotanical study of medicinal plants in Debre Libanos Wereda, Central Ethiopia. *African Journal of Plant Science* **8**(7): 366 - 379.

Sharrock, S., Oldfield, S. and Wilson, O. (2014). A review of progress in implementation of the Global Strategy for Plant Conservation 2011-2020. Secretariat of the Convention on Biological Diversity, Montreal, Canada and Botanic Gardens Conservation International, Richmond, UK. pp. 56.

Shen, Y., Liu, W.Y., Cao, M. and Li, Y. (2007). Seasonal variation in density and species richness of soil seed-banks in karst forests and degraded vegetation in central Yunnan, SW China. *Seed Science Research* **17** (2):99–107.

Sheunesu, R. (2018). The Edge Effect on Plant Diversity & Soil Properties in Abandoned Fields Targeted for Ecological Restoration. *Journal of sustainability* **11**(1):1-12.

Silva, F.D.S., Ramos, M.A., Hanazaki, N. and Albuquerque, U.P. (2011). Dynamics of traditional knowledge of medicinal plants in a rural community in the Brazilian semi-arid region. *Brazilian Journal of Pharmacognosy* **21** (3): 382-391.

Simberloff, D. (1986). Are we on the verge of a mass extinction in tropical rain forests? In: *Dynamics of Extinction*, Elliott, D. K. (ed), John Wiley and Sons, New York. pp 165-180.

Simpson, R. L., Leck, M. A. and Parker, V. T. (1989). Seed banks: general concepts and Methodological issues. pp. 3-8. In: M.A. Leck, V. T. Parker and R. L. Simpson (eds). *Ecology of Soil Seed Banks*. Academic Press, San Diego.

Slikkerveer, L. (1990). Plural Medical Systems in the Horn of Africa: The Legacy of "Sheik" Hippocrates. Kegan-Paul International, London, & New York.

Small, C.J. andMcCarthy, B.C. (2010). Seed Bank Variation under Contrasting Site Quality Conditions in Mixed Oak Forests of Southeastern Ohio, USA. International Journal of Forestry Research. pp. 1-13.

Smith, F. (1996). Biological diversity, ecosystem stability and economic development. *Ecological Economics* **16** (3): 191–203.

Snyman, H.A. (2003). Revegetation of bare patches in a semi-arid rangeland of South Africa: an evaluation of various techniques. *Journal of Arid Environments* **55** (3): 417–432.

Song, G., Li, X. and Hui, R. (2017). Effect of biological soil crusts on seed germination and growth of an exotic and two native plant species in an arid ecosystem. *PLOS ONE* **12**(10): 1-16.

Southwood, T.R.E., Handerson, P.A. (2000). Ecological Methods Blackwell Science Ltd, oxford.

Spellerberg, I.F. (1991). Monitoring ecological change.Cambridge University Press. Cambridge.

Sprent, J. I. (2001). Nodulation in legumes. Royal Botanic Gardens, Kew, UK. Pp. 797-798.

Stephane, D., Sonia, S. and Francois, D. (2008). Spatial ordination of vegetation data using a generalization of Wartenberg's multivariate spatial correlation. *Journal of Vegetation Science* **19** (1): 45-56.

Stolton, S. and Dudley, N. (2010). The Contribution of Protected Areas to Human Health. WWF and Equilibrium Research,Gland, Switzerland.

Suratman, M. N. (2012). Tree species diversity and forest stand structure of Pahang National Park, Malaysia. *Biodiversity enrichment in a diverse world*. pp.473-492.

Swaine, M.D., Lieberman, D., Hall, J.B. (1990). Structure and dynamics of a tropical dry forest in Ghana. *Vegetation* **88** (1): 31-51.

Tadesse Beyene (2015). Ethnobotany of medicinal plants in Erob and Gulomahda districts, Eastern Zone of Tigray Region, Ethiopia. PhD Dissertation. Addis Ababa University, Ethiopia.

Tafesse Mesfin and Mekonen Lemma (2001). The role of traditional veterinary herbal medicine and its constraints in animal healthcare system in Ethiopia. **In**: *Biodiverssity Consevation and Sustainable use of medicinal plants in Ethiopia.* pp 23-33 (Medhin Zewdu and Abebe Demissie, eds.). Proceeding of the National Workshop on 28 April- o1 May 1998. IBCR, Addis Ababa.

Tamrat Bekele (1993). Vegetation ecology of remnant Afromontane forests on the central plateau of Shewa, Ethiopia. *Acta Phytogeographica Suecica* **79**: 1–64.

Tamrat Bekele (1994). Phytosociology and ecology of a humid Afromontane forest on the central plateau of Ethiopia. *Journal of Vegetation Science* **5** (1): 87−98.

Tebkew Mekuanent, Asfaw Zebene and Zewudie Solomon (2015). Ethnobotanical Study of Medicinal Plants in Chilga District, Northwestern Ethiopia. *Journal of Natural Remedies* **15** (2): 88-112.

Tefera Mengistu, Demel Teketay, Hultenc, Y. Yemshaw (2005). The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia. *Journal of Arid Environments* **60** (2): 259–281.

Teferi Gedif and Hahn, H. (2003). The use of Medicinal Plants in self-care in rural central Ethiopia. *Journal of Ethnopharmacology* **87** (3): 155-161.

ter Braak, C.J.F. and Prentice, I.C. (1988). A theory of gradient analysis. *Advances in Ecological Research* **18**: 271-317.

Terborgh, J. and Andresen, E. (1998). The composition of Amazonian forests: patterns at local and regional scales. *Journal of Tropical Ecology* **14** (5): 645–664.

Tesfaye Awas and Sebsebe Demissew (2009). Ethnobotanical study of medicinal plants in Kafficho people, south western Ethiopia. **In**: proceeding of the 16th international conference of Ethiopian studies. pp. 711-726.

Tesfaye Bekele (2000). Plant population dynamics of *Dodonea angustifolia* and *Olea europaea* subsp. *cuspidata* in dry Afromontane forests of Ethiopia. Ph.D. Dissertations, Uppsala University, Uppsala.

Tessema Tanto, Mirutse Giday, Negusu Aklilu and Teshome Hunduma (2003). Medicinal Plants Biodiversity. National Biodiversity Strategy and Action Plan (NBSAP) Project. Institute of Biodiversity Conservation and Research, Addis Ababa, Ethiopia.

TewoldeBerhan GebreEgziabher (1988). Vegetation and environment of the mountains of Ethiopia: Implications for utilization and conservation. *Mountain Research and Development* **8** (2): 211-216.

TewoldeBerhan GebreEgziabher (1991). Diversity of Ethiopian flora. In: Plant Genetic Resources of Ethiopia pp. 75-81, (Engels, J.M.M., Hawkes, J.G. and MelakuWorede, eds.). Cambridge University Press, Cambridge.

Tezera Jemere, Dessie Tegegne and Kefyalew Ayalew (2020). Assessment of Knowledge, Attitude andUtilization of Traditional Medicine among the Communities of Debre Tabor Town, Amhara Regional State, North Central Ethiopia: A Cross-Sectional Study. Evidence-Based Complementary and Alternative Medicine. pp. 1-10.

Thomas, R.J., El-Dessougi, H., Tubeileh, A. (2006).Soil System Management Under Arid and Semi-Arid Conditions. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. pp.41-55.

Tilahun Teklehaymanot (2009). Ethnobotanical study of knowledge and medicinal plants use by people in Dek Island in Ethiopia. *Journal Ethnopharmacology* **124** (1):69–78.

Toledo, L. and Ramos, M. (2011). The soil seed bank in abandoned tropical pastures: source of regeneration or invasion. *Biodiversity* **82** (2): 663-678.

Trotter, R.T. and Logan, M.H. (1998). Informants consensus: a new approach for identifying potentially effective medicinal plants In: *Plants in indigenous Medicine and Diet,* N.L. Etkin (ed.) Redgrave publishing Company, Bedford hill, NY. pp. 91-112.

Tryon, R. C. (1939). Cluster analysis. New York: McGraw-Hill.

Tsehaye Gebrelibanos and Mohammed Assen (2013). Effects of slope aspect and vegetation types on selected soil properties in a dryland Hirmi watershed and adjacent agro-ecosystem, northern highlands of Ethiopia. *African Journal of Ecology* **52** (3):292–299.

Tsehaye Gebrelibanos and Mohammed Assen (2015). Land use/land cover dynamics and their driving forces in the Hirmi watershed and its adjacent agroecosystem, highlands of Northern Ethiopia. *Journal of Land Use Science* **10**(1): 81-94.

Tuomisto, H. (2012). An updated consumer's guide to evenness and related indices. *Oikos* **121** (8): 1203–1218.

Tuxill, J. and Nabhan, G.P. (2001). People, plants and protected areas. Earthscan publication Ltd, London and Sterling. pp.248.

Umulisa, C. (2012). Sampling Methods and Sample Size Calculation for the SMART Methodology. *University* [Internet] 20-30.

USAID (2008). Ethiopia Biodiversity and Tropical Forests 118/119 Assessment, pdf. pp. 1-81.

Van der Maarel, E. (1979). Transformation of cover-abundance values in phytosociology and its effects in community similarity. *Vegetation* **39** (2): 97-114.

Van der Maarel, E. (2005). Vegetation Ecology. Blackwell Science publishing, Ltd, USA.

Van der Valk, A.G. and Pederson, R.L. (1989). Seed banks and the management and restoration of Natural vegetation. **In**: Ecology of seed banks (Leck, M.A; Parker, V.T. and Simpson, R.L. eds.), Academic press, Inc. San Diego. pp.329-346.

van Tongeren, O. F. R. (1995). Cluster analysis. **In**: *Data Analysis in Community and Landscape Ecology*, Jongman, R.H.G., ter Braak, C.J. F. and van Tongeren, O.F.R. (eds), Cambridge University Press, Cambridge, UK, pp. 174-212.

Vieira, D.L. and Scariot, A. (2006). Principles of natural regeneration of tropical dry forests for restoration. *Restoration ecology* **14** (1):11–20.

Vieira, D. L., Scariot, A. and Holl, K. D. (2007). Effects of habitat, cattle grazing and selective logging on seedling survival and growth in dry forests of Central Brazil. *Biotropica* **39**(2) 269-274.

Virgo, K.J. and Munro, R.N. (1978) Soil and erosion features of the Central Plateau region of Tigrai, Ethiopia. Geoderma **20** (2): 131–157.

Vivero, J.L., Ensermu Kelbessa and Sebsebe Demissew (2005). The Red List of Endemic Trees & Shrubs of Ethiopia and Eritrea. Fauna & Flora International, United Kingdom. pp. 28.

Wade, M.R., Gurr,G.M., Wratten, S.D. (2007). Ecological restoration of farmland: progress and prospects. *Ecological restoration of farmland* **363** (1492): 831–847.

Wakene Negassa (2001). Assessment of important physicochemical properties of Dystric Udalf under different management systems in Bako area, western Ethiopia. M.Sc. Thesis Submitted to School of Graduate Studies, Alemaya University, Ethiopia. pp. 93.

Wakshum Shiferaw, Mulugeta Lemenih and Tadesse Woldemariam (2018). Analysis of plant species diversity and forest structure in Arero dry Afromontane forest of Borena zone, South Ethiopia. The Journal of the Society for Tropical Plant Research: DOI: 10.22271/tpr.2018.v5.i2.018.

Walkley, A. and Black, I. A. (1934). An examination of the detjareff method for determining soil organic matter and a proposed modification to the chronic acid titration method. *Soil Science*. **37:** 29–38.

Wang, J., Wang, H., Cao, Y., Bai, Z. and Qin, Q. (2016). Effects of soil and topographic factors on vegetation restoration in opencast coal mine dumps located in a loess area. *Scientific Reports* **6** (1):1–11.

Wang, Y., Jiang, D., Toshio, O. and Zhou, Q. (2013). Recent Advances in Soil Seed Bank Research. *Contemporary Problems of Ecology* **6** (5):520–524.

Wanga, S. M., Zhang, X., Li, Y., Zhang, L., Xiong, Y.C. and Wang, G. (2005). Spatial distribution patterns of the soil seed bank of Stipagrostis pennata (Trin.) de Winter in the Gurbantonggut Desert of north-west China. *Journal of Arid Environments* **63**(1):203-222.

Ward, C. (2008). Encyclopedia of Soil Sciences. University of Guelph, Canada. pp.656.

White, F. (1983). The Vegetation of Africa: A descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. UNESCO, Switzerland. pp. 353.

Whittaker, R.H. (1972). Evolution & measurement of species diversity. *Taxon* **21**(3): 213-251.

Whittaker, R.H. (1975). *Communities and Ecosystems*. MacMillan, London. pp.385.

