



**FLORISTIC DIVERSITY OF JORGO WATO FOREST AND ETHNOBOTANICAL
STUDY OF MEDICINAL AND WILD EDIBLE PLANTS IN NOLE KABA DISTRICT,
WEST WOLLEGA, OROMIA REGION, ETHIOPIA**

By

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Addis Ababa University

Addis Ababa, Ethiopia

June 2019



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A Dissertation Submitted to
The Department of Plant Biology and Biodiversity Management
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Philosophy (Biology: Botanical Sciences)

Addis Ababa University

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GRADUATE PROGRAMMES**

This is to certify that the Dissertation prepared by Kebu Balemie Jima, entitled: *Floristic diversity of Jorgo Wato Forest and ethnobotanical study of medicinal and wild edible plants in Nole Kaba District, West Wollega, Oromia Region, Ethiopia* and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy (Biology: Botanical Sciences) complies with the regulations of the University and meets the accepted standards with respect to originality and quality

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ABSTRACT

Floristic diversity of Jorgo Wato Forest and ethnobotanical study of medicinal and wild edible plants used in Nole Kaba District, West Wollega, Oromia Region, Ethiopia
Kebu Balemie Jima, PhD Dissertation
Addis Ababa University, 2019

*The research was carried out in Nole Kaba District to study the floristic diversity, structure, composition of Jorgo Wato Forest (JWF) and ethnobotany of medicinal and wild edible plants used in selected areas of Nole Kaba District. Floristic data were collected from a total of 73 plots applying standard plot sizes. The number of individuals, dbh (diameter at breast height), and height of woody species ($dbh \geq 2.5$ cm) were enumerated and measured in each plot; their cover abundance was estimated. Ethnobotanical data were documented through semi-structured interviews (371 general informants of whom 174 were females & (12 key informants), group discussions, field observations, market surveys, and pairwise comparisons. Forest structural attributes were computed using descriptive statistics; plant communities were classified using cluster analysis. Redundancy Analysis was employed to analyze relationship between species distribution and environmental factors. Shannon diversity indices were employed to estimate species diversity. ANOVA, Sorenson's similarity, and correlation analysis were computed to analyze mean differences, similarity and relationships in floristic data. Ethnobotanical data were analyzed using descriptive statistics and quantitative indices such as Factor of Informant Consensus (Fic), Fidelity Level (FL), Pairwise Ranking, Correlation, Sorenson Similarity, Use Value and Cultural Importance Index (CI). ANOVA was employed to test the variation in ethnobotanical knowledge among informants and Multiple Linear Regressions (MLR) was employed to determine the strength of the influence of variables that contributed to the knowledge variation. The floristic study found a total of 237 species belonging to 192 genera and 82 families. The highest Important Value Index was recorded for *Pouteria adolfi-friederici*, followed by *Syzygium guineense* subsp. *afromontanum*. Five plant community types were identified. Species diversity and evenness were 3.73 and 0.80, respectively. Altitude and slope significantly influenced ($p < 0.05$) species distribution across plant community types. One hundred sixty two medicinal plants belonging to 135 genera and 65 families were found from the ethnomedicinal and ethnoveterinary study. The highest proportion of medicinal plants were herbs (47.5%), followed by shrubs (27.8%). *Ehretia cymosa* (FL = 100%), *Pentas schimperiana* (FL = 100%) and *Loxogramme abyssinica* (FL = 94%) were among the medicinal plants showing high informant consensus. Age, healing experience, gender, and proximity to forest revealed significant variation and these together accounted for 34.7% ($R^2 = 0.347$) of the total variation in ethnomedicinal knowledge among informants. The ethnobotanical study also found 39 WEPs species belonging to 31 genera and 27 families that are consumed by the community. Nutritional analysis of selected wild edible fruits found rich nutritional composition in the fruits. Medicinal plants with high informant consensus and wild edible fruits (e.g. *Carissa spinarum*, *Syzygium guineense* subsp. *afromontanum*, *Ximenia americana*) with rich nutritional composition are recommended for further development and conservation.*

Keywords: *Ethnobotany, floristic diversity, indigenous knowledge, medicinal plants, wild edible plants,*

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LIST OF ACRONYMS/ ABBREVIATIONS

BA	Basal Area
CBD	Convention on Biological Diversity
CI	Cultural Importance
DAF	Dry Afromontane Forest
Dbh	Diameter at breast height
EBI	Ethiopian Biodiversity Institute
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization
FL	Fidelity Level
Fic	Factor of informant consensus
IBC	Institute of Biodiversity Conservation
IUCN	International Union for Conservation of Nature
IVI	Importance Value Index
JWF	Jorgo Wato Forest
KBG	Kew Botanical Garden
MAF	Moist Afromontane Forest
RDA	Redundancy Analysis
Ss	Sorenson's similarity
UV	Use Value
WEP	Wild Edible Plants
WHO	World Health Organization
WBISP	Woody Biomass Inventory and Strategic Planning Project

CHAPTER ONE

1. INTRODUCTION

1.1 Background

The flora of Ethiopia exhibits an enormous diversity, which is largely due to heterogeneity in climate, soil, topography, and geology. In terms of taxonomic diversity, the flora comprises about 6000 species, 1539 genera and 238 families. Of these, angiosperms are represented by the highest number of species (5,815), genera (1505) and families (202). The families represented by the highest number of species are Fabaceae (678 species), followed by Poaceae (609 species), and Asteraceae (472 species). In terms of endemism, about 10% of the species are endemic to Ethiopia. Asteraceae is represented by the highest number (103) of endemic species, followed by Fabaceae (71) and Poaceae (39) species (Ensermu Kelbessa and Sebsebe Demissew, 2014). Herbs, followed by shrubs are the dominant growth forms of the taxonomic groups. In terms of vegetation types, the wild flora are classified into twelve major and twelve sub-vegetation types (Friis *et al.*, 2011), six of which include forest vegetation (IBC, 2012). These vegetation types vary in species richness, composition, and distribution over wide phytogeographic and climatic landscapes.

The country's flora in general consists of many species that can provide diverse direct and indirect benefits to local communities. Among these, medicinal and wild edible plants are known and used by large proportion of the rural population for multipurpose including healthcare and food needs. Reviews revealed that about 1000 medicinal plants (Zemedu Asfaw and Tigist Wondimu, 2007) and 413 wild and semi-wild edible plants (Ermias Lulekal *et al.*, 2011) have been documented in Ethiopia so far. Although not yet validated and standardized, many medicinal plants such as ginger (*Zingiber officinale*), garlic (*Allium sativum*) and eucalyptus (*Eucalyptus*

globulus) are widely used by Ethiopians at home to treat common health problems such as colds, fevers and headaches in humans (Dawit Abebe and Ahadu Ayehu, 1993; Fekadu Fullas. 2001).

Similarly, many wild edible plants are commonly cherished as snacks by most community members, while others are consumed as gap fillers for grain food shortages during certain seasons of a year (Guinand and Dechassa Lemessa, 2000; Zemedede Asfaw and Mesfin Tadesse, 2001). The nutritional contributions of many wild edible plants are not well known among users. Identification of nutritionally rich and promotion of their wider domestication and use would thus help to reduce malnutrition and contribute to food security; also contributes to the conservation of species and preservation of culture.

The rich flora of Ethiopia is associated with a wealth of ethnobotanical knowledge. A number of ethnobotanical studies on medicinal and wild edible plants have witnessed the existence of rich ethnobotanical knowledge. The vast majority of Ethiopians mostly rural are depending on medicinal plants and associated ethnobotanical knowledge for their healthcare. Some members of the society also depend on wild edible plants and associated ethnobotanical knowledge to cope up with food shortages. Ethnobotanical knowledge is largely oral and becomes vulnerable to distortion/loss. Thus, it should be documented, analyzed, and potentially used for development and sustainable use of botanical resources.

Apart from healthcare and nutritional roles, the economic importance of medicinal and wild edible plants is well documented in many works as indicated by the ethnobotanical literature. As in many other countries around the world (FAO, 1999), these plants, largely medicinal plants contribute to the economic well-being of local communities in Ethiopia who make their

livelihood on collection and selling or through use for treating patients as in the case of traditional healer (Mander *et al.*, 2006).

Despite their immense contributions, the natural vegetation types, which is the source of many useful wild plants are deteriorating in quality and shrinking in size (EBI, 2015). Each year a significant proportion of forests, woodlands, and shrublands have been cleared and converted for both small and large-scale agricultural uses (Mulugeta Lemenih, 2012). Over the past 2-3 decades, deforestation has continued in Ethiopia (FAO, 2010) despite the government's commitment to implement the Climate Resilient Green Economy (CRGE). The deforestation and fragmentation have continued and resulted in a loss of many useful and unique plant species. The over-exploitation of many species such as *Echinops kebericho* and *Taverneia abyssinica* for subsistence and commercial needs are cases in point (Mander *et al.*, 2006). Furthermore, endemic plant assessment report showed that about 32.7% and 22.5% of Ethiopian endemic plants have categorized as critically endangered and endangered threat categories, respectively (Vivero *et al.*, 2006). Many studies have reported a loss of or declining trends of medicinal and wild edible plants. The loss of species is also associated with fading away or eroding of ethnobotanical knowledge (Dawit Abebe and Ahadu Ayehu, 1993; Mirutse Giday *et al.*, 2009; Mirutse Giday *et al.*, 2010).

1.2 Statement of the problem

As in many other parts of Ethiopia, the coverage of the natural vegetation of the present study area has been reduced and many plant species have shown reduced abundance. Remnant tree/shrub stands in farmland and in many parts of the study area are a testimony to shrinkage or deterioration of natural vegetation. On the other hand, studies showed that many species in

Wollega (WG) floristic region were not documented in the flora of Ethiopia and Eritrea (Friis, 2009; Fekadu Gurmessa *et al.*, 2013; Teshome Gemechu *et al.*, 2015; Tamene Yohannes, 2016). This means that species are being lost even before documentation.

Given growing pressures on plant diversity and associated habitats, there is a need for the conservation and sustainable use of plant resources and documentation of associated ethnobotanical knowledge. Numerous floristic and ethnobotanical studies have been undertaken in Ethiopia in different parts of the country. Such studies are, however, scanty in Wollega floristic region. Furthermore, previous floristic studies lack information on human-plant interactions while ethnobotanical studies lack quantitative information on status of abundance of ethnobotanically useful plants. It is suggested that ecological information (diversity, structure, and distribution) (Araújo and Ferraz, 2013; Malik and Bhatt, 2015) and ethnobotanical information (identification of over-utilized/threatened and economically useful species, threat factors leading to loss of species) complement each other for proper conservation and development planning (Martin, 1995; Araújo and Ferraz, 2013).

This research was therefore, initiated and conducted in Nole Kaba District to contribute to the conservation and sustainable use of plant resources. Floristic study was conducted in JWF because this forest borders agroecological zones (midlands and highlands) comprising the highest proportion of Nole Kaba District. It was believed that this forest represent the majority of plant species grown in the district; it was also believed that the forest harbor a high diversity of medicinal and WEPs used in the study area. The assessment of the stock of these species in JWF helps for awareness and sustainable use planning. The floristic study was aimed to assess

and determine the floristic composition, structure and diversity of plants including medicinal and WEPs in JWF. The ethnobotanical study document indigenous knowledge associated to medicinal and WEPs found in JWF and outside in sampled KEBELES.

The findings of this study are believed to contribute: to the conservation and sustainable use of plant resources in the study area, such as threatened, rare, and species that lack regeneration; to contribute to the development of WEPs with high nutritional values and medicinal plants with high informant consensus values; to contribute to the preservation of ethnobotanical knowledge; to contribute to the enrichment of national medicinal and wild edible plants national database; contribute to the enrichment of Flora database of the National Herbarium. In addition, the dissertation is believed to serve as reference material for future studies.

1.3 Research questions and hypotheses

The research was intended to address the following questions and hypotheses.

1.3.1 Research questions

1. What are the species diversity, structure, and regeneration status of JWF?
2. What are plant community types in JWF?
3. Which environmental variables are correlated with species distribution in JWF?
4. What are medicinal and WEPs including their ecological roles in JWF?
5. What is the perception of local people towards the conservation of JWF?
6. What are the medicinal and WEPs used by local communities in Nole Kaba District?
7. What are the medicinal plants having high informant consensus values?
8. What are the most preferred WEPs and their nutritional profile?
9. Are there variations in medicinal and WEPs knowledge among informants with different social (age, gender, education, healing profession) and geographic (proximity to forest, proximity to formal health centers, agroecological settlement) variables?
10. What are the factors threatening plant diversity including the availability of medicinal and WEPs?

1.3.2 Research Hypotheses

1. Plant species diversity is high in Jorgo Wato Forest (JWF) and the diversity does not differ among plant community types;
2. Environmental variables do not affect species distribution in JWF;
3. Distribution/possession of ethnobotanical knowledge about medicinal and wild edible plants does not differ among informants with different social and geographic variables;

4. Culturally important medicinal and WEPs are also ecologically important.

1.4 Research objectives

1.4.1 General objective

The general objective was to study the floristic diversity of JWF and ethnobotany of medicinal and wild edible plants used in selected sites/KEBELES of Nole Kaba District

1.4.2 Specific objectives

1. To identify plant species in JWF and determine the floristic composition, diversity, structure and regeneration status woody of species;
2. To identify plant community types and identify environmental variables underlying the distribution of species in sampled plots;
3. To identify medicinal and wild edible plants and document associated ethnobotanical knowledge in sampled study sites/KEBELES;
4. To identify threats to plant biodiversity in the study area;
5. To determine nutritional values of selected wild edible plants;

CHAPTER TWO

2. Literature Review

2.1 Tropical forests and floristic diversity

Forests are vegetation types occupying about 31% of the terrestrial ecosystem (FAO, 2010). Forests vary greatly in definition across the world. The definition given by the Food and Agriculture Organization (FAO) is widely used by several countries since FAO is coordinating the state of world forests. According to FAO (2010) forest is defined as land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in-situ*. Forests have been symbolized as the biodiversity-rich areas on Earth (Myers *et al.*, 2000; Mayaux *et al.*, 2005) as they vary greatly in species composition and structures (Thomas and Baltzer, 2002).