Whittaker, R.J., Willis, K.J. and Field, R. (2003). Climatic–energetic explanations of diversity: a macroscopic perspective. In: Macroecology: concepts and consequences, Blackburn, T.M. and Gaston, K.J. (eds.), Cambridge University Press; Cambridge, pp. 107-129.

WHO (2003). Traditional medicine. World Health Organizationhttp://www.who.int/ mediacentre/ factsheets/fs134/en/print.html (Accessed date: 12/11/2012).

Williams, V.L. (2004). Trade and socio-economic value of forest and woodland Reserves within the Medicinal plant market in Johannesburg. In**:** *Indigenous Forests and Woodlands in South Africa: Policy. People and Practice*, pp. 439-472.

Wood, A, Stedman-Edwards, P. and Mang, J. (eds) (2000). The root causes of biodiversity loss. Earth scan Publishing Ltd, London.

Wright, D.H., Currie, D.J. and Maurer, B.A. (1993). Energy supply and patterns of species richness on local and regional scales. In: Species Diversity in Ecological Communities (Ricklefs RE, Schluter D, eds), pp. 66–74. University of Chicago Press, Chicago.

Wyatt, J.L. and Silman, M.R. (2004). Distance dependence in two Amazonian palms: effects of spatial and temporal variation in seed predator communities. Oecologia **140** (1): 26-35.

Yilma Abebe (2010). A Glimpse at Biodiversity Hotspots of Ethiopia: the essential directory for Environment and development. Ethiopian Wildlife and Natural History Society, Addis Ababa. pp.1-94

Yitebitu Moges, Zewdu Eshetu and Sisay Nune (2010). Ethiopian forest resources: Current status and future management options In View of Access to Carbon Finances: Ethiopian Climate Research and Networking andThe United Nations Development Programme (UNDP), Addis Ababa, Ethiopia.

Yohannis Teklu (2014). Soil Seed Bank Study at Gera Moist Evergreen Afromontane Forest, Jimma Zone of Oromia Regional State, Southwest Ethiopia. MSc. Thesis. Addis Ababa University, Addis Ababa, Ethiopia.

Zanine, A.M. and Ferreira, D.J. (2015). Animal Manure as a Nitrogen Source to Grass. *American Journal of Plant Sciences* **6** (7**):** 899-910.

Zenebe Girmay (2020).Tropical dry forest dynamics in the context of climate change: syntheses of drivers, gaps andmanagement perspectives. *Ecological Process* **9(**25):1-16.

Zerihun Tadesse, Ensermu Kelbessa and Tamrat Bekele (2018). Structural analysis of *Combretum-Terminalia* mixed Acacia vegetation in Ilu Gelan District, West Shewa Zone, Oromia Region, Central Ethiopia. Tropical Plant Research **5(1):** 61–76.

Zerihun Woldu (1985). Variation in Grassland Vegetation on the Central Plateau of Shewa, Ethiopia: in relation to edaphic factors and grazing conditions. Ph.D. Dissertation, Uppsala University, Uppsala.

Zerihun Woldu (1999). Forests in the vegetation types of Ethiopia and their status in the geographical context. In: The proceedings of the National Forest Genetic resources Conservation Development workshop. Addis Ababa, Ethiopia, pp. 1-38 workshop. Addis Ababa, Ethiopia. pp. 1-38.

Zerihun Woldu, Feoli, E. and Lisanework Nigatu (1989). Partitioning an elevation gradient of vegetation from southeastern Ethiopia by probabilistic methods. Vegetation **81:** 189–198.

Zerihun Woldu (2017). Comprehensive Analysis of Vegetation and Ecological Data: concepts and methods. Addis Ababa: Addis Ababa University Press. pp. 482.

Zhang, M., Chen, F., Chen, S., Xie, Z., Huang, Liu, Y. (2017). The soil seed bank of a rehabilitated draw-down zone and its similarity to standing vegetation in the Three Gorges Reservoir Area. *Ecollogical Research* **32** (6): 1011–1021.

Appendices

Appendix 1. List of plant species in/around Hirmi woodland vegetation (Growth form: T = Tree; S = Shrub; H = Herb; WC = Woody climber; HC =Herbaceous climber; * = species collected from cultivated area (out of the vegetation plots); MG=Mehari Girmay)

No	Scientific name	Family	Growth form	Local Name	Voucher number
1	*Acacia lahai* Steud. & Hochst. ex Benth.	Fabaceae	S	Lihay	MG87
2	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae	T	Chea	MG199
3	*Acacia albida* Del.	Fabaceae	T	Momona	MG176
4	*Acacia nilotica* (L.) Willd. ex. Del.	Fabaceae	T	Kerets	MG51
5	*Acacia polycantha* Willd.	Fabaceae	T	Gumero	MG166
6	*Acacia seyal* Del.	Fabaceae	T	Keyihchea	MG152
7	*Acacia venosa* Hochst. ex Benth.	Fabaceae	S	Kentib	MG37
8	*Acanthospermum hispidum* DC.	Asteraceae	H	Quakito	MG194
9	*Achyranthes aspera* L.	Amaranthaceae	H	Mikiele	MG142
10	*Acokanthera schimperi* (A.DC.) Schweinf.	Apocynaceae	S	Mebtie	MG182
11	*Adansonia digitata* L.	Bombacaceae	T	Dima	MG118
12	*Adiantum lunulatum* Burm.f.	Adiantaceae	H	-	MG139
13	*Agave sisalana* Perrine ex Engl.*	Agavaceae	H	Eika	MG43
14	*Ageratum conyzoides* L.	Asteraceae	H	Tsihay Kewuie	MG150
15	*Albizia amara* (Roxb.) Boiv.	Fabaceae	S	Eichdimu	MG185
16	*Albizia malacophylla* (A. Rich.) Walp.	Fabaceae	T	Turmi	MG115
17	*Allium sativum* L. *	Alliaceae	H	Tseada shugurti	MG81
18	*Aloe elegans* Tod.	Aloaceae	H	Ere	MG35
19	*Andrachne aspera* Spreng.	Euphorbiaceae	H	Hakinur	MG127
20	*Andropogon abyssinicus* Fresen.	Poaceae	H	Keransaeri	MG143
21	*Anogeissus leiocarpa* (DC.)Guill. & Perr.	Combretaceae	T	Hanse	MG126
22	*Antherotoma naudinii* Hook.f.	Melastomataceae	H	-	MG146
23	*Arthraxon micans* (Nees) Hochst.	Poaceae	H	-	MG55
24	*Azadirachta indica* A. Juss. *	Meliaceae	T	Niem	MG135
25	*Balanites aegyptiaca* (L.) Del.	Balanitaceae	T	Mekie	MG75
26	*Bersama abyssinica* Fresen.	Melianthaceae	S	Mirkus zibie	MG137
27	*Bidens macroptera* (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	H	Gelgelemeskel	MG93
28	*Bidens pilosa* L.	Asteraceae	H	Chegogo	MG114
29	*Boswellia papyrifera* (Del.) Hochst.	Burseraceae	T	Meker	MG47
30	*Brassica carinata* A. Br. *	Brassicaceae	H	Hamli Adri	MG2
31	*Buddleja cordata* H.B.K.	Loganiaceae	S	-	MG106
32	*Buddleja polystachya* Fresen.	Loganiaceae	T	Metere	MG28
33	*Calotropis procera* (Ait.) Ait. f.	Asclepiadaceae	S	Gindae	MG104
34	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	S	Hintsawusti	MG160

No	Scientific name	Family	Growth form	Local Name	Voucher number
35	*Capparis tomentosa* Lam.	Capparidaceae	S	Andel	MG141
36	*Capsicum annuum* L. *	Solanaceae	H	Gu'e	MG96
37	*Carissa spinarum* L.	Apocynaceae	S	Agam	MG175
38	*Caylusea abyssinica* (Fresen.) Fisch. & Mey.	Resedaceae	H	Mereret	MG169
39	*Cayratia gracilis* (Guill. & Perr.)	Vitaceae	HC	Hareg	MG134
40	*Cenchrus ciliaris* L.	Poaceae	H	-	MG78
41	*Chamaecrista mimosoides* (L.) Greene	Fabaceae	H	Seraw bayta	MG148
42	*Chloris pycnothrix* Trin.	Poaceae	H	-	MG11
43	*Cissus petiolata* Hook. f.	Vitaceae	WC	Alke	MG61
44	*Citrus aurantifolia* (Christm.) Swingle *	Rutaceae	S	Lemin	MG116
45	*Clematis simensis* Fresen.	Ranunculaceae	WC	Hareg-Temen	MG15
46	*Clerodendrum myricoides* (Hochst.) Vatke	Lamiaceae	S	Surbetri	MG13
47	*Coffea arabica* L. *	Rubiaceae	S	Buna	MG171
48	*Combretum adenogonium* Steud. ex A. Rich.	Combretaceae	T	Weyba	MG122
49	*Combretum hartmannianum* Schweinf.	Combretaceae	T	Sebea	MG18
50	*Combretum molle* R. Br. ex G. Don.	Combretaceae	T	Sesewe	MG82
51	*Combretum rochetianum* A. Rich. ex A. Juss.	Combretaceae	T	Afekemo	MG172
52	*Commelina benghalensis* L.	Commelinaceae	H	Meagui mai	MG200
53	*Conium maculatum* L.	Apiaceae	H	-	MG27
54	*Conyza stricta* Willd.	Asteraceae	H	-	MG154
55	*Cordia africana* Lam.	Boraginaceae	T	Awhi	MG33
56	*Corrigiola capensis* Willd.	Molluginaceae	H	Sibhi tiyel	MG71
57	*Crassocephalum rubens* (Juss. ex Jacq.) S. Moore	Asteraceae	H	-	MG36
58	*Crotalaria glauca* Willd.	Fabaceae	H	-	MG157
59	*Crotalaria goreensis* Guill. & Perr.	Fabaceae	H	-	MG5
60	*Croton macrostachyus* Del.	Euphorbiaceae	T	Tambok	MG190
61	*Cucurbita pepo* L. *	Cucurbitaceae	H	Duba	MG111
62	*Cynanchum abyssinicum* Decne.	Asclepiadaceae	HC	-	MG197
63	*Cynodon dactylon* (L.) Pers.	Poaceae	H	Tehag	MG19
64	*Cynoglossum lanceolatum* Forssk.	Boraginaceae	H	Teneg	MG165
65	*Cyperus rotundus* L.	Cyperaceae	H	Machiquae	MG30
66	*Cyphostemma adenanthum* (Fresen.) Descoings	Vitaceae	H	-	MG21
67	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	H	-	MG39
68	*Dalbergia melanoxylon* Guill. & Perr.	Fabaceae	S	Zibe	MG85
69	*Datura stramonium* L.	Solanaceae	H	Mezerba'e	MG69
70	*Desmodium repandum* (Vahl) DC.	Fabaceae	HC	Hareg	MG120
71	*Desmodium ospriostreblum* Steud. ex Chiov.	Fabaceae	HC	-	MG45
72	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	S	Gonok	MG97

No	Scientific name	Family	Growth form	Local Name	Voucher number
73	*Digitaria abyssinica* (Hochst. ex. A.Rich.) Stapf	Poaceae	H	-	MG100
74	*Dioscorea schimperiana* Kunth	Dioscoreaceae	HC	-	MG34
75	*Diospyros abyssinica* (Hiern) F. White	Ebenaceae	T	Tselimoy	MG198
76	*Diospyros mespiliformis* Hochst. ex A. DC	Ebenaceae	S	Aye	MG121
77	*Dodonaea angustifolia* L. f.	Sapindaceae	S	Tahsos	MG7
78	*Dorstenia cuspidata* A. Rich.	Moraceae	H	-	MG79
79	*Echinops macrochaetus* Fresen.	Asteraceae	H	Dender	MG20
80	*Ehretia cymosa* Thonn.	Boraginaceae	S	Kerah	MG4
81	*Elaeodendron buchananii* (Loes.) Loes.	Celastraceae	S	Mearay	MG123
82	*Eleusine africana* Kenn.-O'Byrne	Poaceae	H	Ancheklay	MG84
83	*Entada abyssinica* Steud. ex A. Rich.	Fabaceae	T	Fashay	MG6
84	*Erythrina abyssinica* Lam. ex DC.	Fabaceae	T	Zwawue	MG90
85	*Eucalyptus camaldulensis* Dehnh. *	Myrtaceae	T	Keyih kelamitos	MG89
86	*Euclea racemosa* subsp. *schimperi*	Ebenaceae	S	Kuleo 1	MG125
87	*Eugenia bukobensis* Engl.	Myrtaceae	S	-	MG86
88	*Eulophia streptopetala* Lindl.	Orchidaceae	H	Shingurtizibie	MG129
89	*Euphorbia abyssinica* Gmel. *	Euphorbiaceae	T	Kolankul	MG195
90	*Euphorbia tirucalli* L.	Euphorbiaceae	S	Kinchib	MG44
91	*Ficus hochstetteri* A. Rich.	Moraceae	T	Tsekente	MG179
92	*Ficus ingens* (Miq.) Miq.	Moraceae	T	Tsekente Harmaz	MG1
93	*Ficus palmata* Forssk.	Moraceae	S	Beleskola	MG65
94	*Ficus salicifolia* Vahl	Moraceae	T	Milhita	MG159
95	*Ficus sycomorus* L.	Moraceae	T	Sagla	MG52
96	*Ficus vasta* Forssk	Moraceae	T	Daero	MG80
97	*Flueggea virosa* (Willd.) Voigt.	Euphorbiaceae	S	Harmazo	MG10
98	*Foeniculum vulgare* Mill *	Apiaceae	H	Shilyan	MG29
99	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	S	Zefertel	MG25
100	*Gardenia ternifolia* Schumach. & Thonn.	Rubiaceae	S	Hatsinay	MG38
101	*Grewia ferruginea* Hochst. exA. Rich.	Tiliaceae	S	Tsumkuya	MG32
102	*Guizotia scabra* (Vis.) Chiov.	Asteraceae	H	Tinigita	MG177
103	*Guizotia schimperi* Sch. Bip. ex Walp.	Asteraceae	H	-	MG68
104	*Harpachne schimperi* Hochst. ex A.Rich.	Poaceae	H	Cheguar Saeri	MG9
105	*Hibiscus crassinervius* Hochst. ex A. Rich.	Malvaceae	H	-	MG196
106	*Hyparrhenia cymbaria* (L.) Stapf	Poaceae	H	Chechewa	MG94
107	*Hyparrhenia hirta* (L.) Stapf	Poaceae	H	-	MG26
108	*Hyparrhenia rufa* (Nees) Stapf	Poaceae	H	Saeriwald	MG158
109	*Hypoestes forskaolii* (Vahl) R. Br.	Acanthaceae	H	-	MG3
110	*Indigofera vohemarensis* Baill.	Fabaceae	H	-	MG130

No	Scientific name	Family	Growth form	Local Name	Voucher number
111	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	WC	Habitselim	MG170
112	*Justicia flava* (Vahl) Vahl	Ancanthaceae	H	-	MG24
113	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae	S	Simieza	MG8
114	*Kleinia grantii* (Oliv. & Hiern) Hook.f. *	Asteraceae	H	Bierir	MG132
115	*Lagenaria siceraria* (Molina) Standi. *	Cucurbitaceae	H	Amham	MG136
116	*Lannea fruticosa* (A. Rich.) Engl.	Anacardiaceae	T	Dugdigugni	MG108
117	*Lannea schimperi* (A. Rich.) Engl.	Anacardiaceae	T	Zerengefya	MG95
118	*Lantana camara* L.	Verbenaceae	S	Alalimo	MG140
119	*Lepidagathis hamiltoniana* Wall	Acanthaceae	H	-	MG163
120	*Leptadenia hastata* (Pers.) Decne.	Asclepiadaceae	S	Hareg adgi	MG49
121	*Leucas martinicensis* (Jacq.) R. Br.	Lamiaceae	H	Karsakarsa	MG41
122	*Linum usitatissimum* L. *	Linaceae	H	Entatie	MG133
123	*Lippia adoensis* Hochst. ex Walp.	Verbenaceae	S	Keskese	MG50
124	*Lonchocarpus laxiflorus* Guill. & Perr.	Fabaceae	S	Tsara	MG128
125	*Maerua angolensis* DC.	Capparidaceae	S	koromo	MG164
126	*Maytenus arbutifolia* (A. Rich.) Wilczek	Celastraceae	S	Atat	MG131
127	*Maytenus senegalensis* (Lam.) Exell	Celastraceae	S	Argudi	MG98
128	*Mentha longifolia* L. *	Lamiaceae	H	Setisemhal	MG149
129	*Mimusops kummel* A. DC.	Sapotaceae	T	Kumel	MG88
130	*Moringa stenopetala* (Bak. f.) Cuf *	Moringaceae	T	Moringa	MG56
131	*Nicotiana tabacum* L. *	Solanaceae	H	Timbuaqua	MG201
132	*Nicandra physaloides* (L.) Gaertn.	Solanaceae	H	Shembebi'ata	MG113
133	*Ocimum basilicum* L. *	Lamiaceae	H	Rihan	MG147
134	*Ocimum forskolei* Benth.	Lamiaceae	H	Sesegzibie	MG46
135	*Ocimum lamiifolium* Hochst. ex Benth. *	Lamiaceae	H	Demakese	MG192
136	*Olea europaea L.* subsp. *cuspidata* (Wall. ex G.Don) Cif.	Oleaceae	T	Awli'e	MG76
137	*Oplismenus burmannii* (Retz.) P. Beauv.	Poaceae	H	Saeri kokah	MG60
138	*Opuntia ficus-indica* (L.) Miller. *	Cactaceae	S	Beles	MG63
139	*Oreosyce africana* Hook.f.	Cucurbitaceae	H	-	MG64
140	*Ormocarpum pubescens* (Hochst.) Cuf. ex Gillett	Fabaceae	S	Alendia	MG156
141	*Otostegia fruticosa* (Forssk.) Schweinf. ex Penzig	Lamiaceae	S	Sasa	MG144
142	*Otostegia integrifolia* Benth.	Lamiaceae	S	Chiendog	MG162
143	*Oxygonum sinuatum* (Meisn.) Dammer	Polygonaceae	H	Akakmo	MG102
144	*Oxytenanthera abyssinica* (A. Rich.) Munro	Poaceae	H	Arkay	MG178
145	*Ozoroa insignis* Del.	Anacardiaceae	T	Tetera	MG191
146	*Pennisetum glaucifolium* Hochst. ex A.Rich.	Poaceae	H	-	MG124
147	*Persea americana* Mill. *	Lauraceae	T	Avocado	MG17

No	Scientific name	Family	Growth form	Local Name	Voucher number
148	*Phoenix reclinata* Jacq.	Arecaceae	T	Siye	MG189
149	*Phragmanthera macrosolen* (A. Rich.) M. Gilbert	Loranthaceae	S	Dikala lihay	MG91
150	*Phytolacca dodecandra* L'Her.	Phytolaccaceae	S	Shimti	MG92
151	*Piliostigma thonningii* (Schumach.) Milne-Redh.	Fabaceae	T	Amamgimel	MG74
152	*Plectranthus longipes* Baker	Lamiaceae	H	-	MG14
153	*Plumbago zeylanica* L. *	Plumbaginaceae	H	Aftuh	MG101
154	*Polygala persicariifolia* DC.	Polygalaceae	H	-	MG16
155	*Rhamnus prinoides* L'Herit. *	Rhamnaceae	S	Gesho	MG181
156	*Rhoicissus tridentata* (L. f.) Wild& Drummond	Vitaceae	HC	-	MG167
157	*Rhus retinorrhoea* Oliv.	Anacardiaceae	S	Tetaelo	MG48
158	*Ricinus communis* L. *	Euphorbiaceae	S	Gul'e	MG99
159	*Rumex abyssinicus* Jacq.	Polygonaceae	H	Mokmoko	MG117
160	*Rumex nervosus* Vahl.	Polygonaceae	S	Mchicho	MG83
161	*Ruta chalepensis* L. *	Rutaceae	H	Chena-Adam	MG12
162	*Satureja punctata* (Benth.) Briq.	Lamiaceae	H	-	MG22
163	*Schinus molle* L. *	Anacardiaceae	T	Tikur Berbere	MG23
164	*Senna italica* Mill.	Fabaceae	H	Seat-Kola	MG31
165	*Senna obtusifolia* (L.) Irwin & Barneby	Fabaceae	H	Shahshata	MG40
166	*Senna singueana* (Delile) Lock	Fabaceae	S	Hambahambo	MG42
167	*Setaria megaphylla* (Steud.) Th. Dur. & Schinz	Poaceae	H	Afgoho	MG53
168	*Setaria pumila* (Poir.) Roem. Schult.	Poaceae	H	Wazwazo	MG54
169	*Sida cordifolia* L.	Malvaceae	H	-	MG57
170	*Sida rhombifolia* L.	Malvaceae	H	Dekikdaero	MG58
171	*Snowdenia polystachya* (Fresen.) Pilg.	Poaceae	H	Mugya	MG59
172	*Solanum incanum* L.	Solanaceae	H	Engule	MG62
173	*Sonchus asper* (L.) Hill	Asteraceae	H	Fesi Aregit	MG66
174	*Spermacoce sphaerostigma* (A. Rich.) Vatke	Rubiaceae	H	-	MG67
175	*Sporobolus panicoides* A.Rich.	Poaceae	H	-	MG70
176	*Sterculia setigera* Del.	Sterculiaceae	T	Darle	MG72
177	*Stereospermum kunthianum* Cham.	Bignoniaceae	T	Adgi Zana	MG73
178	*Striga gesnerioides* (Willd.) Vatke	Scrophulariaceae	H	Metselem	MG77
179	*Strychnos innocua* Del.	Loganiaceae	S	Tinquakya	MG103
180	*Syzygium guineense* (Willd.) DC. subsp. *guineense*	Myrtaceae	T	Liham	MG105
181	*Tagetes minuta* L.	Asteraceae	H	-	MG107
182	*Terminalia laxiflora* Engl. & Diels.	Combretaceae	T	Wawa	MG109
183	*Terminalia macroptera* Guill.	Combretaceae	T	Akuma	MG110
184	*Torilis arevensis* (Hudson) Link	Apiaceae	H	-	MG112

No	Scientific name	Family	Growth form	Local Name	Voucher number
185	*Trachyspermum ammi* (L.) Sprague ex Turrill	Apiaceae	H	-	MG119
186	*Tragia cinerea* (Pax) Gilbert & Radcl.-Smith	Euphorbiaceae	H	Ame'e	MG138
187	*Trifolium campestre* Schreb.	Fabaceae	H	-	MG145
188	*Trifolium rueppellianum* Fresen.	Fabaceae	H	-	MG151
189	*Triumfetta trichocarpa* Hochst. ex A. Rich.	Tiliaceae	H	-	MG153
190	*Urtica simensis* Steudel	Urticaceae	H	Tsehaytu	MG155
191	*Vangueria madagascariensis* Gmel.	Rubiaceae	S	Guramayle	MG161
192	*Verbascum sinaiticum* Benth.	Scrophulariaceae	H	Tirnaka	MG168
193	*Vermifrux abyssinica* (A. Rich.) Gillet	Fabaceae	H	Taetaeta	MG173
194	*Vulpia bromoides* (L.) S.F. Gray	Poaceae	H	-	MG174
195	*Withania somnifera* (L.) Dunal *	Solanaceae	H	Agol	MG180
196	*Woodfordia uniflora* (A. Rich) Koehne.	Lythraceae	S	Lekemeja	MG183
197	*Ximenia americana* L.	Olacaceae	S	Mileo	MG184
198	*Zehneria scabra* (L.f.) Sond	Cucurbitaceae	HC	Hafaflo	MG186
199	*Zingiber officinale* Roscoe *	Zingiberaceae	H	Jinjibl	MG187
200	*Ziziphus mucronata* Willd.	Rhamnaceae	S	Abetere	MG188
201	*Ziziphus spina-christi* L.	Rhamnaceae	S	Gaba	MG193

Appendix 2.Structure (abundance, Density, DBH, Frequency, Basal area and Important Value Index) of Woody species