Among the forests, tropical forests, which represent 44% of the world's forest area, are known to harbor much of known plant species (Mayaux *et al.*, 2005; Moore, 2008). Tropical forests are those existing in tropical countries, situated within the Tropics of Cancer and Capricorn. These forests are distinguished by differences in the distribution of rainfall throughout the year, by elevation and soil type (Thomas and Baltzer, 2002). Studies showed that one of the most fundamental characteristics of tropical forests is their great species richness per unit area (Peter, 1996; Thomas and Baltzer, 2002; Primack and Corlett, 2005; Moore, 2008). In particular, lowland tropical rainforests have exceptional species richness compared to other tropical forests (Peter, 1996; Whitmore, 1998; Primack and Corlett, 2005; Moore, 2008). In parts of the Amazon Basin, for example, up to 300 species of trees have been found in 1-hectare forest (Peter, 1996; Moore, 2008). The warm, wet, and relatively seasonal climate of the tropics is

apparently more favorable for maintaining higher diversity than elsewhere in the world (Thomas and Baltzer, 2002)

Tropical forests are structurally the most complex with tree density and canopies layered at different heights above the ground (Borota, 1991; Thomas and Baltzer, 2002; MacDonald, 2003). A highly stratified forest provides differences in plant composition and microclimate in each stratum. Thus, the structural differences in the tropical forests present a wide range of habitats for birds, mammals, reptiles, and insects. These animals influence the plant composition and ecology of the forests through pollination and seed dispersal (Primack and Corlett, 2005). The different plant species that inhabit different strata serve as food sources for animals (MacDonald, 2003). The vast majority of plant species within the tropical forests are trees. Some tree species in rainforests are common, but most are rare. Even the best-represented species comprise a low proportion of the total number of species (Whitemore, 1998). Trees are of varying heights in both understory and canopy. Shrubs share the heavily shaded forest floor with numerous seedling and sapling trees, ferns, and palms. Herbs are, infrequent, and are found as scattered individuals under dense canopy floor of rainforests (Primack and Corlett, 2005; Montagnini and Jordan, 2005; Moore, 2008). Much of the understory of tropical forests particularly lowland tropical forests are deprived of light and is an important potential limiting factor for plant growth (Moore, 2008). Epiphytes and vines are most abundant, where humidity is highest. The abundance of trees, epiphytes, and lianas generally decreases away from the equator because it is associated in general with the occurrence of a dry season. The existence of distinct forest types is indicative of the diversity of climatic and edaphic factors. Most of the floristically diverse forest areas fall within the global plant diversity centers and global biodiversity hotspots (Myers, 1988). Among

these, Neotropical forests, tropical and subtropical Asia and tropical and subtropical Africa harbor the highest floristic diversity (Peter, 1996; Thomas and Baltzer, 2002). The Afromontane areas of eastern Africa, including the Ethiopian highlands, also constitute forests that have exceptional species richness including endemic elements (Schmitt *et al.*, 2010).

Being species-rich, tropical forests contain a large number of non-timber forest resources such as edible fruits, nuts, oil-seeds, medicines, latexes, gums, resins, rituals, dyes, ornamentals, clothing, and numerous other products (Peter, 1996; Thomas and Baltzer, 2002; Montagnini and Jordan, 2005; Primack and Corlett, 2005; Gibson and Gibson, 2007). For example, estimates show that the higher plants in tropical forests are believed to contain about 375 potential pharmaceuticals, and the majority (328) of them remain undiscovered yet. Forty-seven drugs including vincristine, vinblastine, curare, quinine, codeine, and pilocarpine have been already discovered from tropical forests (Farnsworth and Soejarto, 1991; Mendelsohn and Balick, 1995). Mendelsohn and Balick (1995) estimated the full potential social values of undiscovered drugs in tropical forests at UD \$147 billion. Tropical forests are also an important source of varieties of foods including fruits and bush meat to indigenous people in and around the forests (Montagnini and Jordan, 2005; Moore, 2008). The forests of Southeast Asia have been estimated to contain from 200 to 300 species of native fruits alone (Peter, 1996). Assessing their remarkable biological properties and values thus would help sustainable use planning (Moore, 2008).

However, population growth and subsequent demands for forest products and lands have brought the entire system to a point of collapse (More, 2008). In recent decades, the biological wealth of these forests is rapidly deteriorating; thousands of species are being lost each year (Myers *et al.*,

2000). In many parts of the world, tropical forests have already gone and the remaining fragments are being transformed into other land uses. The loss of a tropical forest area puts more species at risk of extinction than the loss of the same area in any other habitat (Primack and Corlett, 2005; Moore, 2008). Because the species richness in a given tropical forest area is exceptionally richer than any other forest. The loss of tropical forests coupled with climate change is believed to have unpredictable effects on the sustainability of ecosystem functions and services including social and economic values and affect the livelihood of millions of people relying on these forests. In addition, the loss of tropical forests is accompanied by the loss of ethnobotanical knowledge, which is among others the basis of plant use for health and food security.

2.2 Medicinal plants and health importance

2.2.1 Diversity of medicinal plants

Medicinal plants are those plants which, in one or more of their organs, contain substances that can be used for therapeutic purposes or which are precursors for the synthesis of useful drugs (Evans, 2009; Sofowaro *et al.*, 2013). These include plants whose therapeutic properties and constituents have been established scientifically; and plants that have not yet been subjected to a thorough scientific study but known for their efficacy in traditional medication. The therapeutic properties of medicinal plants are due to secondary metabolites (alkaloids, quinones, terpenoids, flavonoids, carotenoids, sterols, simple phenolic glycosides, tannins, saponins, polyphenols, etc.) which are produced as part of their normal metabolic activities (Evans, 2009; Paulsen, 2010). Secondary metabolites had no apparent role within the primary production system of the plants. However, in some plant groups, these substances might be produced as adaptation or evolved by plants to improve their survival and reproduction by reducing environmental impacts. Many

secondary metabolites have therapeutic effects on the human body through processes identical to those compounds in conventional drugs (Meskin and Mark, 2002). This enables herbal medicines to be a source of conventional medicines.

Reports indicate that between 35,000 to 70,000 world's plant species are estimated to have medicinal value (Farnsworth *et al.*, 1991; Mendelsohn and Balick, 1995). Most traditional medicines are prepared from plants with medicinal properties. Estimates show that more than 4,000 plant species are used in traditional medicine in tropical Africa (Odugbemi and Odugbemi, 2008). Among the plant families, the top 12 namely, Moraceae, Apiaceae, Lamiaceae, Solanaceae, Euphorbiaceae, Rutaceae, Ranunculaceae, Annonaceae, Asparagaceae, Malvaceae, and Fabaceae are the richest in medicinal plant species in descending order. Selecting families with the highest number of medicinal plants could possibly serve as a clue for future drug discovery programmes (RBG, 2017).

Most of the medicinal plant species have been collected from wild habitats including forests, woodlands, pasturelands, and farmlands. Global distribution shows that a significant proportion of medicinal plants are concentrated in the global biodiversity 'hotspot' areas such as the Amazon rainforest of South America, the eastern Himalayas and Western Ghats in South Asia, and the Eastern Arc Mountains and Coastal Forests of East Africa (Farnsworth *et al.*, 1991; Odugbemi and Odugbemi, 2008).

2.2.2 Health importance of medicinal plants

2.2.2.1 Medicinal plants and traditional healthcare

Plants have been used for medicinal purposes long before recorded history. The usages began perhaps when humans started making conscious interactions with plants. However, the oldest written evidence referring to medicinal plants' usage for preparation of drugs was found on a Sumerian clay slab from Nagpur, in India approximately 5000 years ago. This comprised 12 recipes for drug preparation referring to over 250 various plants (Kelly, 2009). Paulsen (2010) reported similar historical evidence (drawings and scripts) around 4000 years from Euphrat and Tigris. The Chinese book on roots and grasses "Pen T'Sao," written by Emperor Shen Nung circa 2500 BC, listed 365 plant drugs (dried parts of medicinal plants), many of which such as *Rhei rhisoma*, camphor, *Theae folium*, and *Podophyllum*, the great yellow gentian, ginseng, jimson weed, cinnamon bark, and ephedra are used even today (Wiert, 2006). The Indian holy books Vedas mentioned treatment with plants such as nutmeg, pepper, clove, etc., which are used even today (Paulsen, 2010). Ebers Papyrus, written in 1550 BC, had documented about 800 recipes and 700 medicinal plant species (Paulsen, 2010; Petrovska, 2012). Many catalogs including *De Materia Medica*, *Historia Plantarum* and *Species Plantarum* have been variously published in an attempt to provide information on the medicinal uses of plants (Petrovska, 2012). In his classical work, "De Materia Medica" published in 77A.D, Dioscorides described many drugs, preparations, and the therapeutic effect of about 600 medicinal plants (Osbaldeston, 2000). This work of ancient history translated many times and offered data on the medicinal plants constituting the basic *materia medica* until the late Middle Ages (Paulsen, 2010; Petrovska, 2012). Many of the medicinal plants used in ancient times are in use until today for treating ailments ranging from coughs and colds to parasitic infections and inflammation (Gurib,

2006). These included plants commonly known as aloe, absinth, cannabis as well as garlic, opium, cumin, and *Ricinus* (Paulsen, 2010).

At present, more than three-quarters of the populations in developing countries use medicinal plant raw materials for some aspects of primary healthcare services (Gurib, 2006; Odugbemi and Odugbemi, 2008). The continued use of traditional plant-based medicine in developing countries is mainly due to cultural acceptance, perceived efficacy, affordability, accessibility and it is part of belief systems (Dawit Abebe and Ahadu Ayehu, 1993; Odugbemi and Odugbemi, 2008;). Despite a long history of use, efforts made towards the evaluation of safety, therapeutic properties and standardization, etc. of medicinal plants are still minimal in most of the countries using traditional plant-based medicine.

2.2.2.2 Medicinal plants and drug development

The use of medicinal plants has not been confined to rural, low-income groups or developing countries. The decreasing efficacy of synthetic drugs and the increasing contradictions in their usage make the use of medicinal plants vital (Farnsworth *et al.*, 1991). Thus, with increasing preference for natural products (phytomedicines, nutraceuticals, herbal remedies, teas, and natural pharmaceuticals) as complementary alternative medicine (CAM), the use of medicinal plants is also rapidly spreading in industrialized countries (Rates, 2001). In addition, plants have been selected for drug development programs because they contain specific classes of compounds, such as alkaloids and terpenoids, known to be biologically active in the treatment of many diseases (Farnsworth *et al.*, 1991; RBG, 2017). According to Farnsworth *et al.* (1985), about 121 clinically useful prescription drugs worldwide are derived from higher plants. Pharmaceutical industries are now looking into the medicinal effects of the most commonly and

widely used medicinal plants to use in drug development (Cox and Balick, 1994; FAO, 1997; Rates, 2001; Sofowora *et al.*, 2013). Many prescription drugs available today originate directly or indirectly from plants. The well-known example to date is the synthesis of aspirin from *Filipendula ulmaria*, quinine from *Cinchona pubescens*, pseudoephedrine from *Ephedra sinica*, reserpine from *Rauvolfia serpentine* (Cox and Balick, 1994), artemisinin from *Artemisia annua*, and quinine from *Cinchona officinalis* among the most important remedies (RBG, 2017). Pharmaceutical industries have invested millions of US dollars looking for promising medicinal herbs and novel chemical compounds (Farnsworth *et al.*, 1991). It is therefore evident that plant-derived compounds are making large contributions to healthcare.

2.3 Wild edible plants and their role in food security

2.3.1 Historical usage of wild edible plants

Wild edible plants (WEPs), defined FAO as “plants that grow spontaneously in self-maintaining populations in natural or semi-natural ecosystems and can exist independently of direct human action” (FAO, 1999). These comprise naturally grown trees, shrubs, and herbs in forests, woodlands, farmlands, and other habitats. Wild edible plants are locally accessible resources and their uses are based on indigenous knowledge and cultural practices (FAO, 1999); they are tolerant to water stress and resilience to climate change (Acipa *et al.*, 2013). The exploitation of wild plants for food is as old as human history, and early hunter-gatherers in pre-agricultural times had used readily available fruits, berries, seeds, flowers, shoots, and fleshy roots to complement meat obtained from hunting (Dulloo *et al.*, 2014). During the course of the long history, approximately, 75,000 plants were believed to be edible (Walter and Hamilton, 1993). Although people domesticated some of these over the last 10-11,000 years, most of the edible plant species have remained in the wild with potential utility for humans. The evolution of

agriculture, however, has resulted in reliance of humans on much-reduced plant diversity than was previously utilized (Grivetti and Ogle 2000). In recent years, food security has come to depend on a handful of widely cultivated species resulting in narrowing dietary diversity with low micronutrients (vitamins and minerals) but high in energy content (FAO, 1999). The shift in dietary patterns from traditional food systems to narrow dietary diversity has resulted in the growing incidence of malnutrition and chronic diseases such as cancer (Heinrich *et al.*, 2005).

2.3.2 Contributions of wild edible plants

Millions of people around the world are facing hunger on a daily basis. In Sub-Saharan Africa including Ethiopia, one-third of children experience hunger and are often vulnerable to malnutrition (Giovannucci *et al.*, 2012). In many cases, rural communities survive by harvesting wild foods. Among these, wild edible plants are an essential component of coping strategy against food shortages (FAO, 1999; Ermias Lulekal *et al.*, 2011; Acipa *et al.*, 2013; Kebu Balemie, 2014).