Scientific name	Abundance	Density	DBH	BA (m^2/ha)	frequency	Relative frequency	Relative Density	Relative Dominance	IVI
Acacia abyssinica	57	11.4	504	0.32	22.5	2.77	2.13	2.36	7.26
Acacia albida	8	1.6	88	0.05	5	0.61	0.3	0.38	1.29
Acacia lahai	24	4.8	185	0.1	8.75	1.07	0.9	0.75	2.72
Acacia nilotica	1	0.2	12	0	2.5	0.31	0.04	0	0.35
Acacia polyacantha	64	12.8	677	0.87	20	2.45	2.36	6.42	11.23
Acacia seyal	33	6.6	273	0.35	18.75	2.3	1.23	2.58	6.11
Acacia venosa	40	8	122	0.03	12.5	1.53	1.5	0.22	3.25
Acokanthera schimperi	72	14.4	270	0.09	12.5	1.53	3.35	0.66	5.54
Adansonia digitata	6	1.2	171	0.1	8.75	1.07	0.23	0.75	2.05
Albizia amara	5	1	40	0.01	3.75	0.46	0.19	0.07	0.72
Albizia malacophylla	8	1.6	70	0.05	3.75	0.46	0.3	0.37	1.13
Anogeissus leiocarpa	129	25.8	1176	1.45	40.5	5	4.86	10.69	20.55
Balanites aegyptiaca	12	2.4	130	0.05	7.5	0.92	0.75	0.37	2.04
Bersama abyssinica	46	9.2	81	0.03	6.25	0.77	1.72	0.22	2.71
Boswellia papyrifera	11	2.2	135	0.07	7.5	0.92	0.52	0.52	1.96
Buddleja cordata	2	0.4	4	0	2.5	0.32	0.07	0	0.39
Buddleja polystachya	7	1.4	57	0.03	3.75	0.46	0.3	0.22	0.98
Calpurnia aurea	53	10.6	144	0.08	7.5	0.92	1.98	0.59	3.49
Capparis tomentosa	27	5.4	95	0.02	10	1.22	1.01	0.15	2.38
Carissa spinarum	11	2.2	26	0.01	2.5	0.31	0.41	0.07	0.79
Combretum adenogonium	11	2.2	148	0.12	5	0.61	0.6	0.88	2.09
Combretum hartmannianum	90	18	904	0.82	26.25	3.22	3.81	6.05	13.08
Combretum molle	35	7	336	0.27	12.5	1.53	1.53	1.99	5.05
Combretum rochetianum	27	5.4	371	0.38	16.25	1.99	1.5	2.8	6.29
Cordia africana	2	0.4	28	0.01	2.5	0.31	0.11	0.07	0.49
Croton macrostachyus	5	1	53	0.02	3.75	0.46	0.19	0.15	0.8
Dalbergia melanoxylon	13	2.6	73	0.02	6.25	0.77	0.49	0.15	1.41
Dichrostachys cinerea	61	12.2	315	0.18	18.75	2.3	2.28	1.32	5.9
Diospyros abyssinica	49	9.8	243	0.56	12.5	1.53	3.35	4.13	9.01
Diospyros mespiliformis	140	28	524	0.47	16.25	1.99	2.4	3.47	7.86
Dodonaea angustifolia	156	31.2	390	0.3	12.5	1.53	5.84	2.21	9.58
Ehretia cymosa	33	6.6	173	0.09	10	1.23	1.23	0.66	3.12
Elaeodendron buchananii	39	7.8	204	0.08	15	1.84	1.5	0.59	3.93

Scientific name	No. of individuals	Density	DBH	BA (m^2/ha)	frequency	Relative frequency	Relative Density	Relative Dominance	IVI
Entada abyssinica	26	5.2	220	0.13	10	1.23	0.97	0.96	3.16
Erythrina brucei	3	0.6	46	0.03	3.75	0.46	0.11	0.22	0.79
Euclea racemosa	36	7.2	182	0.06	13.75	1.68	1.35	0.44	3.47
Eugenia bukobensis	5	1	18	0	3.75	0.46	0.19	0	0.65
Ficus hochstetteri	7	1.4	103	0.06	5	0.61	0.26	0.44	1.31
Ficus ingens	28	5.6	590	0.49	18.75	2.3	1.04	3.61	6.95
Ficus palmata	9	1.8	146	0.17	6.25	0.77	0.34	1.25	2.36
Ficus salicifolia	16	3.2	246	0.17	10	1.23	0.6	1.25	3.08
Ficus sycomorus	19	3.8	202	0.2	11.25	1.38	0.75	1.47	3.6
Ficus vasta	4	0.8	116	0.08	5	0.62	0.15	0.59	1.36
Flueggea virosa	146	29.2	420	0.26	18.75	2.3	5.46	1.92	9.68
Gardenia ternifolia	51	10.2	46	0.06	12.5	1.53	0.41	0.44	2.38
Gardenia ternifolia	11	2.2	155	0.01	6.25	0.77	0.41	0.07	1.25
Grewia ferruginea	34	6.8	277	0.18	12.5	1.53	1.27	1.33	4.13
Jasminum abyssinicum	14	2.8	28	0	5	0.61	0.52	0	1.13
Justicia schimperiana	21	4.2	57	0.03	3.75	0.46	0.79	0.22	1.47
Lannea fruticosa	42	8.4	352	0.18	22.5	2.76	1.57	1.33	5.66
Lannea schimperi	8	1.6	95	0.05	5	0.61	0.3	0.37	1.28
Leptadenia hastata	13	2.6	105	0.37	5	0.62	0.49	0.07	1.18
Lonchocarpus laxiflorus	21	4.2	200	0.11	10	1.23	0.79	0.81	2.83
Maerua angolensis	5	1	14	0	5	0.61	0.19	0	0.8
Maytenus arbutifolia	90	18	203	0.09	12.5	1.53	3.35	0.66	5.54
Maytenus senegalensis	57	11.4	190	0.08	15	1.84	2.13	0.6	4.57
Mimusops kummel	28	5.6	168	0.06	11.25	1.25	1.04	0.44	2.73
Olea europaea L. subsp. *cuspidata*	2	0.4	21	0.01	2.5	0.31	0.07	0.07	0.45
Ormocarpum pubescens	22	4.4	110	0.08	11.25	1.38	0.82	0.6	2.8
Otostegia fruticosa	1	0.2	7	0	2.5	0.32	0.11	0	0.43
Otostegia integrifolia	59	11.8	122	0.05	8.75	1.07	2.21	0.37	3.65
Ozoroa insignis	59	11.8	621	0.49	22.5	2.76	1.83	3.61	8.2
Phoenix reclinata	3	0.6	36	0.02	2.5	0.31	0.15	0.15	0.61
Phytolacca dodecandra	3	0.6	16	0	2.5	0.31	0.11	0	0.42
Piliostigma thonningii	14	2.8	192	0.14	7.5	0.92	0.52	1.03	2.47
Rhus retinorrhoea	48	9.6	319	0.17	15	1.84	1.8	1.25	4.89
Senna singueana	8	1.6	42	0.01	5	0.61	0.23	0.07	0.91
Sterculia setigera	10	2	297	0.4	7.5	0.91	0.37	2.95	4.23

Scientific name	No. of individuals	Density	DBH	BA (m^2/ha)	frequency	Relative frequency	Relative Density	Relative Dominance	IVI
Stereospermum kunthianum	16	3.2	271	0.18	6.25	0.77	0.67	1.33	2.77
Strychnos innocua	6	1.2	61	0.04	3.75	0.46	0.23	0.29	0.98
Syzygium guineense	6	1.2	55	0.05	2.5	0.31	0.23	0.37	0.91
Terminalia laxiflora	29	5.8	492	0.57	11.25	1.38	1.16	4.2	6.74
Terminalia macroptera	62	12.4	706	0.79	28.75	3.52	2.66	5.24	11.42
Vangueria madagascariensis	59	11.8	193	0.11	10	1.23	2.28	0.82	4.33
Woodfordia uniflora	12	2.4	35	0.02	3.75	0.46	0.45	0.15	1.06
Ximenia americana	80	16	330	0.19	18.75	2.3	3	1.4	6.7
Ziziphus mucronata	91	18	1172	0.2	32.5	3.98	2.32	1.47	7.77
Ziziphus spina-christi	59	11.8	1462	0.58	26.25	3.22	5.24	4.28	12.74
Total	2200	440	13984	14	816.25	100	100	100	300

Appendix 3. Results of environmental variable and disturbance rates for the plots of Hirmi woodland vegetation (STC= soil teiture class; DR= disturbance rate)

Plot	**Altitude**	**Slope**	**PH**	**EC**	**P**	**SOM**	**N**	**CEC**	**Sand**	**Silt**	**Clay**	**STC**	**DR**
1	1140	23	5.6	0.3	11.9	3.2	0.2	14.4	74	14	12	Sandy Loam	4
2	1170	21	5.7	0.2	14.8	3.7	0.2	18.6	76	8	16	Sandy Loam	2
3	1181	25	6.2	0.4	26.1	5.9	0.3	24	72	14	14	Sandy Loam	4
4	1204	30	5.9	0.1	6.7	1.0	0.5	6.8	80	10	10	Sandy Loam	3
5	1248	20	6.1	0.4	10.5	4.9	0.2	20.2	72	16	10	Sandy Loam	3
6	1281	15	6.0	0.3	10.3	3.6	0.2	15	74	14	12	Sandy Loam	2
7	1293	8	5.6	8.6	2.7	0.9	0.0	18.4	78	12	12	Sandy Loam	1
8	1098	8	5.3	0.1	3.9	0.7	0.3	14.2	74	10	10	Sandy Loam	3
9	1130	15	5.6	8.5	2.9	0.9	0.1	17.98	77	10	13	Sandy Loam	3
10	1177	58	6	0.4	11.0	4	0.3	19.9	75	14	11	Sandy Loam	1
11	1212	30	5.8	0.2	6.7	1	0.5	6.12	79	10	11	Sandy Loam	0
12	1240	28	6.2	0.4	26.0	5.9	0.3	23.9	74	12	14	Sandy Loam	3
13	1265	25	5.8	0.2	14.8	3.7	0.2	18.5	75	9	16	Sandy Loam	1
14	1285	18	5.6	0.3	11.9	3.3	0.2	14	74	14	12	Sandy Loam	0
15	1144	7	6.1	0.5	16.5	4.3	0.2	12.4	74	16	10	Sandy Loam	4
16	1160	8	5.8	0.3	9.8	2.2	0.1	9.2	70	16	14	Sandy Loam	2
17	1173	15	6.2	0.5	16.5	4.3	0.2	12.42	77	13	10	Sandy Loam	4
18	1185	18	5.9	0.3	9.8	2.2	0.2	9.1	72	15	13	Sandy Loam	3
19	1224	24	5.24	9.0	3.3	0.9	0.1	17	74	14	12	Sandy Loam	1
20	1264	28	5.06	0.2	6.6	2.1	0.1	8	64	26	10	Sandy Loam	1
21	1330	30	6.0	9.0	3.3	0.9	0.1	16.85	74	14	12	Sandy Loam	0
22	1432	45	5.1	0.2	6.9	2.1	0.1	8.18	66	24	10	Sandy Loam	0
23	1565	55	5.	0.3	11.8	3.2	0.2	14.4	74	14	12	Sandy Loam	2
24	1152	8	5.7	0.5	21.4	4.7	0.2	20.6	72	12	16	Sandy Loam	3
25	1173	2	5.8	0.4	16.5	4.9	0.2	22.4	62	26	12	Sandy Loam	0
26	1195	7	5.4	0.1	18.5	2.0	0.1	20.2	72	18	10	Sandy Loam	1
27	1234	11	5.3	0.2	6.8	3.2	0.2	49.4	76	10	14	Sandy Loam	0
28	1279	25	5.6	0.3	11.9	3.3	0.2	14.4	74	14	12	Sandy Loam	1
29	1315	28	5.7	0.2	14.8	3.7	0.2	18.6	76	8	16	Sandy Loam	1
30	1320	25	6	0.5	20.9	4.8	0.2	20.62	70	13	17	Sandy Loam	0
31	1370	30	5.8	0.4	16.5	5	0.2	22.45	68	22	10	Sandy Loam	1
32	1380	20	5.4	0.1	18.5	2	0.1	20.22	72	16	12	Sandy Loam	0
33	1420	12	5.0	0.2	6.8	3.2	0.	41.14	75	10	15	Sandy Loam	0
34	1458	23	5.6	0.3	11.9	3.3	0.2	15	74	15	11	Sandy Loam	1
35	1490	26	5.7	0.2	14.8	3.7	0.2	17.6	77	7	16	Sandy Loam	1
36	1521	28	6.1	0.5	21.0	5.0	0.2	21.02	70	13	17	Sandy Loam	1
37	1544	31	5.8	0.3	9.8	2.3	0.1	9.11	68	18	14	Sandy Loam	0
38	1560	23	5.5	0.4	10.0	1.6	0.1	28	60	26	14	Sandy Loam	0

Plot	Altitude	Slope	PH	EC	P	SOM	N	CEC	Sand	Silt	Clay	STC	DR
39	1615	32	5.6	0.4	10.3	1.5	0.1	13.8	70	14	16	Sandy Loam	1
40	1660	42	5.2	0.2	6.6	1.5	0.1	5.4	74	16	10	Sandy Loam	0
41	1690	60	5.2	0.3	13.4	1.3	0.1	18.4	76	10	14	Sandy Loam	0
42	1735	68	5.6	0.5	10	1.6	0.1	24.8	64	24	12	Sandy Loam	0
43	1785	54	5.7	0.4	10.0	1.5	0.1	11.99	70	15	15	Sandy Loam	0
44	1840	28	6	0.2	6.0	1.6	0.1	5.88	74	16	10	Sandy Loam	1
45	1456	18	5.4	0.2	18.5	2.0	0.1	20.2	12	16	72	Sandy Loam	2
46	1500	20	5.3	0.2	6.9	3.2	0.2	49.4	14	10	76	Sandy Loam	1
47	1550	34	5.8	0.5	21.4	4.7	0.2	20.6	15	11	73	Sandy Loam	4
48	1595	36	5.7	0.4	16.5	4.9	0.3	20.9	12	26	62	Sandy Loam	4
49	1648	42	6	0.2	6.8	3.2	0.2	30.4	14	10	76	Sandy Loam	1
50	1714	48	6.0	0.3	11.9	3.3	0.2	24.48	13	12	75	Sandy Loam	1
51	1790	50	5.6	1.3	52.9	4.2	0.2	49.2	14	32	54	Sandy Loam	0
52	1868	45	5.2	0.2	5.3	4.5	0.2	26.6	10	32	58	Sandy Loam	0
53	1906	40	5.5	0.3	3.4	4.3	0.2	23.4	16	32	52	Sandy Loam	0
54	1988	38	5.8	0.6	6.6	3.5	0.3	30	24	34	42	Loam	0
55	2002	33	5.9	0.6	6.59	3.5	0.2	28.3	26	34	40	Loam	0
56	1400	7	6.0	0.4	8.9	3.4	0.2	28	18	33	49	Loam	2
57	1405	8	6.3	0.4	7.9	2.9	0.1	20	14	38	48	Loam	2
58	1438	22	6.3	0.4	7.9	2.9	0.1	20	14	38	48	Loam	0
59	1512	40	6.1	0.2	2.8	2.3	0.1	37.2	20	33	47	Loam	0
60	1480	0	6.6	0.2	8.7	1.4	0.1	21.6	14	40	46	Loam	1
61	1520	34	6.0	0.6	6.5	2.92	0.2	26.4	22	34	44	Loam	0
62	1675	58	5.3	0.6	6.6	3.0	0.2	27.5	24	42	34	Loam	0
63	1412	18	6	0.5	11.4	4.8	0.3	20.6	24	38	38	Clay loam	0
64	1432	23	6.1	0.5	15.4	5.0	0.3	22.4	24	36	40	Clay loam	0
65	1500	30	6.8	0.2	10.5	3.3	0.2	12.4	24	36	40	Clay loam	0
66	1570	55	6.8	0.2	8.7	2.4	0.1	16.63	25	35	40	Clay loam	1
67	1660	70	6.8	0.3	7.9	2.9	0.1	18.12	25	34	41	Clay loam	1
68	1816	75	6.6	0.4	10.0	4.1	0.2	17.22	26	32	42	Clay loam	1
69	1542	16	6.3	0.1	3.0	2.7	0.1	21.6	25	60	15	Sandy Loam	0
70	1572	20	6.1	0.1	3	2.7	0.1	20.63	26	60	14	Sandy Loam	0
71	1620	28	6	0.2	3.1	3.0	0.2	21.6	22	58	20	Sandy Loam	0
72	1680	32	6.0	0.2	3.8	1.7	0.2	22.61	18	64	18	Sandy Loam	0
73	1742	38	5.9	0.2	4.1	3.0	0.1	27.6	20	56	24	Sandy Loam	1
74	1837	48	5.7	0.2	4.5	2.8	0.2	19.6	26	55	19	Sandy Loam	2
75	1285	12	5.6	0.2	3.5	2.0	0.1	15.4	23	65	12	Sandy Loam	0
76	1400	27	5.5	0.2	4.1	2.0	0.1	18.2	24	66	10	Sandy Loam	1
77	1498	28	5.4	0.1	2.7	1.6	0.1	20	26	64	10	Sandy Loam	1
78	1582	32	5.3	0.2	4.2	2.7	0.2	21.6	28	62	10	Sandy Loam	2
79	1632	52	6.2	0.2	4.3	2.9	0.2	23.22	15	70	15	Sandy Loam	4
80	1682	58	6.6	0.2	5.0	3.1	0.2	26.66	14	72	14	Sandy Loam	4

Appendix 4. Density of seedling, sapling and Tree/shrubs per hectare of woody species in the study area

Scientific name	T or S /ha	Sapling /ha	Seedling /ha
Acacia abyssinica	11.4	62.5	75
Acacia albida	1.6	12.5	6.25
Acacia lahai	4.8	31.25	25
Acacia nilotica	0.2	0	0
Acacia polyacantha	11.8	43.75	31.25
Acacia seyal	6.6	43.75	31.25
Acacia venosa	8	50	31.25
Acokanthera schimperi	14.4	56.25	56.25
Adansonia digitata	1.2	18.75	0
Albizia amara	1	12.5	18.75
Albizia malacophylla	1.6	18.75	31.25
Anogeissus leiocarpa	25.8	131.25	162.5
Balanites aegyptiaca	2.4	6.25	0
Bersama abyssinica	9.2	12.5	12.5
Boswellia papyrifera	2.2	56.25	156.25
Buddleja cordata	0.4	0	6.25
Buddleja polystachya	1.4	18.75	31.25
Calpurnia aurea	10.6	25	6.25
Capparis tomentosa	5.4	31.25	50
Carissa spinarum	2.2	12.5	18.75
Combretum adenogonium	2.2	31.25	56.25
Combretum hartmannianum	18	68.75	50
Combretum molle	7	31.25	43.75
Combretum rochetianum	5.4	31.25	25
Cordia africana	0.4	0	0
Croton macrostachyus	1	6.25	0
Dichrostachys cinerea	12.2	68.75	62.5
Diospyros abyssinica	18	75	50
Diospyros mespiliformis	12.8	43.75	37.5
Dodonaea angustifolia	31.2	62.5	62.5
Ehretia cymosa	6.6	37.5	37.5
Elaeodendron buchananii	7.8	75	43.75
Entada abyssinica	5.2	100	68.75
Erythrina abyssinica	0.6	6.25	0
Euclea racemosa	7.2	25	31.25
Euclea schimperi	2.6	12.5	12.5
Eugenia bukobensis	1	6.25	6.25
Ficus hochstetteri	1.4	37.5	25

Scientific name	T or S /ha	Sapling /ha	Seedling /ha
Ficus ingens	5.6	37.5	56.25
Ficus palmata	1.8	12.5	18.75
Ficus salicifolia	3.2	37.5	75
Ficus sycomorus	3.8	18.75	50
Ficus vasta	0.8	0	6.25
Flueggea virosa	29.2	137.5	100
Galiniera saxifraga	10.2	68.75	37.5
Gardenia ternifolia	2.2	25	25
Grewia ferruginea	6.8	18.75	25
Jasminum abyssinicum	2.8	25	12.5
Justicia schimperiana	4.2	0	0
Lannea schimperi	1.6	0	6.25
Leptadenia hastata	2.6	18.75	12.5
Lonchocarpus laxiflorus	4.2	50	37.5
Maerua angolensis	1	0	6.25
Maytenus arbutifolia	18	56.25	18.75
Maytenus senegalensis	11.4	62.5	18.75
Mimusops kummel	5.6	43.75	31.25
Olea europaea	0.4	6.25	12.5
Ormocarpum pubescensm	4.4	37.5	12.5
Otostegia fruticosa	0.2	18.75	12.5
Otostegia integrifolia	11.8	31.25	37.5
Ozoroa insignis	9.8	106.25	81.25
Phoenix reclinata	0.6	0	0
Phytolacca dodecandra	0.6	0	0
Piliostigma thonningii	2.8	18.75	0
Rhus retinorrhoea	9.6	56.25	56.25
Lannea fruticosa	8.4	43.75	37.5
Senna singueana	1.6	18.75	18.75
Sterculia setigera	2	0	6.25
Stereospermum kunthianum	3.2	12.5	6.25
Strychnos innocua	1.2	31.25	25
Syzygium guineense	1.2	12.5	12.5
Terminalia laxiflora	5.8	50	25
Terminalia macroptera	11.8	137.5	43.75
Vangueria madagascariensis	11.8	37.5	31.25
Woodfordia uniflora	2.4	25	43.75
Ximenia americana	16	56.25	50
Ziziphus mucronata	28	200	162.5
Ziziphus spina-christi	12.4	143.75	175
Total	**528.4**	**3025**	**2750**

Appendix 5. List of plant species obtained from soil seed bank (Habit: T = Tree, S = Shrub, H = Herb, HC = Herbaceous climber; Species Code; SSB = soil seed bank; LUT= Land use types: F= forest, S=shrubland, G= grassland, B= bare land)

No	Scientific name	Family	Growth form	Species Code	LUT found
1	*Achyranthes aspera* L.	Amaranthaceae	H	SSB52	F,S
2	*Ageratum conyzoides* L.	Asteraceae	H	SSB4	F, G,
3	*Arthraxon micans* (Nees) Hochst.	Poaceae	H	SSB38	F, S,G
4	*Bidens macroptera* (Sch.-Bip. ex Chiov.)	Asteraceae	H	SSB11	F,S, G
5	*Bidens pilosa* L	Asteraceae	H	SSB13	S, G
6	*Caylusea abyssinica* (Fresen.) Fisch. & Mey.	Resedaceae	H	SSB36	F,S
7	*Cenchrus ciliaris* L.	Poaceae	H	SSB12	F,G
8	*Chloris pycnothrix* Trin.	Poaceae	H	SSB26	S, G
9	*Crotalaria goreensis* Guill. & Perr.	Fabaceae	H	SSB57	S
10	*Crotalaria onobrychis* A. Rich.	Fabaceae	H	SSB49	F,S
11	*Croton macrostachyus* Del.	Euphorbiaceae	T	SSB46	F,S
12	*Cynodon dactylon* (L.) Pers.	Poaceae	H	SSB16	G,
13	*Cyperus schimperianus* Steud.	Cyperaceae	H	SSB23	S, B
14	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	H	SSB22	S
15	*Desmodium repandum* (Vahl) DC.	Fabaceae	HC	SSB30	F
16	*Digitaria abyssinica* (Hochst. ex. A. Rich.)	Poaceae	H	SSB58	S,G
17	*Digitaria ternata* (A.Rich.) Stapf	Poaceae	H	SSB20	G
18	*Digitaria intecta* Stapf	Poaceae	H	SSB9	S, G, B
19	*Dioscorea schimperiana* Kunth	Dioscoreaceae	HC	SSB33	F,S
20	*Diospyros mespiliformis* Hochst. ex A. DC.	Ebenaceae	T	SSB58	F
21	*Dodonaea angustifolia* L. f.	Sapindaceae	S	SSB46	F,S,B
22	*Eleusine africana* Kenn.-O'Byrne	Poaceae	H	SSB44	F,S, G,B
23	*Eragrostis aspera* (Jacq.) Nees	Poaceae	H	SSB21	G,B
24	*Eragrostis tef* (Zucc.) Trotter	Poaceae	H	SSB7	G,B
25	*Euclea racemosa* Murr.	Ebenaceae	S	SSB54	F,S
26	*Eulophia streptopetala* Lindl.	Orchidaceae	H	SSB32	F,
27	*Galinsoga parviflora* (Hochst.)	Asteraceae	H	SSB50	F, G,B
28	*Galium aparinoides* Forssk.	Rubiaceae	H	SSB51	S
29	*Guizotia villosa* Sch. Bip. ex Walp.	Asteraceae	H	SSB5	G,B
30	*Harpachne schimperi* Hochst. ex A.Rich.	Poaceae	H	SSB25	G,B
31	*Hibiscus crassinervius* Hochst. ex A. Rich.	Malvaceae	H	SSB37	F,S
32	*Hyparrhenia rufa* (Nees) Stapf	Poaceae	H	SSB31	F
33	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	S	SSB47	F, G
34	*Leonotis ocymifolia* (Burm. f.) Iwarsson	Lamiaceae	H	SSB43	S

No	**Scientific name**	**Family**	**Growth form**	**Species Code**	**LUT found**
35	*Leucas martinicensis*(Jacq.) R. Br.	Lamiaceae	H	SSB34	F,S
36	*Nicandra physaloides* (L.) Gaertn.	Solanaceae	H	SSB1	F,
37	*Oldenlandia herbacea* (L.) Roxb.	Rubiaceae	H	SSB18	F, S
38	*Oplismenus burmannii* (Retz.) P. Beauv.	Poaceae	H	SSB14	F,S,G
39	*Oxytenanthera abyssinica* (A. Rich.) Munro	Poaceae	H	SSB55	G,
40	*Pennisetum glaucifolium* Hochst. ex A.Rich.	Poaceae	H	SSB41	F,S, G, B
41	*Pilea tetraphylla* (Steudel) Blume	Urticaceae	H	SSB19	S
42	*Plantago lanceolata* L.	Plantaginaceae	H	SSB42	F,S,G
43	*Plectranthus longipes* Baker	Lamiaceae	H	SSB24	S
44	*Rhus retinorrhoea* Oliv.	Anacardiaceae	S	SSB60	S
45	*Satureja punctata* (Benth.) Briq.	Lamiaceae	H	SSB29	S
46	*Setaria barbata* (Lam.) Kunth	Poaceae	H	SSB8	F
47	*Setaria pumila* (Poir.) Roem.	Poaceae	H	SSB53	S, G,B
48	*Snowdenia polystachya* (Fresen.) Pilg.	Poaceae	H	SSB40	F, G
49	*Solanum americanum* Mill.	Solanaceae	H	SSB10	F,S,G,
50	*Sonchus asper* (L.) Hill	Asteraceae	H	SSB39	S,
51	*Spermacoce sphaerostigma* (A. Rich.) Vatke	Rubiaceae	H	SSB27	S
52	*Syzygium guineense* (Willd.) DC. subsp. *guineense*	Myrtaceae	T	SSB56	F,S
53	*Tagetes minuta* L.	Asteraceae	H	SSB3	F,S, G, B
54	*Trifolium campestre* Schreb.	Fabaceae	H	SSB35	S,B
55	*Trifolium rueppellianum* Fresen.	Fabaceae	H	SSB48	S,B
56	*Triumfetta trichocarpa* Hochst. ex A. Rich.	Tiliaceae	H	SSB6	S,G
57	*Urtica simensis* Steudel	Urticaceae	H	SSB2	F, S
58	*Woodfordia uniflora* (A. Rich) Koehne.	Lythraceae	S	SSB28	S