Rural communities habitually harvest a wide range of leafy vegetables, roots, tubers, fruits from the wild because of its taste, cultural uses, as food supplements. Many of these plant parts are rich in health-promoting components, including vitamins, minerals, and other bioactive factors, and have low fat and high fiber content (Grivetti and Ogle, 2000; Acipa *et al.*, 2013). Nutritional analysis of some WEPs has shown comparable or richer dietary nutrient than domesticated food plants (Musinguzi *et al.*, 2007; Tabuti, 2007; Debela Hunde *et al.*, 2012; Getachew Addis *et al.*, 2013). In particular, some wild fruits and leafy vegetables supplement micro-nutrients and vitamins and thereby combat hidden hunger or malnutrition (Grivetti and Ogle, 2000; Acipa *et al.*, 2013). A large number of wild edible plants have additional health benefits such as

antioxidants, prevention of deficiency diseases and chronic diseases such as cancer (Cassius *et al.*, 2000). Thus, foraging or integration of wild edibles into the diets of household members might add crucial vitamins and minerals and benefit particularly, women, children, and malnourished socioeconomic groups (Cassius *et al.*, 2000; Grivetti and Ogle, 2000). Indeed, the contribution of WEPs may be apparently more important during certain seasons of the year such as during major stress periods particularly drought period (Grivetti and Ogle 2000; Guinand and Dechassa Lemessa, 2000; Ermias Lulekal *et al.*, 2011; Acipa *et al.*, 2013). Apart from supplementary, nutritional and health benefits, WEPs have many other economic roles. The collection and sale of wild edibles can provide considerable support to local livelihoods, especially for those who lack alternative sources of income (FAO, 1999). A study conducted in five districts of the Orissa State in eastern India showed that tribal communities derive, on average, 15 percent of their gross family income from selling fruits (Mahapatra and Panda, 2012). In Ethiopia, some poorer people use wild edible plants as a source of cash (Zemedu Asfaw and Mesfin Tadesse, 2001).

2.4 Ethnobotany and ethnobotanical knowledge

2.4.1 Ethnobotany

Ethnobotanical documentation has begun long before the term “ethnobotany” was introduced by John Harshberger in 1895. Early scholars of Greek, Roman, China, and India had recorded and cataloged information on useful plants including medicinal and food plants (Osbaldeston, 2000; Chivian and Bernstein, 2008). Later, many European travelers or adventurers and explorers in the 15th century recorded in their diaries the economic uses of plants used by indigenous peoples whom they encountered in their travels (Petrovska, 2012). Ethnobotany has, thus, its roots in the numerous observations of early explorers, naturalists, anthropologists, and botanists (Davis,

1995). Since its introduction, ethnobotany has evolved into scientific discipline that focuses on the exploration and understanding of the meaning behind human-plant relationship in a multidisciplinary manner, incorporating not only collection and documentation of indigenous uses but also ecology, economics, pharmacology, public health, and other disciplines (Martin, 1995; Cotton, 1996). It has dealt with studying cross-cultural variation; explaining how different human groups select and use plants; analyze how ethnobotanical knowledge changes over space and time and which variables explain patterns of ethnobotanical knowledge distributions, transmission and changes (Leporatti and Ivancheva, 2003).

Ethnobotanical studies can help demonstrate the complexities and dynamics of plant use knowledge and offer insight into cultural change. Presently, ethnobotanical research allowed the knowledge, wisdom, and practices of local people to play fuller roles in development and conservation programmes (Balick and Cox, 1996). They provided access to local knowledge in order to combine it with scientific wisdom for the use and conservation of biodiversity. Furthermore, the information on the ethnomedicinal uses of plants has provided an important lead in the discovery of the greater number of clinically useful plant drugs worldwide (Balick and Cox, 1996; Evans, 2009). Plants employed in traditional medicines are two to five times more likely to test out as pharmacologically active than those randomly sampled (Balick and Cox, 1996). Ethno-directed research has reportedly contributed approximately 74% of all pharmaceutical drugs derived from plants (Farnsworth *et al.*, 1985). Notable examples include the discovery antimalarial constituent (quinine) from bark of *Cinchona officinalis*, natives from the forests of Peru in South America, which was used by local communities to treat fever caused by malaria; artemisinin, antimalarial compound was isolated from *Artemisia annua*, a plant

which was recorded in old Chinese manuscripts as being useful for treating fevers and malaria. An alkaloid having beneficial effects on memory in patients was isolated from *Huperzia serrata*, a club moss used as a traditional tea for elderly people in several areas of China (Evans, 2009). Several other examples could be cited wherein an increasing number of pharmaceutical industries and research institutes are screening thousands of plant extracts based on ethnobotanical information of traditional medicine (Gonsalves, 2010). It is also a suitable source of information about useful plants such as edible plants for domestication and food security. Furthermore, ethnobotanical research helps to identify priority species (rare, overexploited, and economically important) for conservation or to promote their commercial importance; it has rescued the disappearing indigenous knowledge and practices (Martin, 1995; Cotton, 1996). Ethnobotanical research also deals with ethical issues for greater recognition of local people for their intellectual property rights, informed consent, the need for acknowledgment, and the share of benefits from commercial use of their knowledge, innovations, and practices (Martin, 1995). In sum, ethnobotany strives to recover a great deal of information, analyze, and explain complex relationships between cultures and plants, focusing primarily on how plants are used, perceived and managed in different cultures; give the scientific basis of their uses for the benefits of societies.

2.4.2 Ethnobotanical knowledge

Historically, humans have learned instinctively which plants are used as food, medicine and which provide materials for housing, clothing, tools, and dyes through trial and error experiment (Gibson and Gibson, 2007). Indeed, it was essential to know which plants were useful and which were not; identification of poisonous from non-poisonous plants. In the case of medicinal plants, the knowledge about the therapeutic values of plants was acquired through various mechanisms.

For example, observing the feeding habits of animals, dream, magic, and trial and error were means used by herbal practitioners to select plants and acquire knowledge about their therapeutic properties (Abbiw, 1996). Another popular belief used by early physicians and herbalists for understanding or selecting medicinal herbs was the ‘Doctrine of Signatures’ (Gibson and Gibson, 2006). This was a medical belief through 16th and 19th centuries. It has been a method of selecting plants having therapeutic values based on symbology and the unique appearances of plants and animals and relating them with treated health problems/or organs. For example, the lobed liverwort thallus was used to treat liver complaints because it resembles a human liver. *Viscum album* was a symbol of magic and love. Heart-shaped leaves of *Melissa officinalis* were employed to treat heart weakness (Dafni and Lev, 2002). Similar beliefs are still common around the world and used by many practitioners for understanding and selection of plants of medicinal importance (Bennett, 2007).

Ethnobotanical knowledge of plant use is context-specific as it is related to and contained within, a group of people who live in a defined geographic region. It is derived from the web of human-plant interactions. The acquired knowledge and skills have evolved overtime and adding new discoveries (Balick and Cox, 1996). In the case of medicinal plants, the knowledge was held in high regard by medicine men or healers. Their knowledge and skills have been kept secret from others and handed down orally to generations, largely within genealogy (vertical transmission). It has been argued that such transmission is highly conservative and less innovative (Cavalli-Sforza *et al.*, 1982). This knowledge is still alive and is widely used in traditional use of medicinal plants.

In another aspect of ethnobotanical uses such as food, the knowledge and skills have been shared among members of a society largely through cultural traditions. The cultural transmission may occur between individuals of the same generation (horizontal transmission) and between individuals of different generations (Cavalli-Sforza *et al.*, 1982). Ethnobotanical knowledge is diverse and can differ markedly from one individual to another, as well as from one community to another (Martin, 1995; Beltrán-Rodríguez *et al.*, 2014). Ethnobotanical knowledge possession is dependent on many factors including gender, age, education, social and economic status, roles, and responsibilities in the home and community. This knowledge is valuable not only for the survival of a particular society but also offers the potential uses of plants that are new to others (Martin, 1995). Historically, ethnobotanical knowledge has been the basis of agriculture and healthcare (Martin, 1995). Now, this knowledge is applied to practical areas such as bioprospecting of health and other industrial products (Rates, 2001). Furthermore, this knowledge is vital for the conservation of plant diversity and its habitats. In many cultures, rural communities hold genuine beliefs and respect forests and these have contributed to the preservation of sacred forests, trees, and other environmental resources (Martin, 1995). Under Article 8(j), the Convention on Biological Diversity (CBD) firmly recognized the contribution of this knowledge and promoted its use as a new norm in conservation and indigenous healthcare.

Despite their contributions, thousands of year's accumulated wisdom of indigenous knowledge is disappearing or eroding (Dawit Abebe and Ahadu Ayehu, 1993; Mirutse Giday *et al.*, 2010; Hanazak *et al.*, 2013). Many social, economic, and environmental factors are contributing to this loss or erosion of the knowledge. Among these, the disruption of traditional ways of life induced by acculturation, displacement from native villages has resulted in disruption of the web of

relationships between people and plants. In addition, younger generation lacks interest in learning traditional use of plants; schooling where young students have less time for exposure to and use of plants (Hanazaki *et al.*, 2013); lack of written documentation and distortions occurring during the transfer of the knowledge; secrecy in transmission of knowledge of medicinal plant by knowledgeable healers (Dawit Abebe and Ahadu Ayeyehu, 1993; Abbiw, 1996); loss of plant species due to various anthropogenic factors (Hanazaki *et al.*, 2013) contributed to the loss of ethnobotanical knowledge. Ethnobotanical studies are thus becoming increasingly important to document and analyze the complex relationship between people and plants in different cultures for sustainable use of plants and preservation of indigenous knowledge.

2.5 The flora and forest vegetation of Ethiopia

Ethiopia is home to an enormous diversity of plant species. Topographic heterogeneity, climatic variability, geological factors, and cultural diversity have accounted much to the availability of the plant diversity. The higher plants are estimated at about 6000 species, about 10% of which are endemic to the country. Most of the plants (5,815 species) are angiosperm species. The families with the richest taxonomic diversity are Fabaceae, Poaceae, and Asteraceae (Ensermu Kelbessa and Sebsebe Demissew, 2014). The taxonomic diversity of the Ethiopian flora may increase since exploration and collection in some flora regions are not exhaustive (Friis, 2009). The high floristic endowment of the country provides a vast array of medicinal, edible and many other useful plants that are harvested by local people for a wide variety of purposes.

The wild flora is largely assembled into different natural vegetation types, which are distributed in various ecosystems of the country. The structure and composition of the natural vegetation are both diverse and unique, reflecting their uniqueness in species type, number, and distribution

over wide physiognomic and climatic landscapes. The natural vegetation types are classified into twelve major vegetation types primarily based on climate and altitude. Some of the major vegetation types are further divided into two or more subtypes (Friis *et al.*, 2011). Six vegetation types namely, moist Afromontane forest, dry Afromontane forest and grassland complex, *Acacia-Commiphora* woodland, *Combretum-Terminalia* woodland, Transitional rainforest, and Riverine vegetation types comprise forest vegetation types (IBC, 2012). Each of this forest vegetation type has its own unique plant assemblages. Besides, some of the forest vegetation types have many shared species (Friis *et al.*, 2011). For example, riverine vegetation and *Acacia-Commiphora* shared the highest number of woody species with dry Afromontane forest and grassland complex. The second highest similarly in term of the number of shared woody species was between moist Afromontane forest and dry Afromontane forest and grassland complex. The shared species could have adapted to a wider range of phytogeographic regions. In terms of uniqueness, *Acacia-Commiphora* woodland encompasses 52.8% unique species, followed by Transitional rainforest 46.5% and *Combretum-Terminalia* woodland 40.7% (Friis *et al.*, 2011).

In terms of distribution, the moist Afromontane forest occupies areas mainly in southeastern (on the southern slopes of the Bale Mountains), southwestern (Jima, Kefa, Illubabor, Sheka) and western (West Shewa, West Wollega) parts of Ethiopian plateaus between 1800 and 2600 m altitudes, with annual rainfall between 700-2000 mm and a mean annual temperature between 18 and 20°C (Friis, 1992; Friis *et al.*, 2011). The dry Afromontane forests and grassland complex forests, on the other hand, are found between 1800 and 3000m altitudes, in northern, central, eastern and southeastern plateaus of Ethiopia, avoiding the higher rainfall in western and southeastern plateaus, where it is replaced by moist vegetation (Zerihun Woldu, 1999; Friis *et*

al., 2011). The *Acacia-Commiphora* woodland vegetation is mainly distributed in southern, northeast, eastern lowlands and Central Rift Valley of Ethiopia (Friis *et al.*, 2011; IBC, 2012). The *Combretum-Terminalia* woodland is distributed mainly in northwestern and western lowlands of the country between 300 and 1700m altitudes, with annual rainfall between 800 and 1400mm. The transitional rainforests are scattered in western escarpments of Wollega, Illubabor, and Kefa between 450 and 1500 m altitudes with annual rainfall between 2000 and 2700 mm; in some areas, the rainfall is available year-round (Friis *et al.*, 2011). The riverine forest vegetation is found in most parts of the country with permanent or temporary rivers and other streams below 1800 m altitudes (Friis *et al.*, 2011).

There were contrasting reports in terms of area coverage. Some argued that the forest cover is increasing, while others argued that it is decreasing. Previous field assessment by WBISPP (2004) had estimated the Ethiopian forest cover at about 3.33 million ha (about 3.3%). Based on reclassification and extrapolation of the WBISPP (2004) data and estimates of 2005, FAO (2010) forecasted and estimated the forest cover at about 12.29 million ha (11.78 million ha natural forest and 0.51 million ha plantation forests). This amounts to 11% of the total land area of Ethiopia (FAO, 2010). The varying forest definitions and the lack of forest inventory information have attributed to the varying estimate of forest cover in the country. Overall, the lack of updated data on forest cover has resulted in contrasting reports. Various research reports indicate that the forests of the country are under various anthropogenic impacts. The realities in the ground also witnessed that the forests cover is deteriorating. The remaining high forest areas of the country are left now largely in the west and western part of the country. These include the moist Afromontane forests and transitional rainforest.

2.5.1 Moist Afromontane forest of Ethiopia

The moist Afromontane forests (MAF) consist of high forests of the country and occur in wettest and humid parts of the country. Typically, the canopies contain a mixture of *Podocarpus falcatus* and broad-leaved species such as *Pouteria (Aningeria) adolfi-friederic*. However, *Podocarpus falcatus* is gradually rare towards the southwestern parts as the rainfall increases, while *P. adolfi-friederic* becomes more prominent in the same directions (Friis, 1992; Feyera Senbeta, 2006).

The MAFs are among important biodiversity centers in Ethiopia. MAFs include multi-layered trees, shrubs, lianas, and epiphytes. The epiphytes include ferns, orchids, and *Peperomia*. The MAFs have also dense stands of tree ferns, *Cyathea* in the riverine. The forest floor is usually dark and moist and is poor in species (Friis, 1992; Sebsebe Demissew and Friis, 2009). Where light permits, the forest floor may be covered with herbs and shrubs of various sizes. Where the tree canopy is very dense and excludes light, the ground is devoid of herbs. The drier part of MAF has a high floristic affinity with dry Afromontane forest and grassland complex (Sebsebe Demissew and Friis, 2009; Friis *et al.*, 2011). This might reflect some degree of niche overlap between the two forest vegetation types and the shared species can be considered as linking species. In his comparative observations among the MAFs of the southeast (Hareenna) and southwest (Bonga, Berhane-Kontir, Maji, Yayu), Feyera Senbeta (2006) found 60% and 44% floristic relationship at family and species levels, respectively.

Under the canopy of emergent trees like *Podocarpus falcatus* and *Pouteria adolfi-friederic*, there are many medium-sized trees species such as *Albizia schimperiana*, *A. gummifera*, *Ilex mitis*, *Ocotea kenyensis*, *Olea capensis* subsp. *hochstetteri*, *O. welwitschii*, *Polyscias fulva*, *Prunus africana*, *Sapium ellipticum*, and *Syzygium guineense* subsp. *afromontanum*. The shrub layers

include *Allophylus abyssinicus*, *Coffea arabica*, *Cyathea manniana*, *Draceana afromontana*, *Galiniera saxifraga*, *Rothmannia urcelliformis*, and *Teclea nobilis* (Friis, 1992; Sebsebe Demissew and Friis, 2009). The herbaceous species in the ground layer are mainly species of *Acanthus*, *Justicia*, *Impatiens*, *Urtica* and different grass species including *Pennisetum* and *Hyparrhenia* (Zerihun Woldu, 1999). Epiphytic vascular plants are common on trees and shrubs in the forest. MAFs harbor important gene pools of wild Arabica coffee and spices such as *Afromomum corrorima* (Tadesse Woldemariam, 2003; Feyera Senbeta, 2006). There are also a number of endemic plant species in the MAFs (Feyera Senbeta, 2006; Abreham Assefa *et al.*, 2013; Fekadu Gurmessa *et al.*, 2013; Yohannes Mulugeta *et al.*, 2015; Admasu Addi *et al.*, 2016).

2.5.1.1 Contributions of moist Afromontane forest

The moist forest resources of Ethiopia have been contributing to social, economic, and ecological benefits to people living in and around them (Feyera Senbeta, 2006). They have accounted both direct (timber, poles, charcoal, firewood, fodder, food, medicine, honey, and beeswax, coffee) and indirect use values (carbon sequestration, source water, and other ecosystem services). It is also the source of important wild gene pool for economically important cash crops such as coffee and spices. Forage from the forest is another vital NTFP that support livestock production (Sisay Nune *et al.*, 2010). The most important forest products that generate substantial income and foreign currency earnings in Ethiopia are coffee, spice, honey and wax (Mulugeta Lemenih and Tadesse Woldemariam, 2010; Sisay Nune *et al.*, 2010). Recent estimates indicate that about 26-30% of the total coffee production of the country originates from southwest forests and semi-managed coffee forests and its annual value was estimated at US \$

130 million. Forest beekeeping is common cultural practice of many farmers around southwest moist Afromontane forests (Sisay Nune *et al.*, 2010).

2.5.1.2 Threats to and conservation of moist Afromontane forest

The moist Afromontane forests of southwest Ethiopia have faced deforestation and degradations (Zerihun Woldu, 1999; Reusing, 2000; Tadesse Woldemariam, 2003; Gatzweiler, 2007; Feyera Senebta *et al.*, 2007; Sisay Nune, 2008; Dereje Tadesse, 2010; Kefelegn Getahun *et al.*, 2013). In a forest cover change study in southwest Ethiopia, Dereje Tadesse (2010) found a significant reduction of forest cover between 1973 and 2005. In a similar study, Kefelegn Getahun *et al.* (2013) reported a 19% reduction of forest cover between 1957 and 2007 in selected villages of Jimma zone. Reusing (2000) reported major forest degradation around settlements like Bonga, Mizan Teferi, Tepi and Gore in southwest Ethiopia. In addition, large-scale coffee and tea plantations were established by deforestation of a large expanse of forestlands. The deforestation and fragmentation have inevitably resulted in the loss of plant species including gene pool of wild coffee (Feyera Senbeta, 2006; Kitessa Hundera *et al.*, 2013) and other ecosystem services. Several social, economic and natural factors have been claimed to be the drivers of deforestation in Ethiopia (Zerihun Woldu, 1999; Reusing, 2000). The main direct drivers are small and large agricultural expansions, including plantations and over-harvesting of wood products (Gessesse Dessie and Kleman, 2007).

Given the increasing rate of deforestation, various *in-situ* conservation efforts have been undertaken to conserve the MAFs. The Participatory Forest Management (PFM) scheme, which involves the local community, government, and NGOs, is being implemented in Oromia and South Nation Nationalities. This management intervention was aimed at increasing the

participation and responsibilities of local communities on sustainable use and conservation of the forest. Similarly, a biosphere reserve approach is being implemented in Kafa and Shaka MAFs. In Oromia Region, the Oromia Forest and Wildlife Enterprise is taking care of natural and plantation forest areas in the region. However, this organization is blamed in many places by local communities because it does not focus on conservation but on the sale of forest products. It was also blamed for not respecting their rights to access and benefit sharing.

2.5.2 Medicinal plants diversity and usage in Ethiopia

2.5.2.1 Medicinal plants diversity

The Ethiopian flora comprises a great variety of medicinal plants. Several ethnobotanical studies and monographs showed that the diverse medicinal plants are traditionally used by ethnic communities in different parts of the country (e.g Kebu Balemie *et al*, 2004; Gemedo Dalle *et al.*, 2005; Ermias Lulekal *et al.*, 2008; Mirutse Giday *et al.*, 2009; Getnet Chekole *et al.*, 2015). The current estimate shows that over 1000 medicinal plants are used in various parts of Ethiopia (Zemedu Asfaw and Tigist Wondimu, 2007). Information extracted from ethnobotanical studies revealed that Fabaceae and Asteraceae (123 species each), followed by Lamiaceae (61 species), Euphorbiaceae (50 species), Solanaceae (32 species), Poaceae (31 species), Acanthaceae (26 species), Malvaceae (26 species), Apiaceae (23 species) and Asclepiadaceae (20 species) are the families with the highest proportion of medicinal species. In terms of growth forms, herbs, followed by shrubs make up the highest proportion of medicinal plants in Ethiopia.

2.5.2.2 Historical and current usage of medicinal plants

As in many other developing countries, medicinal plants have long been playing an important role in human healthcare in Ethiopia. Ancient medical manuscripts written in Ge'ez and Arabic

languages possibly by Ethiopian church and Muslim scholars during the Axumite Kingdom (7th to 11th century), Zagwe Kindom (ruled from 11th to 13th century) and Gondar Kingdom (ruled from 1636 to 1865) have preserved information on recipes /prescriptions and list of medicinal plants used in the preparation and list of treated diseases (Pankhurst, 1990; Fassil Kebebew, 2001; Fekadu Fullas, 2001). Furthermore, the 16th century Portuguese Jesuits and Spanish travelers documented some Ethiopian medicinal plants and their importance (Pankhurst, 1990). However, most of the early accounts of medicinal plant records are fragmentary (Fekadu Fullas, 2001) and they are now accessible only in foreign collections (Pankhurst, 1990; Fassil Kebebew, 2001). The Ethiopian traditional healing practices have been described as medico-religious and were related to Christian, Islamic and indigenous religions (Dawit Abebe and Ahadu Ayehu, 1993; Fekadu Fullas, 2001). This might be because of the fact that traditional healing practices often involve spiritual healing practices such as praying, using spiritual water, and performing rituals. Even today, these are common healing practices in Ethiopian traditional medicine. The knowledge and skills used in traditional medicines have been passed on orally to their own family members by traditional healers, knowledgeable elders, priests and other members of the clergy for most of the centuries (Jansen, 1981; Dawit Abebe and Ahadu Ayehu, 1993). Ingredients such as salts, diets, and animal products have been prescribed in some medicinal plants (Dawit Abebe and Ahadu Ayehu, 1993). In addition to renowned traditional healers, many Ethiopians have practiced and still practice home based medications using various herbs such as ginger, garlic and steamed eucalyptus leaves to treat health problems such as colds, fevers, and headaches. Although current estimates are lacking, previous estimates indicate that the use of plant-based traditional medicine meets up to 70% of human and 90% of livestock health needs in Ethiopia (Endashaw Bekele, 2007).

2.5.2.3 Threats to medicinal plants and associated ethnomedicinal knowledge

Assessments of threatened plant species by Vivero *et al.* (2005, 2006) indicate that the number of threatened plants is increasing over the years. Some of these species are medicinal plants used in traditional medicine. Among the threatened species, *Echinops ellenbeckii* and *Taverneia abyssinica* are endangered and critically endangered respectively. Similarly, species such as *Echinops kebericho* and *Securidaca longepedunculata* are highly declined and endangered due to over exploitation and habitat destruction (Mander *et al.*, 2006). Roots of *E. kebericho*, *Securidaca longepedunculata* and *T. abyssinica* have been harvested from wild environments and sold in most urban and rural towns of Ethiopia (Mander *et al.*, 2006). In a market survey, healers reported about 78% scarcity of their medicinal plants (Mander *et al.*, 2006) implying the conservation concern of these scarce medicinal plants. Over-harvesting is the principal threat to medicinal plants of high market demand (Hamilton, 2004). The exploitation of medicinal species has a variable effect depending on the parts harvested. For example, destructive harvesting such as uprooting and debarking has a significant impact on regeneration and on the survival of the species (Zemedet Asfaw, 2001; Hamilton, 2004). Regular harvesting of flowers, fruits, and seeds can have also adverse ecological impacts and can influence the natural regeneration of the species (Hamilton, 2004). The most endangered species are medicinal plants harvested by debarking and uprooting in large quantities (Zemedet Asfaw, 2001; Hamilton, 2004). In particular, rare, slow growing and endemic species with limited distribution are highly vulnerable to extinction.

2.5.2.4 Conservation of medicinal plants in Ethiopia

In view of growing threats to wild flora, the government and various NGOs have made various efforts to reduce habitat degradation. Some of the efforts are aimed at restoring the habitats.

Conservation of habitats is can be considered as part of conservation of medicinal plants. These include establishment of area closures, watershed-based natural resources conservation (soil and water conservation, afforestation), participatory forest management, and the establishment of protected areas (Demel Teketay *et al.*, 2010). MELCA Ethiopia, a local NGO, supports the revival of traditional ecological governance systems, education on environmental laws and policies in addition to participating in improving the governance of protected areas and enhancing biodiversity conservation. Besides, the Ethiopian Biodiversity Institute (EBI), in collaboration with International Organization has established field genebanks and botanic gardens for the conservation of medicinal plants. Currently, over 300 medicinal plants are being managed under *ex-situ* conditions in cold store and in field genebanks (IBC, 2009). Universities and research institutes undertake research related to medicinal plants, including ethnobotanical studies. These studies have contributed to the conservation of medicinal plants. In addition, local communities have a long tradition of maintaining highly valued wild plant species in home gardens, farm plots and forests and grazing lands. Several ethnobotanical studies (e.g Feleke Woldeyes, 2011) reported the diversity of medicinal plants managed in homegardens. Of plant diversity in homegardens in Ethiopia, approximately 6% are believed to have medicinal value (Zemedet Asfaw, 2001). A recent review by Abiyot Berhanu and Zemedet Asfaw (2014) reported about 81 medicinal plant species being managed in some selected homegardens in Ethiopia. This showed some increase in the number of medicinal plants managed in homegardens. A number of herbal growers and traditional healers also grow different medicinal plants in their gardens. Although the information fragmented and data is lacking, the contribution of various stakeholders to the conservation of medicinal plants is immense.

2.5.3 Wild edible plants diversity and usage in Ethiopia

2.5.3.1 Wild edible plants diversity

The food plants of Ethiopia are believed to constitute about 8% of the total of vascular plant species in the country. Of these, about 75% could be categorized as wild, semi-wild naturalized in different agroecological zones or vegetation types (Zemed Asfaw and MesfinTadesse, 2001). Forests, woodlands, grasslands, riverine environments and farmlands are sources of numerous WEPs in Ethiopia (Zemed Asfaw, 2009). Currently, a total of 413 WEPs belonging to 224 genera and 77 families were documented by Ermias Lulekal *et al.* (2011). The number of WEPs could exceed this as more ethnobotanical studies are undertaken in unstudied remote parts of the country. The families contributing the highest number of wild edible species were Fabaceae (35 species) followed by Tiliaceae (20) and Capparidaceae (19) species each. Shrubs make up the highest proportion (31%) of growth forms, followed by trees (30), herbs (29%), and climbers (9%). Ermias Lulekal *et al.* (2011) further reported that the previous ethnobotanical studies covered only 5% of the total areas of the country.