Appendix 6. List of plant species and methods of preparation to treat human ailments

Key: Scientific name; local name; family; GF = Growth form: T = tree, S = shrub, H= herb; Source: W = Wild (from Hirmi vegetation plots), C = cultivated, WC = both wild and cultivated; PU = plant part used: L = leaf, S = stem, R = root, B = bark, Ag = above ground, F= fruit, Sd = seed, Rh = Rhizome, Bl = Bulb, Yt =Young twig, Lx = latex; MRPA = mode of remedy preparation and application: 1 = Boil and drink the decoction up on cooling, 2 = Squeeze or sniff the freshly crushed part, 3 = Add chopped plant part(s) to bath water and do bath, 4= Crush and mix with cold water then drink;, 5=Drink as herbal tea, 6 = Rub/paste the latex/sap//juice directly, 7 = Eat the plant part (raw/cooked), 8 = chewing/hold with teeth, 9 = Burn or boil the plant part and fumigation, 10 = Drink the concoction, 11 = Grind and paint the powder or crushed part, 12 = tie the crushed or plant part; RA = route of remedy administration: Or = oral, Au = auricular, Na = nasal, Dm = dermal, Op = optical, Ts = Tooth surface; Dis=District: TK = Tahtay Koraro, MZ, Medebay Zana, AT = Asgedetsimbla

No	Scientific name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
1	*Acacia abyssinica* Hochst. ex Benth.	Chea	Fabaceae	T	W	B	12	Dm	None	Internal bleeding	TK MZ AT	- Firewood -Charcoal production -Fence -Soil fertility
						B	10	Or	lomi's leaf	Dysentery		
2	*Acacia albida* Del.	Momona	Fabaceae	T	W C	B	6	Dm	Water	Viral skin disease	TK MZ AT	-Soil fertility -Fence
3	*Achyranthes aspera* L.	Michiele	Amaranthaceae	H	W	R	8	Op	None	Eye irritation	TK MZ AT	
4	*Acokanthera schimperi* (A.DC.) Schweinf.	Mebtie	Apocynaceae	S	W	L	9	Dm	None	Insecticide	TK AT	-Firewood -Fence
						L	11	Dm	None	Insect bite		

No	Scientific name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
5	*Adansonia digitata* L.	Dima	Bombacaceae	T	W	F	4	Dm	Water	Drink appetite	TK AT	-Food
						B	1	Dm	Water	Infant fever		- Fodder
						L	4	Or	Water	Stomachache		
						L	4	Or	Water	Infant diarrhea		
						R	12	Or	None	Backbone ache		
6	*Agave sisalana* Perrine ex Engl.	Eka (toothless)	Agavaceae	H	C	L	6	Dm	Garlic and butter	Ear disease	TK MZ AT	-Material culture
7	*Allium sativum* L.	Tseada-shungurti	Alliaceae	H	C	Bl	10	Or	Honey	Abdominal pain	TK MZ AT	-Spice of food
									Water			
						Bl	7	Or	Enjera	Blood pressure		
						Bl	1	Or	Honey	Common cold		
									Water			
									Lime fruit			
						Bl	7	Or	None	Bad mouth smell		
8	*Aloe elegans* Tod.	Ere	Aloaceae	H	W	Lx	6	Dm	None	Eye disease	AT	To stop baby Brest feeding
						R	4	Or	Lime	Diabetes		
									Honey			
9	*Anogeissus leiocarpa* (DC.) Guill. & Perr.	Hanse	Combretaceae	T	W	L	7	Or	Honey	Diarrhea/abdominal disease	TK MZ AT	-Fodder
									Garlic			-Material culture -Firewood
						R	4	Or	Water	Pneumonia		
10	*Azadirachta indica* A. Juss.	Niem	Meliaceae	T	C	L	4	Na	Water	Leech infestation	TK MZ AT	
						L	4	Na	water	Ear diseases		

No.	Scientific Name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
11	*Brassica nigra* (L.) Koch	Hamli-Adri	Brassicaceae	H	C	L	7	Or	Enjera	Abdominal diseases	TK MZ AT	-Food
						F	7	Or	Enjera	Head ache		
12	*Boswellia papyrifera* (Del.) Hochst.	Meker	Burseraceae	T	W	S	9	Dm	None	Abdominal diseases	TK AT	
						Lx	9	Na	None	Evil sprit		
13	*Buddleja polystachya* Fresen.	Metere	Loganiaceae	T	W	Yt	2	Dm	None	Headache or migraine	MZ	-Firewood
14	*Calpurnia aurea* (Alt.) Benth.	Hintsawutsi	Fabaceae	S	W	S	9	Dm	None	Anti-insect bite	TK MZ AT	-Firewood
						L	4	Or	Water	Abdominal tract/pain		
15	*Calotropis procera* (Ait.)	Gindae	Asclepiadaceae	H	W	L	12	Dm	None	Snake/ scorpion bite	TK MZ AT	
						S	6	Ts	None	Tooth disease		
						S	6	Or	None	Hemorrhoids		
16	*Capparis tomentosa* Lam.	Andiel	Capparidaceae	S	W	R	1	Or	Sugar/ honey, water	Common cold	MZ AT	
						B	11	Dm	None	Wound		
						R		Or	None	Tooth disease		
						R	9	Dm	None	Evil sprit		
17	*Capsicum annuum L.*	Berbere	Solanaceae	H	C	L	2	Dm	*Urticasi mensis*	Tinea versicolor	TK MZ AT	
									Premna oligotricha			
18	*Carissa spinarum* L.	Agam	Apocynaceae	S	W	S	9	Dm	None	Evil eye	TK MZ	-Food -Firewood
						R	8	Or	None	Tooth ache		

No	Scientific Name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
19	*Citrus aurantiifolia* (Christm.) Swingle	Lemin	Rutaceae	S	C	F	2	Na	None	Cough	TK MZ AT	
						F	2	Na	None	Headache		
						F	6	Dm	Butter	Tetanus		
						F	5	Or	Sugar	Blood pressure		
						R	7	Or	None	Insect bite		
20	*Cissus petiolata* Hook. f.	Alke	Vitaceae	WC	W	S	12	Dm	None	Preconditions for anti-Evil	TK MZ	
						S	12	Dm	None	Epilepsy		
21	*Clerodendrum myricoides* (Hochst.) Vatke	Surbetri	Lamiaceae	S	W	S	12	Dm	None	Sprain	MZ	
						R	9	Dm	*Sidarhombifolia*	Epilepsy		
22	*Coffea arabica* L.	Buna	Rubiaceae	S	W	Sd	10	Or	Honey	Amoebiasis	TK	
						Sd	4	Or	Sugar	Head ache		
						Sd	4	Or	Water	Blood pressure		
23	*Combretum adenogonium* Steud. ex A. Rich.	Weyba	Combretaceae	T	W	B	1	Or	Salt Water	Diarrhea	MZ AT	- Firewood -Wood materials
						L	6	Dm	None	Jaundice		
						B	6	Op	None	Eye blinking jaundice/መወዩብ/		
24	*Cordia africana* Lam.	Awhi	Boraginaceae	T	W	L	10	Dm	Coffee	Fever	TK MZ AT	Fourniture -Food
25	*Croton macrostachyus* Hochst. ex Delile	Tamboque	Euphorbiaceae	T	WC	R	10	Or	None	Indigestion	TK MZ AT	-Firewood -Material culture -
						R	4	Or	Water	Rabbis		
						B	1	Or	Milk Water	Tapeworm infestation		
						SD	6	Au	None	Ear problems		

No	Scientific Name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
26	*Cucurbita pepo* L.	Duba	Cucurbitaceae	H	C	Sd	7	Or	None	Tapeworm	TK MZ AT	-Food
						F	10	Or	Water	Urine retention		
									Maize powder			
27	*Cynoglossum lanceolatum* Forssk.	Teneg	Boraginaceae	H	W	L	11	Dm	None	Wound/injured body	TK MZ	
28	*Datura stramonium* L.	Mezerbae	Solanaceae	H	W	L	11	Dm	Butter	Tetanus	TK MZ AT	
						L	4	Or	None	Abdominal cramp		
						L	11	Dm	None	Leishmaniosis		
						L& F	4	Or	Water	Intelligence		
29	*Dichrostachys cinerea* (L)	Gonok	Fabaceae	S	W	S	12	Dm	None	Dislocated bone	TK MZ	-Fence
30	*Dodonaea angustifolia* L.	Tahsos	Sapindaceae	S	W	L	11	Dm	Butter	Herpes zoster	MZ	-Firewood, -Material culture
						L	11	Dm	None	Wound		
						S	6	Dm	None	Warts		
31	*Echinops macrochaetus* Fresen.	Dender	Asteraceae	H	W	R	2	Dm	None	Headache	TK MZ AT	-Fence
32	*Erythrina abyssinica* Lam. ex DC.	Zwawue	Fabaceae	T	W	B	9	Na	None	Evil eye	TK MZ AT	-
						L	11	Dm	Butter	Teniaversicolor /mada/		
33	*Eucalyptus camaldulensis* Dehnh.	Kelamitos	Myrtaceae	T	C	L	9	Na	None	Evil eye	TK MZ AT	-Firewood, -fence
34	*Euphorbia abyssinica* Gmel.	Kolankul	Euphorbiaceae	T	W	Lx	5	Or	None	Coughs	TK	-Fence
						Lx	5	Or	None	Tuberculosis		
						lx	5	Or	Enjera	Gonorrhea		

No	Scientific Name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
35	*Euclea racemosa* subsp. *schimperi*	Kuleo	Ebenaceae	S	W	R	4	Or	None	Scorpion bite	TK MZ AT	-Firewood
						S	3	Dm		Rheumatism/ joint pain		
36	*Eulophia streptopetala* Lindl.	Shingurti-zibie	Orchidaceae	H	W	Bl	12	Dm	None	Elephantiasis	TK	
						Ag	3	Dm	*Rumex nervosus*	Evil eye		
37	*Euphorbia tirucalli* L.	Kinchib	Euphorbiaceae	T	W	Lx	6	Dm	Butter	Skin disease/warts	TK MZ AT	-Firewood
38	*Flueggea virosa* (Willd.) Voigt.	Harmazo	Euphorbiaceae	S	W	Yt	2	Dm	None	Sprain	TK MZ	-Fruit is edible
39	*Foeniculum vulgare* Mill	Shilyan	Apiaceae	H	C	F	5	Or	Sugar/ honey	Kidney sandstone	AT	-For smelling
						F	5	Or	Sugar/ honey	Urine retention		
						S	8	Ts	None	Mouth bad smell		
40	*Gardenia ternifolia* Schumach. & Thonn.	Hatsinay	Rubiaceae	S	W	S	12	Dm	None	Sprain	TK	-Firewood
						R	10	Or	sorghum flour	Malaria		
						R	10	Or	honey/b utter/ sugar	Energy loss		
						L	7	Or	Honey Enjera	Abdominal cramp		
41	*Grewia ferruginea* Hochst. exA. Rich.	Tsumkuya	Tiliaceae	T	W	R	6	Dm	Ricinusc ommunis Latex	Hemorrhoids	TK	-Food
						L	7	Or	None	Abdominal disease	MZ	
						L	2	Dm	None	Fire burn	AT	