2.5.3.2 Wild edible plants usage

Wild edible plants are widely known and used by many people in rural parts of Ethiopia. In Southern Ethiopia, where there are many different ethnic communities still living with their indigenous beliefs and traditions, the consumption of wild food plants appear to be one of the important local survival strategies, particularly during critical periods (Guinand and Dechassa Lemessa, 2000; Tilahun Teklehaymanot and Mirutse Giday, 2010; Getachew Addis *et al.*, 2013). Such periods include the beginning of the rainy season during which food shortage is most acute as households usually exhaust previous year's harvest; and in periods of climate induced vulnerability (Faye *et al.*, 2010). The frequency of gathering and consumption of WEPs varies

from place to place depending on the availability of grain in stocks (Guinand and Dechassa, 2000). For example, some communities in south Ethiopia such as Konso people compensate damaged or reduced crop harvests by increasing the collection of wild food plants (Getachew Addis *et al.*, 2013). In normal times, wild edible plants are consumed as snack largely ripe fruits. Studies showed that many wild edible plants are rich sources of nutrients (Debela Hunde *et al.*, 2012; Getachew Addis *et al.*, 2013). In some cases, WEPs contain higher nutritional contents than cultivated species (Getachew Addis *et al.*, 2013). For example, the nutritional values of *Urtica semensis* are much higher compared to green leafy vegetables commonly cultivated and consumed in Ethiopia. Compared to cultivated leafy vegetables, its protein and mineral content is also exceptionally high (Eskedar Getachew *et al.*, 2013).

2.5.3.3 Factors affecting the consumption of wild edible plants

Despite their indispensable contributions, the consumption of WEPs is gradually diminished in Ethiopia due to various reasons (Guinand and Dechassa Lemessa, 2000; Zemedu Asfaw and Mesfin Tadesse, 2001; Getachew Addis *et al.*, 2013; Kebu Balemie, 2014). Some species, once used by some landless or poor for the survival, are no longer eaten or consumed. Similar trends have also been reported elsewhere outside Ethiopia (Tabuti, 2007). Modernization, acculturation, attitudes, food aids, schooling, and decreasing wild edible plants were often blamed for declining consumption or neglect of some WEPs in Ethiopia. Taste preference, harvesting and processing time and labor demand and toxic effects of some WEPs have also discouraged their consumption (Guinand and Dechassa Lemessa, 2000; Zemedu Asfaw and Mesfin Tadesse, 2001; Getachew Addis *et al.*, 2013). With the declining use of wild edible plants, the erosion of ethnobotanical knowledge and traditional customs has increased (Zemedu Asfaw and Mesfin Tadesse, 2001).

2.5.3.4 Conservation status of wild edible plants

Wild edible plants are found in various wild habitats, most of which are under growing anthropogenic threats. The plant resources, including WEPs found in these habitats, have faced increased vulnerability over time. The conservation of WEPs in the country is related to the conservation of natural habitats. As in the case of medicinal plants, area closures, watershed-based natural resources conservation (soil and water conservation, afforestation), participatory forest management and establishment of protected areas (Demel Teketay *et al.*, 2010) were among the efforts that could contribute to the conservation of natural habitats, which could be home to WEPs. Unlike medicinal plants, WEPs have little conservation attention; no projects dedicated to this group and therefore there is a general disregard by the scientific community for this wild plant category. This is happening despite the fact that a paper entitled “*Prospects for sustainable use and development of wild food plants in Ethiopia*” was published in 2001 in the Journal of Economic Botany. Although accurate data is lacking, ethnobotanical studies have reported homegarden management of some WEPs. Abiyot Berhanu and Zemedu Asfaw (2014) have reported 137 food plants grown in homegardens, some of which wild and semi-wild edible plants. Overall, national conservation attention and efforts towards WEPs is weak or minimal compared to that of medicinal plants.

2.5.4 Floristic and ethnobotanical research in Ethiopia

2.5.4.1 Floristic researches on moist Afromontane forest

Several authors have studied the moist Afromontane vegetation types in Ethiopia. Some of the studies dealt with forest floristic composition, structure and regeneration status (Ermias Lulekal *et al.*, 2008; Fekadu Gurmessa *et al.*, 2013; Abreham Assefa *et al.*, 2013; Kflay Gebrehiwot and Kitessa Hundera, 2014; Yohannes Mulugeta *et al.*, 2015). Other related studies focused on

floristic composition and plant community analysis (Kumelachew Yeshitela and Tamrat Bekele, 2002; Feyera Senbeta *et al.*, 2007; Mamo Kebede *et al.*, 2013; Admassu Addi, *et al.*, 2016). Tadesse Woldemariam (2003) and Feyera Senbeta (2006) studied vegetation ecology of transitional rainforest and Afromontane rainforests with wild *Coffea arabica*, respectively. These studies found impressive species composition, structure, and richness, indicating habitat heterogeneity of moist Afromontane forests in Ethiopia. The studies have also contributed significantly to the understanding of plant species composition and the development of conservation planning. On the other hand, deforestation and subsequent loss of species occur in many forest areas in the country.

Most moist Afromontane forest vegetations are inhabited by rural communities that have customary rights to the forests and have developed lifestyles and associated traditional knowledge. Forests have a customary and spiritual meaning as a source of livelihood and cultural significance for these communities. In line with this, Martin (1995) suggested that scientific research into human-plant interactions such as ethnobotanical study is essential to understand the problems of sustainable use of biodiversity and to contribute to conservation and sustainable use planning. The present study was an effort to link floristic and ethnobotanical information and contribute to better understanding, sustainable use, and management of plant diversity in the study area.

2.5.4.2 Ethnobotanical researches

Since the introduction of ethnobotany as an academic discipline in the Department of Biology, Addis Ababa University in 1996/97 (Zemedu Asfaw and Tigist Wondimu, 2007), ethnobotanical research have been expanded and several publications have appeared in various publishing

media. These studies have come up with identification and documentation of diversity of medicinal and wild edible plants and associated indigenous knowledge. The studies have contributed immensely to the national information on medicinal and WEPs. The studies have also contributed to the conservation of some of the medicinal plants in Ethiopia. More advanced ethnobotanical studies with more quantitative approaches and hypothesis testing have recently been undertaken in conjunction with floristic diversity assessment, chemical and nutritional analysis (e.g., Getachew Addis *et al.*, 2013; Ermias Lulekal, 2014).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of the study area

The study area, Nole Kaba District is geographically located between 8°39'45"N and 8°58'10"N latitude and 35°34'41" E and 35°58'49" E longitude in West Wollega Zone, Oromia Region, Western Ethiopia. The town of Nole Kaba, Bube, is located at about 491 km west of Addis Ababa. The district is bordered in the west by Sayo Nole and on the north by Haru Districts (west Wollega Zone), on the southeast and south west by Meko and Alge Sachi Districts (Illubabor Zone) (Fig.1). The district's total land area is about 65,557 ha. Its topographical features include flat to gentle slopes, hills, and valleys. The elevation ranges from 1510 to 2585 m (a.s.l.) (Tilahun Taddese *et al.*, 2015). There are three agroecological zones namely, wet lowlands, 1500 - 1900 m (a.s.l.), wet midlands, 1900-2100 m (a.s.l.), and moist highlands, above 2100 m) (a.s.l.). In terms of area coverage, the majority of the district is categorized as wet midlands (61%), followed by moist highlands (25%) and wet lowlands (14%) (Azene Bekele, 2007; Tilahun Taddese *et al.*, 2015).

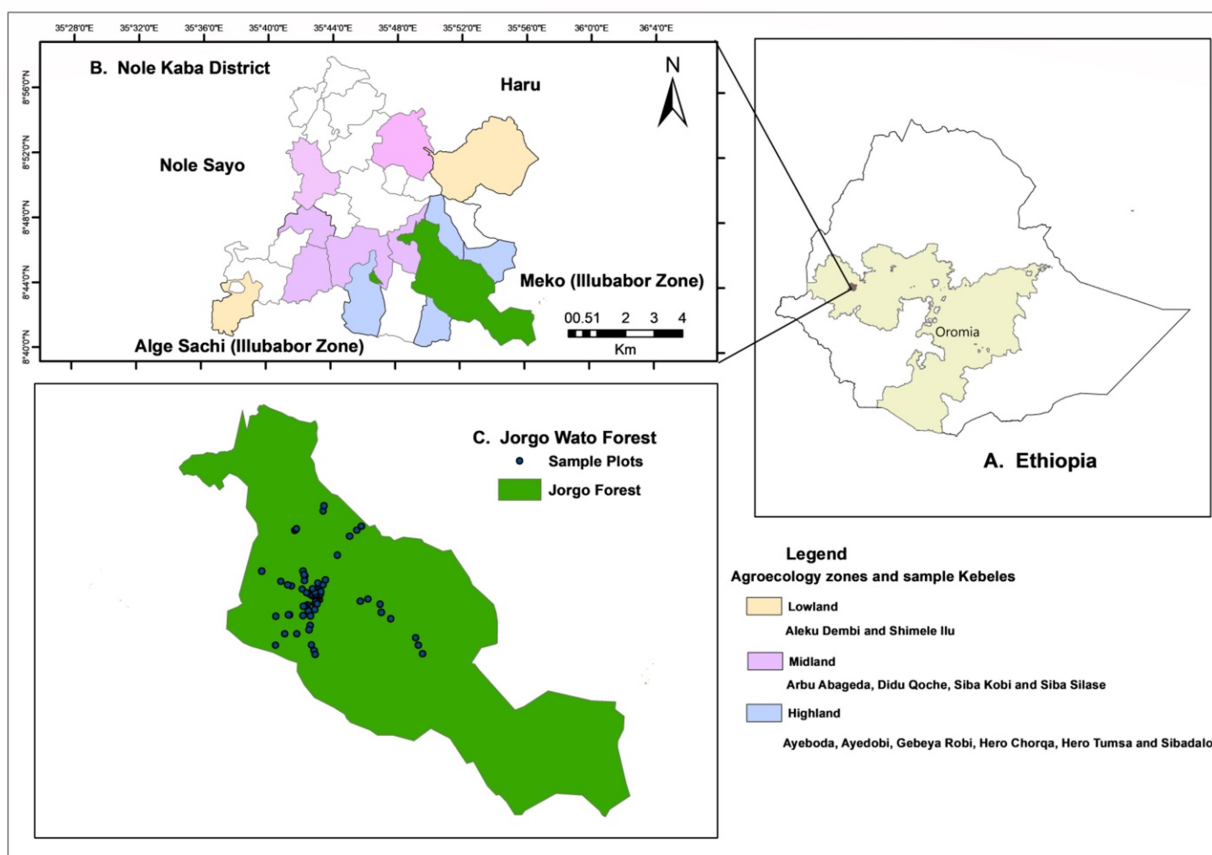


Figure 1 Map of Ethiopia showing the study area: (A) Ethiopia and Oromia Region (B) Nole Kaba District and sampled KEBELES (c) JWF showing sampled plots

3.1.1. Climate

The climate of western Ethiopia including the present study area in general exhibits a warm and humid tropical climate. According to the rainfall and temperature data collected by the National Meteorological Service Agency for the years between (1990-2015), the mean monthly temperature of Nole Kaba District was 21.4°C, with the minimum and maximum monthly temperature of 14.3°C and 30.5°C, respectively. The mean annual rainfall for the above stated years was 1610 mm (Fig. 2). The climate diagram depicts that the rainfall distribution of the study area is unimodal and rain found between April and October, with the highest rainfall

between July and September. The area remained moist for most of the months but drier between November and March.

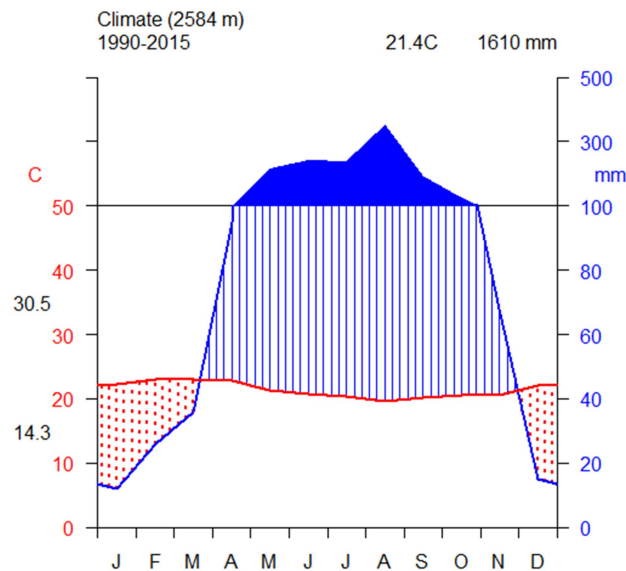


Figure 2 Climate diagram showing the climatic distribution of Nole Kaba District

3.1.2 Geology

Geologically western Ethiopia, including western Wollega is largely covered by Precambrian intrusive rocks (Mengesha Tefera *et al.*, 1996; Solomon Tadesse *et al.*, 2003; Williams, 2016) which consist of low-grade metavolcano-sedimentary rocks and associated intrusive rocks, high-grade gneiss and migmatites, trap series of volcano, metavolcano-sediments and associated mafic-ultramafic rocks of probable ophiolitic origin. The low-grade metavolcano-sedimentary rocks and associated intrusive outcrop are remarkably persistent and can be traced for the entire length of the Precambrian rocks of western Ethiopia (Mengesha Tefera *et al.*, 1996; Solomon Tadesse *et al.*, 2003). The Precambrian rock is richer in light elements such as potassium and sodium. It also contains a high proportion of silicon (silicon dioxide) (Williams, 2016). It is characterized by a variety of lithological units, including gneisses, metabasalt, meta andesite,

green schist, phyllite, metaconglomerate, quartzite and marble, metamorphosed volcanic, volcanoclastic and sedimentary succession with associated mafic-ultramafic rocks of probable ophiolitic association and granitoid intrusive (Mengesha Tefera *et al.*, 1996; Solomon Tadesse *et al.*, 2003).