No	Scientific Name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
42	*Jasminum abyssinicum* Hochets. ex DC.	Habitselim	Oleaceae	S	W	L	7	Or	None	Tape worm	TK	-Firewood
						L	8	Or	None	Vomiting	MZ	
						L	8	Or	None	Abdominal disease/Nausea	AT	
						L	5	Or	Sugar	Ascariasis		
43	*Justicia schimperiana* (Hochst. ex. A.Nees) T. Anders	Simieza	Acanthaceae	S	W	L	5	Or	Sugar	Ascariasis	TK MZ	-Fodder
44	*Kleinia grantii* (Oliv. &Hiern) Hook.f.	Bierir	Asteraceae	H	C	L	11	D	None	Swelling	TK MZ AT	
						Ag	9	Na	None	Evil eye/ evil spirit		
45	*Lagenaria siceraria* (Molina)	*Amham*	Cucurbitaceae	H	C	F	9	Na	None	influenza	TK MZ AT	-Furniture
						L	6	Dm	None	Dandruff		
46	*Lantana camara* var. alba	Alalimo	Verbenaceae	H	W	L	2	Dm	None	Scabies	TK MZ	
						L	6	Dm		Fresh wound		
47	*Leucas martinicensis* (Jacq.) R. Br.	Karsa-karsa	Lamiaceae	H	W	Ag	2	Dm	*None*	Tumor	TK MZ AT	
48	*Linum usitatissimum* L.	Entatie	Linaceae	H	C	F	11	Or	*Water, sugar/ honey*	Abdominal desiccation	TK	
49	*Lippia adoensis* Hochst. ex Walp.	Kosoeret (caltivated)	Verbenaceae	S	C	L	2	Dm	*None*	Body swelling	AT MZ	
50	*Maytenus arbutifolia* (A. Rich.)	Atat	Celastraceae	S	W	L	12	Dm	None	Sprain	TK MZ AT	-Fence
51	*Maytenus senegalensis* (Lam.) Exell	Argudi	Celastraceae	S	W	R	4	Or	None	Irregular/ excessive menstruation	TK MZ AT	-Fence

No	Scientific Name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
52	*Mentha longifolia* L.	Setisemhal	Lamiaceae	H	W	L	2	Na	None	Head ache	TK AT	-Source of incombe
53	*Moringa stenopetala* (Bak. f.) Cuf	Moringa	Moringaceae	H	**C**	L	7	Or	Enjera	Diabetes mellitus	TK AT	-Food -Source of income
						L	5	Or	Sugar	Blood pressure		
						L	5	Or	None	Diarrhea		
						F	11	Dm	None	Pimple/ cosmetics		
54	*Olea europaea* subsp. *cuspidata*	Awulie	*Oleaceae*	T	W	B	9	Na	None	Bronchitis/tonsil	TK MZ AT	-Firewood -Furniture
						R	8	Or	None	Toothache		
						L	10	Or	Milk/ Water	Asthma		
55	*Ocimum basilicum* L.	Seseg/rihan	Lamiaceae	H	W	Ag	2	Dm	None	Swelling	MZ	
56	*Ocimum lamiifolium* Hochst. ex Benth.	Demakese	Lamiaceae	H	C	L	2	Dm	water	Fever	TK	
						L	5	Or	Coffee	Febrile illness (michi)		
57	*Opuntia ficus-indica* (L.) Miller	Beles	Cactaceae	S	C	L	6	Dm	None	Tenia versicolor	MZ	-Food -Fodder
58	*Ormocarpum pubescensm* (Hochst.) Cuf. ex Gillett	Alendia	Fabaceae	S	W	S	2	Dm	Butter	Ligament/joint disease	MZ	-Firewood -Fence
59	*Otostegia integrifolia* Benth.	Chiendog	Lamiaceae	S	W	L	5	Or	Water Salt	Blood pressure	TK MZ	
						R	9	Na	None	Pneumonia		
60	*Persea americana* Mill.	Avocado	Lauraceae	T	C	F	7	Or	Garlic Enjera	Malaria	AT	-Food
61	*Phytolacca dodecandra* L'Her.	Shibti	Phytolaccaceae	W C	W	F	4	Or	Water	Rabies	TK AT	-For washing cloth
						L	11	Dm	None	Warts		
						F	6	Or	None	Abortion		
						L	7	Or	Chicken	children's TB		

No	Scientific Name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
62	*Piliostigma thonningii* (Schumach.)	Amamgimel	Fabaceae	T	W	S	12	Dm	None	Broken bone	TK AT	
						L	12	Dm	None	Wound		
63	*Plumbago zeylanica* L.	Aftuh	Plumbaginaceae	H	W	R	7	Or	None	Tooth infection,	TK MZ AT	-Fodder
						L	4	Or	Water	stomach pain/diarrhea		
						L	2	Dm	None	skin swelling		
						L	12	Dm	None	ear problems		
						Ag	12	Dm	None	Evil sprit		
64	*Otostegia fruticosa* (Forssk.) Schweinf.ex Penzig	Sasa	Lamiaceae	S	W	L	4	Or	Sugar	Ascariasis	TK	
5	*Rhamnus prinoides* L'Herit.	Gesho	Rhamnaceae	S	C	L	6	Dm	None	Dandruff	TK MZ AT	-For making 'Tela"
						L	1	Or	None	Tonsil		
66	*Rhus retinorrhoea* Oliv.	Tetealo	Anacardiaceae	S	W	R	4	Or	Milk/ water	Anti-abortion of women	TK MZ AT	-Food
67	*Ricinus communis* L.	Guile	Euphorbiaceae	S	W	Lx	6	Dm	*Grewiaferruginea*	Hemorrhoids	TK MZ AT	-Fruit is for backing, -Firewood
						Lx	6	Dm	None	Wounds		
						F	6	Dm	None	dandruff		
						Sd	5	Or	Tea	Giardiasis/ amoebiasis		
						Sd	11	Dm	Lime sap	Dandruff		
68	*Rumex abyssinicus* Jacq.	Mokmoko	Polygonaceae	H	W	R	5	Or	Tea	Vomiting	TK MZ AT	- Eaten as spice
						R	5	Or	Tea	TB		
						R	8	Or	None	Tooth disease		
69	*Rumex nervosus* Vahl.	Machicho/ hahot	Polygonaceae	S	W	Rh	11	Dm	None	Herpes zoster	TK MZ AT	-The young twig is edible
						S	10	Or	Water Salt	Gastritis		

No	Scientific Name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
70	*Ruta chalepensis* L.	Chena-adam	Rutaceae	H	C	L	2	Na	Garlic	Evil spirit/ Evil eye	TK MZ AT	
						L	1	Or	Tea	Headache		
						L	1	Or	Tea	Fever		
						L	1	Or	Tea	common cold		
71	*Schinus molle* L	Tikurberbere	Anacardiaceae	T	C	L	1	Or	Tea	Digestion problem	TK MZ AT	-Firewood, -Furniture
						L	9	Op	None	Eye infection		
72	*Senna singueana* (Delile) Lock	Hambohambo	Fabaceae	S	W	S		Dm	None	Pesticide	TK MZ AT	-Firewood
						R	8	Or	None	Jaundice/yellowness of skin/		
73	*Sida rhombifolia L.*	Dekidaero	Malvaceae	H	W	R	9	Na	None	Epilepsy	TK MZ	
						Ag	12	Dm	None	anti-swelling		
74	*Solanum incanum* L.	Engule	Solanaceae	H	W	R	10	Or	None	Stomach pain	AT	
						R	6	Op	None	Eye infection		
						R	8	Or	None	Tooth disease		
75	*Stereospermum kunthianum* Cham	Adgizana	Bignoniaceae	T	W	B	12	Dm	None	Dislocated backbone	TK MZ AT	-Firewood
						S	12	Dm	None	Broken limb		
						L	11	Dm	None	Bleeding wound		
76	*Tagetes minuta* L.	Etsefarus	Asteraceae	H	W	Ag	9	Na	None	Evil eye	AT	
77	*Tragia cinerea* (Pax) Gilbert & Radcl.-Smith	Ame'e	Euphorbiaceae	H	W		2	Dm	-*Urtica simensis*	Tinea versicolor	TK MZ AT	
78	*Verbascum stelurum* Murb.	Tirnaka	Scrophulariaceae	H	W	L	11	Dm	None	bleeding	TK MZ AT	-Firewood
						L	9	Op	None	eye disease		
						L	11	Dm	None	fire burn		

No	**Scientific Name**	**Local name**	**Family**	**GF**	**source**	**PU**	**MRPA**	**RA**	**Additive**	**Disease treated**	**District**	**Other uses**
79	*Withania somnifera* (L.) Dunal	Agol	Solanaceae	H	C	L	2	Dm	None	Swelling	TK	
						L	3	Dm	*Allium sativum,*	Itch infection	MZ AT	
						F& L	9	Na	Paper fruit	Eye disease		
80	*Ximenia americana* L.	Muleo	Olacaceae	S	W	L	4	Or	Grlic water	Vomiting	TK AT	-Food -Source of income
						B	1	Or	Tea	Malaria		
						B	11	Dm	None	Wound		
81	*Zehneria scabra* (L.f.) Sond	Hafaflo	Cucurbitaceae	C	W	R	4	Or	None	abodminal disease/Diarrhea	TK MZ AT	
						F	10	Or	Milk	Food poisoned infections		
						R	10	Or	Honey Water	Tuberculosis		
82	*Zingiber officinale* Roscoe	Gingibl	Zingiberaceae	T	C	Rz	4	Or	None	Blood pressure	TK MZ AT	
						Rz	1	Or	Sugar Water	Common cold		
						Rz	5	Or	Sugar Water	Abdominal cramp/disease		
83	*Ziziphus spina-christi* L.	Gaba	Rhamnaceae	T	W	B		Or	Honey Water	Abdominal pain	TK MZ	-Food -Source of income
						L		Dm	None	Dandruff	AT	

Appendix 7. List of plant species and methods of preparation to treat Livestock ailments

Key: Scientific name; local name; family; GF=growth form: T = tree, S= shrub, H = herb; Source: W= Wild, C= cultivated; PU = plant part used: L = leaf, S = stem, R = root, B = bark, Ag = above ground, F = fruit, Sd = seed, Rh = Rhizome, Bl = Bulb, Yt = Young twig, Lx = latex; MRPA = mode of remedy preparation and application: 1 = crush and mix with cold water then drink, 2 = Burn or boil the plant part and inhale its smoke, 3 = Squeeze or sniff the freshly crushed part, 4 = Rub/paste the latex/sap/juice directly, 5 = Grind and paint the powder or crushed part, 6 = Tie the crushed or plant part, 7 = Eat the plant part, 8 = Drink the concoction; RA = Route of remedy administration; Or = Oral, Na = Nasal, Dm=Dermal, Op=Optical; Dis = District: TK = Tahtay Koraro, MZ = Medebay Zana, AT= Asgedetsimbla

No	**Scientific name**	**Local name**	**Family**	**GF**	**source**	**PU**	**MRPA**	**RA**	**Additive**	**Disease treated**	**District**	**Other uses**
1	*Acacia venosa* Hochst. ex Benth.	Kentib	Fabaceae	S	W	S	6	Dm	None	Dislocated bone	TK MZ AT	Fence
2	*Anogeissus leiocarpa* (DC.) Guill. & Perr.	Hanse	Combretaceae	T	W	R	1	Or	None	Anthrax	TK MZ AT	Fodder -material culture -Firewood
3	*Azadirachta indica* **A. Juss.**	Niem	Meliaceae	T	C	L	1	Or	Water	Anthrax	TK MZ AT	
						L	1	Or	Water	Diarrhea of hens		
4	*Boswellia papyrifera* (Del.) Hochst.	Meker	Burseraceae	T	W	S	2	Dm	*Calotropis procera*	Snake repelling	TK AT	
5	*Buddleja polystachya* Fresen.	Metere	Scrophulariaceae	T	W	Yt	4	Dm	None	Skin disease/ Itch	MZ	Firewood Fodder
						Yt	4	Dm	None	Animal wound		
6	*Calotropis procera* (Ait.)	Gindae	Asclepiadaceae	S	W	R	3	Na	*Boswellia papyrifera*	Snake repelling	TK MZ AT	
7	*Capparis tomentosa* Lam.	Andiel	Capparidaceae	S	W	B	5	Dm	None	Wound	MZ AT	

No	Scientific name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
8	*Calpurnia aurea* (Alt.) Benth.	Hitsawutsi	Fabaceae	S	W	L	2	Dm	None	Skin disease	TK, MZ, AT	
9	*Cissus petiolata* Hook. f.	Alkie	Vitaceae	W C	W	S/L	2	Dm	None	Skin disease	TK MZ	
						L	4	Or	None	Swelling		
10	*Citrus aurantiifolia* (Christm.) Swingle	Lemin	Rutaceae	S	C	F	2	Dm	None	Animal's Exo-parasite	TK MZ AT	
11	*Croton macrostachyus* Del.	Tamboque	Euphorbiaceae	T	W	S/B	2	Dm	None	Animal's Ectoparasite	TK, MZ, AT	-Firewood -Material culture
12	*Datura stramonium* L.	Mezerbae	Solanaceae	H	W	L	4	Dm	Lime juice	Skin disease	TK, MZ, AT	
13	*Dodonaea angustifolia* L. f.	Tahsos	Sapindaceae	S	W	L	4	Dm	Milk	Wound	MZ	-irewood, -Material culture
14	*Echinops macrochaetus* Fresen.	Dender	Asteraceae	H	W	R	6	Dm	None	Bone distort/dislocate	TK, MZ, AT	-Fence
15	*Flueggea virosa* (Willd.) Voigt.	Harmazo	Euphorbiaceae	S	W	R	8	Or	None	Rabbis infected animal	TK, MZ	-Food
16	*Grewia ferruginea* Hochst	Tsumkuya	Tiliaceae	S	W	L	1	Or	None	Leech infection	TK MZ AT	-Firewood
17	*Justicia schimperiana* (Hochst. ex. A.Nees) T. Anders	Simieza	Acanthaceae	S	W	R	6	Dm	None	Blackleg/cattle limp disease	TK MZ	-Fodder
18	*Nicotiana tabacum* L.	Timbuaqua	Solanaceae	H	C	L	1	Na	Water	Leech infection	TK	
						L	4	Dm	Water	Skin parasites/ Ectoparasite	MZ AT	

No	Scientific name	Local name	Family	GF	source	PU	MRPA	RA	Additive	Disease treated	District	Other uses
19	*Phytolacca dodecandra* L'Her	Shibti	Phytolaccaceae	WC	W	S	5	Na	water	Leech infection	TK	-For washing cloth
						F	5	Dm	None	Ectoparasite/ Itch infection	AT	
						R	4	Or	None	Rabbis		
20	*Plumbago zeylanica* L.	Aftuh	Plumbaginaceae	H	W	L	7	Or	None	-Anthrax	TK MZ AT	Fodder
						L	3	Dm	None	-To cure cuttle with bloody milk		
21	*Premna oligotricha* L.	Sasa	Lamiaceae	S	W	L	3	Or	None	Cattle's thin down, locally 'ebran'	TK	
22	*Senna singueana* (Delile) Lock	Hambahambo	Fabaceae	S	W	L	1	Or	Water	Abdominal cramp	TK MZ AT	-Firewood
						L	3	Dm	Water	Abdominal swelling		
23	*Solanum incanum* L.	Engule	Solanaceae	H	W	F	1	Na	water	Cattle cough	TK MZ AT	
						R	1	Or	Water	Goat cough		
24	*Stereospermum kunthianum* Cham	Adgizana	Bignoniaceae	T	W	B	5	Dm	None	Wound	TK MZ AT	-Firewood
25	*Tragia cinerea* (Pax) Gilbert & Radcl.-Smith	Ami'e	Euphorbiaceae	H	W	L	3	Dm	None	Bleeding	TK, MZ, AT	
26	*Ximenia americana* L.	Mileo	Olacaceae	S	W	L	1	Na	water	Leech infection	TK	-Food
						B	5	Dm	None	wound	AT	-Source of income
27	*Zehneria scabra* (L.f.) Sond	Hafaflo	Cucurbitaceae	H	W	R	5	Op	None	Eye infection	TK, MZ, AT	Fodder

Appendix 8. Semi-structured interview questions employed to collect medicinal plants

1. **Background of informants**

1.1. Name: __________

1.2. Gender: a) Male b) Female

1.3. Age: a)18-40 b) > 40

1.4. District: a)Tahtay Koraro b) Medebay Zana c) Asgede Tsimbla

1.5. Name of kebele ________________

1.6. Marital status: a) single b) Married

1.7. Educational status: a)Literate (able to read & write) b) Illiterate (unable to read & write)

1.8. Religion: a) Christian Orthodox b) Muslim C) Others

2. **Information related to the medicinal use of the plants**

2.1. Do you use medicinal plants?

2.2. Mention plant types used to treat a given disease in the area (give local names)?

2.3. What are the most common human diseases in your area?

2.4. What are the most common livestock diseases in your area?

2.5. What are the plants used to treat only human diseases?

2.6. What are the plants used to treat only livestock diseases?

2.7. Habitat of the medicinal plant? a) cultivated b) wild

2.8. Where do the medicinal plants grow?

a) Garden b) forests land c) Agricultural land d) Fallowed land

2.9. What is the habit of the plant?

a) Tree b) Shrub c) Herb d) Climber e) Liana

2.10. Which part/ parts of the medicinal plant (s) is/are used? Choose one of the given alternatives)

a) The whole plant (WP) b) Bark (B) c) fruit (F) d) Leaf (L) e) pollen nectar f) root (R) g) young twig(Yt) h) Latex(Lx) i) Bulb(Bl) j) Seed (Sd) k) Rhizome (Rh) l) Stem(S) M) the whole plant

2.11. Does the dose of the remedies have standard measurement and prescriptions?

2.12. Is there any noticeable adverse effect (side effect) caused by the medicine? If yes, is/ is there any antidote (s) for those adverse effects?

2.13. Ingredients or additives (if any)?

2.14. How are the prepared remedies taken by the patient (s)/routes of administration?

a) Oral b) Auricular c) Nasal d) Dermal e) Optical f) Tooth surface

2.15. Who is the source for your indigenous knowledge of medicinal plants?

2.16. How is the knowledge on traditional medicine passed to a family member/younger generation?

2.17. Could you tell me ten medicinal plants of your preference to treat the common disease occurring frequently in this area based on their rank of effectiveness?

2.18. What are the main threats for those medicinal plants?

a) Deforestation b) Expansion of agriculture c) firewood collection d) Over-harvesting by humans e) Overgrazing/browsing f) Lack of knowledge on use and management of WEP g) Drought h) charcoal production i) others mention it

2.19. Which medicinal plants species is commonly threatened in study area?

2.20. How do you conserve medicinal plants?

2.21. Do the medicinal plants have any use other than medicine? If yes, state

2.22. List seven medicinal plants and arrange them based on their multipurpose uses?

Thank you for your cooperation!

Appendix 9. Publications (two articles) of the study

A

Ecological Processes

RESEARCH — Open Access

Ecological and floristic study of Hirmi woodland vegetation in Tigray Region, Northern Ethiopia

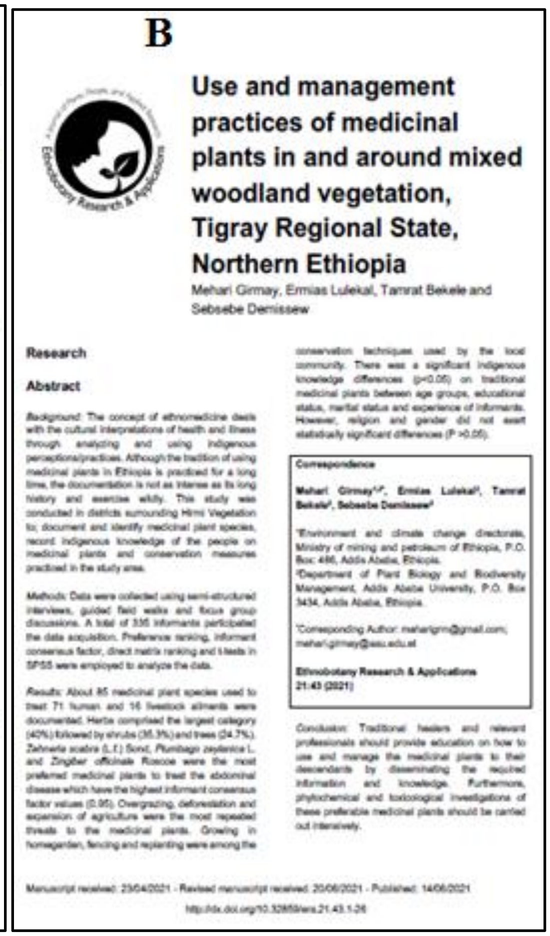
Mehari Girmay[1,2*], Tamrat Bekele[2], Sebsebe Demissew[2] and Ermias Lulekal[2]

Abstract

The dryland area in Ethiopia covers a substantial region endowed with diverse plant resources. However, the landmass has received less attention even if it has high ecological, environmental, and economic uses. The present study was conducted in Hirmi woodland vegetation, which is one of the dryland areas in Ethiopia, with the objective of investigating the floristic composition, plant community types, vegetation structure, community-environment relations and its regeneration status. Vegetation and environmental data were collected from 80 sampling plots with a size of 25 m × 25 m designated as the main plots. Diameter at breast height (DBH), height, basal area, density, vertical structure, importance value index (IVI), and frequency were computed. Species diversity and evenness were analyzed using Shannon diversity and evenness indices. The plant community types and vegetation-environment relationships were analyzed using classification and ordination tools, respectively. A total of 171 vascular plant species belonging to 133 genera and 56 families were recorded. About 5.3% of the species were endemic and near-endemic to Ethiopia. The highest number of species was recorded in families Fabaceae (16.4%) and Poaceae (11.7%) followed by Asteraceae (7.0%), Combretaceae, Lamiaceae, and Moraceae (3.5% each). Five plant communities were identified. According to the results from ordination analysis, the floristic composition of these plant communities was significantly affected by altitude, slope, sand, silt, soil organic matter, total nitrogen, and disturbance. The vegetation structure reveals that a large number of individual species was categorized in the lower DBH, frequency, and height classes. The highest Shannon diversity index and evenness values of the study area were 4.21 and 0.95, respectively. *Anogeissus leiocarpa*, *Combretum hartmannianum*, *Ziziphus mucronata*, *Terminalia macroptera*, and *Acacia polyacantha* were the species with high IVI. Some endemic plants were in the IUCN red list categories of Ethiopia and Eritrea. The overall regeneration status of the study area was poor because of anthropogenic disturbances and grazing pressures. Although the study area is endowed with high plant species diversity including endemism, it is under poor regeneration status due to various disturbances. To overcome this challenge, integrated management measures including monitoring and application of restoration techniques by taking into consideration the significant environmental factors associated with species diversity as well as observed regeneration status and IUCN threat level of the species are highly recommended.

Keywords: Diversity, Dryland, Hirmi woodland, Regeneration status, Plant communities

Springer Open



B

Use and management practices of medicinal plants in and around mixed woodland vegetation, Tigray Regional State, Northern Ethiopia

Mehari Girmay, Ermias Lulekal, Tamrat Bekele and Sebsebe Demissew

Research

Abstract

Background: The concept of ethnomedicine deals with the cultural interpretations of health and illness through analyzing and using indigenous perceptions/practices. Although the tradition of using medicinal plants in Ethiopia is practiced for a long time, the documentation is not as intense as its long history and exercise wildly. This study was conducted in districts surrounding Hirmi Vegetation to; document and identify medicinal plant species, record indigenous knowledge of the people on medicinal plants and conservation measures practiced in the study area.

Methods: Data were collected using semi-structured interviews, guided field walks and focus group discussions. A total of 336 informants participated the data acquisition. Preference ranking, informant consensus factor, direct matrix ranking and t-tests in SPSS were employed to analyze the data.

Results: About 85 medicinal plant species used to treat 71 human and 16 livestock ailments were documented. Herbs comprised the largest category (40%) followed by shrubs (35.3%) and trees (24.7%). *Zehneria scabra* (L.f.) Sond, *Plumbago zeylanica* L. and *Zingiber officinale* Roscoe were the most preferred medicinal plants to treat the abdominal disease which have the highest informant consensus factor values (0.95). Overgrazing, deforestation and expansion of agriculture were the most repeated threats to the medicinal plants. Growing in homegarden, fencing and replanting were among the conservation techniques used by the local community. There was a significant indigenous knowledge differences (p<0.05) on traditional medicinal plants between age groups, educational status, marital status and experience of informants. However, religion and gender did not exert statistically significant differences (P >0.05).

Conclusion: Traditional healers and relevant professionals should provide education on how to use and manage the medicinal plants to their descendants by disseminating the required information and knowledge. Furthermore, phytochemical and toxicological investigations of these preferable medicinal plants should be carried out intensively.

Correspondence

Mehari Girmay[1,2*], Ermias Lulekal[2], Tamrat Bekele[2], Sebsebe Demissew[2]

[1]Environment and climate change directorate, Ministry of mining and petroleum of Ethiopia, P.O. Box: 486, Addis Ababa, Ethiopia.
[2]Department of Plant Biology and Biodiversity Management, Addis Ababa University, P.O. Box 3434, Addis Ababa, Ethiopia.

*Corresponding Author: meharigrm@gmail.com; mehari.girmay@aau.edu.et

Ethnobotany Research & Applications
21:43 (2021)

Manuscript received: 23/04/2021 - Revised manuscript received: 20/06/2021 - Published: 14/06/2021

http://dx.doi.org/10.32859/era.21.43.1-26

<u>The above articles are free online acess at:</u>

A☞https://doi.org/10.1186/s13717-020-00257-2

(@Springer nature: Journal of Ecological Processes)

B ☞http://www.ethnobotanyjournal.org/index.php/era/article/view/2779

(@Journal of Ethnobotany Research & Applications)