3.1.3 Soil

The soils in west Wollega are highly weathered soils (Mesfin Abebe, 1998). They are finely textured weathering products of intermediate to basic parent rocks possibly rejuvenated by recent admixtures of volcanic ash and undifferentiated lower complex granite to basic parent rock. Generally, the soils in these areas are strong to moderately acidic, well-drained, deep, and reddish brown in color. Nitisols are found on almost flat to the sloping terrain in high rainfall areas; they have relatively high contents of weathering mineral. The clay assemblage of Nitisols is dominated by iron oxides (Mesfin Abebe, 1998).

3.1.4 Vegetation

The vegetation cover of Nole Kaba District consists of a mosaic of trees/shrubs with agricultural crops. There are relic trees and shrubs found here and there in agricultural fields and grazing areas; some patchy forests occur between valleys. Trees such as *Albizia grandibracteata*, *Bersama abyssinica*, *Cordia africana*, *Ficus exasperata*, *Sapium ellipticum*, *Syzygium guineense* subsp. *afromontanum* and shrubs include *Allophylus abyssinicus* and *Brucea antidysentrica* are found in farmlands and pasturelands outside the forest. The natural forest found in the district is Jorgo Wato Forest (JWF), which belongs to the moist Afromontane forests (MAFs). The characteristic plant species found in this forest include *Pouteria adolfi-friedericii*, *Cyathea manniana*, *Draceana afromontana*, *Galiniera saxifraga*, *Rytigynia neglecta*, and *Vepris dainellii*. The

woody climbers (liana) of the forest include *Combretum paniculatum*, *Landolphia buchananii*, and *Urera hypselodendron*. Mountainous foothills areas are under cultivation and grazing pressure. The eastern part of the study district (altitude 1510-1600 m) borders Dabena valley and the vegetation in this part of the study area is typical of *Combretum-Terminalia* woodland (CTW) (Friis *et al.*, 2011). Small to moderate trees and shrub species such as *Syzygium guineense* subsp. *macrocarpa*, *Combretum molle*, *Piliostigma thonningii*, *Stereospermum kunthianum*, and *Warburgia ugandensis* were found in this vegetation type.

Management history of Jorgo Wato Forest (JWF)

According to informants participated on group discussion, JWF was established as a protected forest during in 1948. After the fall of the Emperor's regime, the local inhabitants encroached into the forest and the size of the forest was reduced. Realizing the pressure on this forest, the military government re-demarcated in 1976. The demarcation expanded beyond the previous forest boundary by including a large expanse of farmlands, villages and grazing lands, private forest land making up a total area of 19, 900 ha. During subsequent years, the government with the participation of local communities planted exotic species such as *Acacia decurrens*, *Cupressus lusitanica*, *Pinus patula*, *P. radiata* and *Eucalyptus globulus*. Similarly, some indigenous species like *Hagenia abyssinica*, *Juniperus procera*, *Olea europaea* subsp *cuspidata* and *Podocarpus falcatus* were planted in some parts of the natural forest. The forest was part of the National Priority Forest Areas (NFPAs) of Ethiopia (Reusing, 1998). After the fall of the military regime, the JWF was remained as community forest, which has been protected by the local community. Since 2013, participatory forest management (PFM) (a joint government-community management) approach has been introduced with the objective of conservation

through reducing conflict between the forest and local people. The forest was demarcated by excluding some grazing lands, coffee farms, and farmlands that were taken by force from communities around the forest. Currently, the JWF has a total area of 8,524 hectares. Of these, 7,624 hectares are a natural forest, while the remaining 900 hectares are plantation forests. About 80% of the forest is found in Nole Kaba District and the remaining 20% is bordered by KBELEs found in Meko District (Illu Ababor Zone).

The Jorgo Wato Forest is home to a number of wild mammals, bird, and reptiles. Larger and small wild mammals including *Syncerus caffer* (buffalo), *Panthera pardus* (leopard), *Colobus guereza* (colobus monkey), *Tragelaphus scriptus* (bushbuck), *Papio anubis* (anubis baboon), *Chlorocebus aethiops* (vervet monkey), *Sus scrofa* (wild pig), *Hystrix cristata* (porcupine), and *Hyaena hyaena* (hyena).

3.2 Demographics and land use

According to the 2007 national census report, the total human population of Nole Kaba District is 60,793, consisting of 29,667 men and 31,126 women (CSA, 2007). Of these, 55,698 were rural and 5,095 were urban dwellers. The population density was estimated at 117.4 people/ sq. km. A total of 11386 households were found in the district. Rural landholding was between 0.5 and 1.0 ha per household (Tilahun Taddese *et al.*, 2015). The Oromo ethnic group constitutes the majority (97%) of the population. In religion, the majority of the inhabitants (77%) are Protestants, 16% are orthodox Christian, 5% are Muslim, and the rest (2%) are followers of traditional belief (WAQQEFATAA) (Tilahun Taddese *et al.*, 2015). These people have ethnobotanical knowledge and traditions about plant use and management.

Rural land is an important asset of households for the production of crops and rearing of livestock. According to poster report from the Nole Kaba Agriculture and Natural Resource Office (2014/15), land is used for different use categories. The major land-use categories were farmlands (28,445 ha), forest (natural and plantation) (15,045 ha), pasture lands 4887 ha and grasslands.

3.3 Agriculture and livestock

As in many farming communities in Ethiopia, rain-fed agriculture is the main livelihood activity for the majority of the population in the district (Tilahun Taddese *et al.*, 2015). Diverse food crops are grown in different agroecological zones. These include cereals (*Zea mays*, *Sorghum bicolor*, *Eragrostis tef*, *Hordeum vulgare*, *Eleusine spp.*, *Triticum spp.*), pulses (*Cicer arietinum*, *Pisum sativum*, *Vicia faba*, *Phaseolus vulgaris*), oil crops (*Linum usitatissimum*, *Guizotia abyssinica*, *Sesamum orientale*), root crops (*Coccinia abyssinica*, *Solanum tuberosum*, *Ipomoea batatas*), vegetable and fruits (*Brassica oleracea*, *Citrus aurantifolia*, *Musa x paradisiaca*, *Mangifera indica*, *Carica papaya*, *Persea americana*, *Capsicum annuum*), spices/food additives (*Aframomum corrorima*, *Piper capense*, *Allium sativum*), and stimulants (*Coffea arabica* and *Catha edulis*). Among these, *Zea mays*, *Sorghum bicolor*, and *Eragrostis tef* are the staple crops grown on a large proportion of midland and lowland agroecological zones, while barley and tef are widely grown in the highland zone. *Zea mays*, *Sorghum bicolor*, and *Eragrostis tef* are also the main sources of household cash. Coffee is another important cash crop grown on 18, 000 ha of farmlands (Nole Kaba Agriculture office poster report, 2014/15).

In addition to crops, livestock makes a substantial contribution to the household economy of the local people. The livestock components and number include cattle (64, 320), sheep (22, 426), goats (7,785), equines (22,935) and poultry (4, 5249) (Nole Kaba Agriculture Office report). The

livestock serves as source food (milk, meat, egg, hides, and skins, etc), manure, draught power for farming, means of transportation of people and goods. The livestock is also the source of cash and support household livelihoods. Apiculture is another income generating activity done by a few people around the homestead and in nearby forests.

3.4 Human and livestock healthcare

The major health problems, which have confronted human health at present, are stomachache, fever, snakebite, evil eye, rabies, back pain, febrile, and toothache (personal. comm. with health expert). The available health centers are located in towns. The use of traditional medicine is also common. The traditional healthcare has been managed by knowledgeable traditional healers (for serious health problems) and knowledgeable elders (women, men) using traditional medicine largely medicinal plants.

Similarly, livestock performance and their contributions have been constrained by the prevalence of various animal diseases. The major reported livestock diseases were: babesiosis, blackleg rabies, pasteurellosis, snakebite, and trypanosomiasis (personal comm. with a veterinary expert). Local communities relied on plant-based traditional medicine to manage their livestock health problems. In eight established veterinary clinics, formal veterinary health personnel provide anti-trypanosomal treatments with 17 health center experts (personal comm. with a veterinary expert). This shows that most of the animal health problems have been treated using ethnoveterinary medicine, mainly medicinal plants.

3.5 Research methods

3.5.1 Floristic study

A reconnaissance survey was undertaken in September 2014 to get an overview of the study area and to get permission to work in the study area from local authorities. The field data collections were undertaken in both dry and wet seasons between January 2015 and January 2016. Systematic sampling was employed to gather the floristic data following Kent and Cooker (1992). Eight transects were established in (N, E, S, W) and (NE, SE, SW, NW) directions from the highest elevation of the forest. A total of 73, 400m² (20 x 20 m) plots were laid along transects at every 50 m altitudinal drops (Fig.1). As can be seen in Fig.1 the distribution of the main plots are clustered at the center of the forest. This was happened because of steeply slope in these areas so that 50 m altitudinal drops were encountered within short distance and coordinate readings locate plots very close to each other. Within the plots, five 2 m x 2 m subplots (four at corners and one at the center) were laid to enumerate seedlings (woody species less than 1m height) and saplings (dbh < 2.5 cm). Similarly, within the plots, five 1 m x 1 m subplots (one at each corner of the plots and one at the center) were laid to estimate the cover abundance (percent) of herbaceous species. Stem abundance, cover abundance estimate, diameter at breast height (dbh) (1.3m) and height of wood species having dbh $\geq$ 2.5 cm were recorded in each plot following Mueller-Dombois and Ellenberg (1974). The diameter was measured using caliper and diameter tape. Height was measured using hypsometer and where it was not possible visually estimated. The cover abundance values of species in all plots were later transformed into modified Braun-Blanquet cover-abundance scale (van der Maarel, 2005). In each plot, altitude, slope (percent), aspect, and geographic locations were recorded using altimeter/GPS, clinometers and compass, respectively. The values of aspects of the plots were quantified as: N = 0, NE =

1, NW = 1.3, E = 2, W = 2.5, SE = 3, SW = 3.3, S = 4, following Zerihun Woldu *et al.* (1989). Medicinal and wild edible plants were assessed from the enumerated floristic data of main and subplots based on information given by informants during ethnobotanical study. This was aimed to determine the structure and ecological significance of medicinal and wild edible plants in JWF following Araújo and Ferraz (2013). Furthermore, species occurring outside plots were collected to compile a comprehensive floristic list of JWF.

3.5.2 Ethnobotanical study

Selection of study sites and informants

The study area was stratified into agroecological strata namely, highland, midland, and lowland. These agroecological zones have a varied temperature, altitude, and vegetation assemblages. Within each agroecological stratum, representative number of study sites or KEBELEs (the lowest administrative units next to district) were identified based on the area coverage/proportion of the agroecological zones in the study district. Accordingly, six from midlands, four from highlands, and two from lowland agroecological zones were selected. Prior to undertaking actual field research, the objectives of the study were discussed with the Nole Kaba District government authorities to obtain permission in the present study area. After permission was obtained from authorities, similar discussions were held with leaders of study sites/KEBELEs to obtain permission and their collaboration. Besides, in each KEBELE informants were briefed about the purposes and contributions of the study. Following the discussions, verbal consent was obtained from the informants.

Informants were sampled randomly at each village following Martin (1995). Traditional healers were included purposively. The sample size was determined following Espinosa *et al.* (2013) from the total 11386 households of the study district.

$$n = \frac{Np(1-p)}{(N-1)\left(\frac{d}{Z\alpha/2}\right)^2 + p(1-p)}$$

Where:

n = sample size of informants;

N = size of households in the district

p = proportion of maximum variability considered (=50%)

d = margin of error estimate (0.05%);

α = level of significance considered (alpha = 0.05);

$Z\alpha/2$ = value obtained from the table of standard normal distribution (1.96) for one tail (at $\alpha = 0.025$).

At each KEBELE 30-35 informants were interviewed. Overall, 371 informants (197 males and 174 females) with age range between 13-90 years were involved. Accordingly, 112 informants were aged below 25 years; 191 informants were between 25 and 50; 68 were aged above 50 years. In the course of interviews, 12 more knowledgeable informants were considered as key informants for pairwise comparisons.

Ethnobotanical data collection

Ethnobotanical information on medicinal and wild edible plants (WEPs) was gathered from selected informants between September 2015 and April 2017 through the following ethnobotanical methods:

Semi-structured interview

This method has been used widely in ethnobotanical studies. It is largely flexible and allows to raise additional issues that might arise during the interview (Martin, 1995; Cotton, 1996). A semi-structured interview was conducted with informants to gather information on medicinal and wild edible plants including local names, habitats, plant parts used, methods of preparation, and

additional ethnobotanical uses. In cases of medicinal plants, additional information on dosage forms of remedies, ingredients, routes of administration, diseases treated and other uses of medicinal plants were recorded using the interview guide in Appendix 9.

Group discussions

This approach helps to obtain opinions or perceptions in a community by discussing an issue with some of its members (Martin, 1995). Group discussions were undertaken with 12 key informants (8 male and 4 female) on factors threatening medicinal and WEPs within and outside the forest. Four group discussions were also held with 48 elders (35 males 13 females) informants in four KEBELEs (Arbu Abagada, Siba Silasie, Siba Dalo, Siba Kopi) bordering JWF (12 informants at each KEBELE) to understand their perception of JWF conservation and threat factors.

Field observations

Field observation provides an opportunity to validate the information and allow investigating the habitat status, plant species conservation and perceived threats (Cunningham, 2001). In the present study, field observations were conducted with informants and field guides to gather voucher specimens and to note additional information about growth forms and habitat characteristics (vegetation type) of medicinal and wild edible plants.

Market survey

Marketplaces are important sources of ethnobotanical information. A number of useful wild and cultivated plants are sold at the marketplace by local people (Martin, 1995). Four marketplaces (Bube, Arbu Abaga, Shimela Ilu, Aybeda) in the study sites were visited 2-3 times to document marketable medicinal and wild edible plants and to see the level of harvest for market.

Pairwise comparison

This method is often used to select species of high local importance or high preference from pairs. It is also used to prioritize factors threatening the survival of plant species. Accordingly, informants were asked to select one from a pair at a time based on their knowledge, experience, perceptions, feelings or attitudes. The numbers of pairs for comparisons are calculated using the relation $N(N-1)/2$, where, N is the number of compared species or factors (Martin, 1995; Cotton, 1996). All pairs are randomized and presented to each key informant one pair at a time in the randomized order to select one from each pair that he/she felt important (Martin, 1995; Cotton, 1996). Then the scores from each key informant were summed up and the factor that received the highest total score ranked first (Martin, 1995; Cotton, 1996).

In this study, pairwise comparisons were made twice. The first was to identify wild edible fruits with high local preferences as food from five edible fruits and place them in order of importance; the second was to identify and prioritize threat to plants diversity from five factors. Prior to undertaking pairwise comparisons, the most preferred WEPs and potential threats to plant diversity were identified during individual interviews. Accordingly, fruits of five WEPs and five threat factors were identified for pairwise comparisons. Key informants were asked to compare and prioritize WEPs and threat factors in order of their importance from pairs. Comparison scores of each informant were recorded in a matrix and summed up following Martin (1995) and Cotton (1996).

Herbarium collection and identification

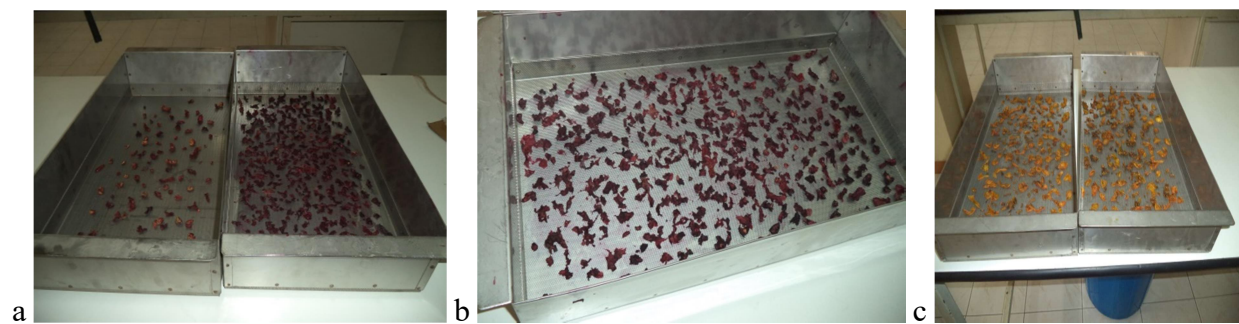
In order to determine the scientific names, samples of all recorded plants including medicinal and wild edible plants were collected, pressed, dried and later all identifications were confirmed

at the National Herbarium, Addis Ababa University. Plant identification was based on Flora of Ethiopia and Eritrea (Volume 1-8) and by cross-checking with authenticated herbarium specimens. The accuracy of plant identification was re-checked and re-confirmed by a senior plant taxonomist.

3.5.3 Nutritional analysis of wild edible fruits

Wild edible fruit sample collection

Healthy and mature fruit samples of WEPs identified during ethnobotanical study were collected from different agroecological areas of the study area. The fruits were identified based on use report of most informants. Accordingly, *Syzgium guineese* subsp. *afromontanum* was considered with high (323, 87%) report, followed by *Carissa spinarum* (269, 73%), *S. guineese* subsp. *macrocarpa* (189, 51%), *S. guineese* subsp. *guineese* (175, 47%) and *Ximenia americana* (124, 33%). These fruits were washed with distilled water to remove wastes and kept at room temperature to remove residual moisture at Ethiopian Biodiversity Institute. Fleshy edible parts of fruit samples were peeled-off and dried under room temperature (Fig.3).



Carissa spinarum & *Syzgium guineese* subsp. *afromontanum* (a), *S. guineese* subsp. *macrocarpa* (b), *Ximenia americana* (c)
Figure 3 Drying process of fruit samples before nutritional analysis (EBI seed preparation laboratory)

The dried samples were taken to the Ethiopian Health and Nutrition Research Institute, Addis Ababa for the analysis of proximate (ash, crude fat, crude fiber, crude protein), mineral (phosphorus, potassium, sodium) and vitamin C. The proximate (protein, fat, and ash) content was expressed in percentage; mineral (sodium and potassium) and vitamin C content was expressed in g/100g, while phosphorus was expressed in mg/Kg of dry matter

Determination of proximate composition

The dried samples were ground into fine powder by using Thomas- Wiley laboratory Mill. The powder was used for analysis of proximate composition and mineral contents as described below:

Determination of ash

The ash content was determined following AOAC (2000) method. Dried silica crucible was weighed (W_1) and 3 g of sample (W_2) was weighed in crucible. The sample incinerated (burned) in a muffle furnace at 550 °C for 2 hr, then cooled in desiccator and weighed again (W_3). The increase in weight of the crucible gave the ash content in the sample and was determined as follows:

$$\text{Ash (\%)} = \frac{W_3 - W_1}{W_2} \times 100$$

Determination of crude fat

The crude fat content was determined following method in AOAC (2000). The initial weight of the aluminum-cup (W_1) was taken by heating in boiling chips 100°C for 30 min followed by cooling in desiccator. 2 g of sample (W_2) was placed in porous thimbles and plugged with cotton; 80 ml diethyl ether was poured into cup and placed in condenser and fitted with sohxlet extraction units. Extraction of fat was carried out at 105 °C for 20 min and then 40 min. The same mixture was placed in the third extraction unit for complete removal of diethyl ether from fats extracted in the cup. After the extraction, cup was removed from the extraction unit apparatus and dried in the oven at 100°C for 30 min, followed by cooling in desiccator for 30

min and then weighed (W₃). The difference in weight of the cup gave the amount of crude fat content in the plants and expressed in percentage as follows:

$$\text{Crude fat (\%)} = \frac{W_3 - W_1}{W_2} \times 100$$

Where W₁ = weight of empty cup; W₂ = Weight of cup + sample taken; W₃ = weight of cup + fat (g)

Determination of crude protein

Crude protein was determined by Kjeldhal method following the method in AOAC (2001). 0.5 g of the sample was digested in a digestion chamber with 20 mL concentrated H₂SO₄ and Kjeldhal catalyst (CuSO₄) for 1:10 hr. The blank test was performed without the sample. After digestion, it was distilled in Kjeldhal distillation chamber. The ammonia liberated was collected over 50 ml 4% boric acid-mixed indicator solution, cooled and titrated with standard 0.1N HCl solution in order to obtain nitrogen content. Crude protein was computed from sample percentage nitrogen content. The concentration of nitrogen was calculated by the following formula.

$$\text{Nitrogen(\%)} = \frac{(V_S - V_B) \times 4 \times 0.1N \text{ HCl}}{\text{sample weight}} \times 1000$$

Where, V_S = Volume (mL) of (0.1 N) HCl used in sample titration

V_B = Volume (mL) of (0.1 N) HCl used in blank titration

14 = Atomic weight of Nitrogen.

The percentage of crude protein content was then estimated by multiplying the percentage of nitrogen with a protein conversion factor (6.25).

$$\text{Crude protein (\%)} = \text{N (\%)} \times \text{Conversion factor (6.25)}$$

Determination of crude fiber

Crude fiber was also determined following AOAC (2000). 1.5 g of the milled sample was measured in pre-weighted 500 ml beaker (W₁), digested with 200 ml 1.25% H₂SO₄ for 30 min and again digested with 25 ml 28% KOH for another 30 min. Digested part of the sample (organic matter) was separated or filtered from the residue (undigested or crude fiber) using half

filled crucible with sand and placed under vacuum pump and the digested materials were collected in section flask. The digested material remaining in the crucible that contains sand and residue was further washed into section flask by 1% NaOH 1% H₂SO₄ and 96% acetone. The crucible containing residue and sand was dried in oven under 135 °C for 2 hrs and then weighed (W₂); it was again heated in furnace under 550 °C for 30 min to burn organic matter; then removed from furnace, cooled in a desiccator and the ash was weighed (W₃). The crude fiber content was expressed as percentage loss in weight upon ignition and was obtained using the following formula.

$$\text{Crude fibre (\%)} = \frac{(W_2 - W_3)}{W_1} \times 100$$

Determination of sodium (Na) and Potassium (K)

0.5 of sample was taken in cleaned conical flask, mixed with 20 mL nitric acid (1:1) ratio and placed on hot plate for 10 min to digest the sample. The flask was cooled and the solution was filtered into a 100 ml standard flask and filled up to the mark with distilled water. The resulting extract was then subjected for the analysis of their content of specific major minerals. Instrumental calibrations were performed using dilutions of the standard elemental solutions at 1000 mg/L containing Na and K minerals. The determinations were carried out as follows: For Sodium, 5 ml potassium chloride (KCl) was added to 50 ml aliquot solution of mineralized samples in 100 ml flask and filled up to the required mark. The solution was then filtered into measuring flasks and filled up to 50 ml with distilled water. The same procedure was followed for K except the missing of KCl. The concentration of sodium and potassium were then determined from this solution using Flame Photometer. The yellow colored solution was

aspirated at the wavelength of flame photometer to detect the concentration of sodium and potassium and expressed as follows.

$$\text{Na (mg)/100g} = \frac{(\text{absorbance of sample (ppm)} - \text{absorbance of blank (ppm)})}{10 \times \text{sample weight}} \times 200$$

$$\text{K (mg)/100g} = \frac{(\text{absorbance of sample (ppm)} - \text{absorbance of blank (ppm)})}{10 \times \text{sample weight}} \times 2000$$

Determination of Phosphorus (P)

One gram of sample was taken in cleaned crucible, mixed with 0.5g zinc oxide and burned on hot plate at 110 °C for 2 hr, followed by further ashing at 525 °C for 4 hr. The crucible was cooled at room T⁰, boiled on hot plate after mixed with 5 ml distilled water and 5 ml 37% HCl. The mixture was cooled and filtered into 100 mL flask. 50% KOH was poured into the in filtrate 100 ml flask followed by extra 2 drops of 37% HCl and filled up to the mark with distilled water. From this 5 ml was taken to 50 mL flask and diluted with 10 ml distilled water and add 20 ml molbidade ascorbic acid solution and mix carefully; placed in metal basket and boiled in boiling bath for 15 min and cooled. This flask was filled with distilled water making brown color mixture. From this a series of stand solutions containing phosphorus were prepared to check the absorbance intensity on spectrophotometer. Add 20 ml molbidade ascorbic acid solution to phosphorus working or standard solution; put in metal basket & then put in boiling bath for 15 min and then put under tap water for cooling. Take some solution into cuvate UV to measure wavelength and to see the absorbance readings. Calibration curve was constructed and used to calculate its concentration. The phosphorus content was finally determined as follows:

$$\text{P (mg)/Kg} = \frac{100 \times V1 \times V2 \times p}{\text{Sample weight (mg)}}$$

Where, V1 = volume of digest

V2 = volume of dilution

p = concentration

Determination of vitamin C

100mg Ascorbic Acid (AA) is weighed in beaker and dissolved to 100ml in 5% metaphosphoric acid and serve as standard solution. Each ml of the solution contains 20 μ g AA. 5g of the fruit samples were prepared by 100ml of 6% trichloroacetic acid TCA and add 1-2 drop of saturated bromine solution in a conical flask containing extracted sample solution. To 10 ml aliquot, add 10ml of 2% thiourea and pipette 4ml from this into three test tubes. Set one tube aside to serve as blank and to each of the remaining test tubes add 1ml of 2% 2,4-dinitrophenylhydrazine (2,4-DNPH) and then put them in water bath at 37°C for 3hr and cool in an ice for 5 min. Add slowly 85% H₂SO₄ while the test tubes are in ice bath. Add 1ml of 2%DNPH to the blank and mix all the tubes and standing at room temperature for 30 min. Read the absorbance of the standards, blank, and test samples at 515 nm. Absorbance readings were used in the calculation of vitamin C content as follows:

$$[(A_s - A_b) * 10] / [A_{10\mu} \text{ Sta.} - A_b]$$

Where, A_s = Absorbance of samples; A_b = Absorbance of blank

A_{10 μ} Sta. = Absorbance of 10 μ Ascorbic Acid Standard

3.5.4 Data Analysis

3.5.4.1 Floristic data analysis

Forest structure

Forest structural variables: density (*d*), frequency (*f*), basal area (*ba*) and importance value index (IVI) were computed on Microsoft Excel spreadsheet (Version 2007) for all woody species including that of medicinal and WEPs. Density (*d*) is expressed as the total number of individuals of a species (dbh $\geq$ 2.5) per hectare. Frequency (*f*) is expressed as the percentage of

the number of times a plant species is present in plots per total number of plots. Individuals of woody species ($dbh \geq 2.5$) in sampled plots were classified following Raunkiaer (1934) frequency classes (A = 1-20%; B = 21-40%; C = 41-60%; D = 61-80%; E = 81-100%).

Stem basal area (ba) was calculated from dbh measurements as follows:

$$\text{Basal area } (ba) = \pi (\pi) * (dbh)^2 / 4, \text{ where } \pi = 3.14$$

Relative density (Rd), relative frequency (Rf), and Relative basal area (Rba) were calculated/computed for each species as follows:

$$ba = \pi(dbh/2)^2 \times 100$$

Where ba is the basal area in m^2 of a species, $\pi = 3.14$ and dbh is diameter at breast height.

$$Rd = \frac{di}{dt} \times 100$$

Where di is density of i^{th} species and dt is the total density of all species in the sample.

$$Rf = \frac{fi}{ft} \times 100$$

Where fi is the frequency of i^{th} species and it is the total frequency of all species in the sample.

$$Rba = \frac{bai}{bat} \times 100$$

Where bai is the basal area of i^{th} species and bat is the sum of the basal area of all species in the sample.

The Importance Value Index (IVI) of each species was obtained by adding the values of relative density, relative dominance, and relative frequency ($IVI = Rf + Rd + Rba$) following Mueller-Dombois and Ellenberg (1974) and Kent and Coker (1992). Importance Value Index is used to rank each species as it gives an insight into the ecological importance and status of each species in a vegetation (Kent and Coker, 1992). Spearman correlation was computed to evaluate relationships between structural variables (density, dbh , and height); between IVI and cultural

importance (CI) (ethnobotanical importance) of medicinal and wild edible plants found in the forest.

Population structure and natural regeneration

The population structure of plant species is often described in terms of diameter size of individuals, and life stages of woody perennial species (Rao *et al*, 1990). In the present study, individuals of woody species with dbh ≥ 2.5 cm in sampled plots was classified and enumerated in nine dbh (2.5-12.5, 12.6-22.5, 22.6-32.5, 32.6-42.5, 42.6-52.5, 52.6-62.5, 62.6-72.5, 72.6-82.5, >82.6 cm) and height (1.5-5, 5.1-10, 10.1-15, 15.1-20, 20.1-25, 25.1-30, 30.1-35, 35.1-40, >40 m) classes following Peter (1996). Graphs were constructed to depict the patterns of distribution of the individuals of woody species across the dbh and height classes. Besides, the population structure of tree species was illustrated graphically. Furthermore, the seedling and sapling density of woody species with dbh < 2.5 cm were compared with the mature woody species. The regeneration status of woody species in general and tree species, in particular, was determined based on density, presence and absence of seedlings and saplings following (1987).

Classification and ordination

Classification (clustering) was employed to group samples (plots) by their species compositional similarities and dissimilarities (Dufrêne and Legendre, 1997; Zerihun Woldu, 2012). In order to define groups of plots having similar species composition and identify the floristic relationship, hierarchical agglomerative cluster analysis with euclidean distance measure and ward method was performed using cover abundance data as input. The optimal number of clusters was determined using objective K-mean method in which a sharp bend in the plot could be a good indication of the number of clusters (Zerihun Woldu, 2012).

To determine the indicator species in each cluster or plant community type, indicator species analysis (ISA) was employed as suggested in Dufrene and Legendre (1997). Indicator species are characteristic species of each group that are used as ecological indicators of community or habitat types, environmental conditions, or environmental changes (Dufrene and Legendre, 1997). A synoptic table containing indicator values (the relative abundance and frequency of species) was constructed following IAS using “indicspecies” in R-software. Multi-Response Permutation Procedures (MRPP) (R-Core Team, 2017) determined the statistical significance of indicator values between clusters/communities. Plant community types were named by the first two species having the highest and significant ($p < 0.05$) indicator values. Redundancy Analysis (RDA) was used to assess the relationship between species distribution and underlying environmental variables (altitude, aspect, and slope). RDA is used to identify environmental variables that could influence distribution of species (Zerihun Woldu, 2012). R-package (R-Core Team, 2017) was used for species classification and ordination.

Species diversity

Plant species diversity in different community types was determined using diversity indices. One of the widely used diversity indices in plant ecology is Shannon-Wiener diversity measure (Krebs, 1989; Magurran, 2004). *Shannon diversity index* (H') takes into account both the richness and evenness in a given community. A greater H' value implies greater species diversity. The Shannon diversity index increases as both the richness and the evenness of the community increase. The index was computed from the following relation:

$$\text{Shannon diversity index}(H') = - \sum_{i=1}^s P_i \ln P_i$$

Where, s is the total number of species; p_i is the proportion of individuals of a given species to the total number of individuals in the community. $p_i = \frac{n_i}{N}$ where, n_i is the number of individuals in each species, N is the total number of all individuals in all species, $\ln$ is natural logarithm. *Shannon Evenness (E)* is a measure of the relative abundance of the different species making up the richness of an area. The principle of the evenness measure is to quantify the unequal representation of species against a hypothetical community in which all species are equally common (Krebs, 1989). Evenness assumes a value between 0 and 1, with 1 being complete evenness (Kent and Cooker, 1992). The higher the value of evenness index indicates the more even the distribution and diversity of species within the given area. Evenness was determined using the Shannon-Weiner index as follows:

$$\text{Evenness (E)} = H' / \ln (S)$$

Where, H' is the Shannon-Wiener Diversity Index, S is the number of species of a community type and $\ln$ is natural logarithm. R-software was employed to compute the species diversity (R Core Team, 2017). One-way ANOVA was used to compare species richness, diversity, and evenness among community types.

Floristic similarity

Species similarity estimators are used to compare the species composition within two or more study sites using incidence or quantitative data (Sorenson, 1948). Sorensen's coefficient is one of the most widely used similarity measures. In the present study, it was used to determine floristic similarity between JWF and other Afromontane forests (MAFs and DAFs) of Ethiopia.

Sorensen's (Ss) similarity coefficient was computed as defined below:

$$\text{Sorensen's similarity (Ss)} = 2a / [2a+b+c]$$

Where, S_s is Sorensen's (S_s) similarity coefficient, a = the number of species shared by the two samples (sample 1 and 2), b and c are the number of species in every two samples (samples 1 and 2). The similarity values range from zero (no similarity) to one (complete similarity) (Kent and Coker, 1992).

3.5.4.2 Ethnobotanical data analysis

Ethnobotanical data were analyzed using both descriptive and inferential methods. Percentages and graphs were computed using Microsoft Excel (Version 2007) to analyze qualitative data. Quantitative data were analyzed using various techniques used in various ethnobotanical researches. These methods have been developed to make useful comparisons among informants on the uses and importance of different plant species (Phillips and Gentry, 1993). Quantitative techniques provide insight into the relative importance of plants in the sample as well as the distribution of knowledge among members of the community. They also help in the identification of priority species for development and conservation planning (Camou-Guerrero *et al.*, 2008). Quantitative techniques have also been used to compare indigenous knowledge found among different social groups in communities or between different use categories among and between communities. The following quantitative approaches were applied to analyze quantitative data.

Factor of Informant Consensus (Fic)

One of the most widely used quantitative tools is the factor of informant consensus (*Fic*), which was adopted by Heinrich *et al.* (1998) to see the degree of agreement among different people interviewed concerning the use of plant species within a given ailment category. In order to compute *Fic*, it is necessary to classify illnesses into broad disease categories. *Fic* was computed

following Heinrich *et al.* (1998) to see if there were agreements on the use of medicinal plants for treatment of a particular health problem category among informants in the study areas.

$$Fic = \frac{n_{ur} - n_t}{n_{ur} - 1}$$

Where, n_{ur} is the number of use reports for a particular disease category and n_t is the number of different plants (taxa) that are reported to treat this disease category. *Fic* values range from 0.00 to 1.00. High *Fic* values (close to 1.0) are obtained when only one or a few plant species are reported to be used by a high proportion of informants to treat a particular disease category whereas low *Fic* values indicate that informants disagree on the species to be used for the treatment within a disease category (Andrade-Cetto and Heinrich, 2011).

Fidelity Level (FL)

Another important consensus analysis commonly used as a quantitative ethnobotanical tool is the fidelity level (FL) index (Friedman *et al.*, 1986). This was calculated to estimate the relative importance of medicinal plants reported for treating particular disease categories. A limitation of this tool is that a plant with a low number of use reports might have high FL, which does not necessarily indicate more FL for this plant; in contrast, another plant with more use reports may have a lower FL value. To avoid this problem, the informant use report (Ur) is considered. The Ur is the number of use reports for one plant given by all of the informants for a specific disease (Andrade-Cetto and Heinrich, 2011). The fidelity level value was computed from the following relation:

$$\text{Fidelity level (FL)} = \left(\frac{I_p}{I_u} \right) \times 100 \text{ (Friedman } et al., 1986)$$

Where I_p = number of informants that use a species for principal disease; I_u = total number of informants that cited the species to treat any other disease.

Distribution of ethnobotanical knowledge

The patterns of ethnobotanical (medicinal and edible plants) knowledge distribution among social variables (age, gender, education, healing profession) and geographic variables (proximity to forest and formal healthcare, and settlement agroecological zones) were assessed based on the number of medicinal and WEPs reported by each informant. Several studies evaluated the distribution of ethnobotanical knowledge by taking the number of reported plants as a proxy variable representing ethnobotanical knowledge (Camou-Guerrero *et al.*, 2008; Souto and Ticktin, 2012; Beltrán-Rodríguez *et al.*, 2014). Analysis of Variance (ANOVA) was computed to determine significant mean variation in number of medicinal plants reported by informants with different social and geographic variables. Significant means among age and agroecological variable categories were further identified using One-way ANOVA *post-hoc* analysis with Least Significant Difference (LSD) test. Multiple linear regressions (MLR) was computed to determine the contribution of significant variables to the total variation in ethnobotanical knowledge among informants. SPSS (2016) package was used for analysis of ethnobotanical data.

Medicinal plants use similarity

Medicinal plants use similarity among informants in different study sites (KEBELE) was computed based on presence/absence data matrices using Sorensen's (Ss) similarity. This also helps to understand the level of shared ethnobotanical knowledge among communities in different KEBELES.

Cultural Importance and Use value

Cultural Importance (CI) and Use-Value (UV) indices have been used to evaluate the importance of plants in a given culture. These analytical tools indicate which species are important in

providing cultural or commercial values (Phillip and Gentry 1993b). Culturally important species are those that are used by a large number of people for the same category of use (Heinrich *et al.*, 1998). In this study, cultural importance (CI) of medicinal and WEPs reported by many informants were computed following Tardío and Pardo-de-santayana (2008) to evaluate the relative contribution of these plants in the study area.

$$CIs = \sum_{u=u_1}^{u_{NC}} X \sum_{i=1}^{i_N} UR_{ui}/N$$

Where, NC = total number of use-categories ($u_1, u_2, \dots, u_{NC}$); N = informants ($i_1, i_2, \dots, i_N$), UR_{ui} = use-report of informant i who mention each use-category for the species s in the use-category u.”

Similarly, the use-value index proposed by Phillips and Gentry (1993) later adapted by Albuquerque *et al.* (2007) were employed to assess the use-values of medicinal and wild edible plants. This index is often used to evaluate the relative importance of a species to local communities.

The index was computed following Albuquerque *et al.* (2007):

$$UV_s = \Sigma U_s / n_s$$

Where UV_s = use value for a species; ΣU_s = sum of the uses mentioned for a species ‘s’; n_s = total number of informants.

3.5.4.3 Nutritional analysis of wild edible fruits

Results of proximate (ash, crude fat, crude fiber, crude protein), mineral (phosphorus, potassium, sodium) and vitamin C analysis were presented as means and standard errors ($M \pm SE$). Significant mean differences among the parameters of the analyzed fruits were identified using One-way ANOVA *post-hoc* analysis with LSD test.

CHAPTER FOUR

4. RESULTS

4.1 Floristic study

4.1.1 Floristic diversity and composition of JWF

A total of 237 vascular plant species belonging to 192 genera and 82 families were recorded from Jorgo Wato Forest. Of these species, 221 (93.2%) species were Angiosperms, 15 (6.3%) were Pteridophytes (ferns and related species such as *Huperzia* spp.) and the remaining one was Gymnosperms (Appendix 1). The most species-rich families were Fabaceae (27 species), followed by Asteraceae (21) and Acanthaceae, Lamiaceae and Poaceae (11 species each) (Fig. 4). The top ten species rich-families contributed 50% to the total species in JWF. The most common species found in the forest were *Dracaena afromontana*, *Chionanthes mildbraedii*, *Syzygium guineense* subsp. *afromontanum*, *Pouteria adolfi-friederici*, *Maytenus gracilipes* and *Landolphia buchananii*. In terms of growth forms, herbs including herbaceous climber contributed the highest proportion of species (119, 50%) to the recorded floristic composition followed by shrubs (58, 25%), trees (39, 16%) and liana (21, 9%).

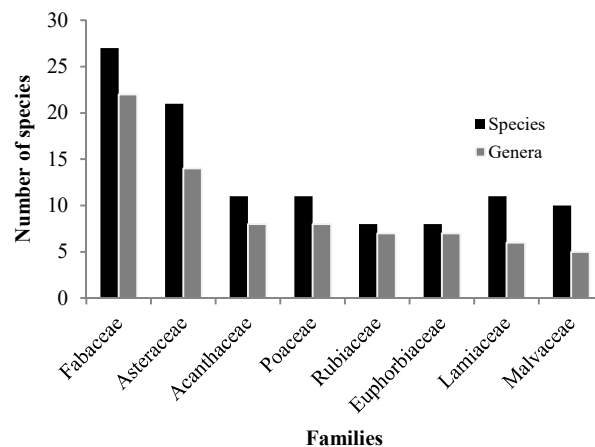


Figure 4 Families with the richest species and genera

Furthermore, the study has recorded 95 species that were not reported in the Flora of Ethiopia and Eritrea for Wollega floristic region (Appendix 2). The floristic diversity of JWF also comprises 10 endemic species, which constitute 4% of the total recorded species (Table 1). Of the recorded endemics species, three belongs to Asteraceae family.

Table 1 Endemic plants found in JWF

N0	Botanical name	Family name	Growth forms
1	<i>Bothriocline schimperi</i> Oliv. & Hiern ex Benth.	Asteraceae	Sh
2	<i>Crotalaria gillettii</i> Polhill	Fabaceae	H
3	<i>Lippia adoensis</i> Hochst. ex Walp.	Verbenaceae	Sh
4	<i>Maytenus addat</i> (Loes) Sebsebe	Celastraceae	T
5	<i>Millettia ferruginea</i> (Hochst.) Bak.	Fabaceae	T
6	<i>Pycnostachys abyssinica</i> Fresen.	Lamiaceae	Liana
7	<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Asteraceae	Sh
8	<i>Trifolium mattirolanum</i> Chiov.	Fabaceae	H
9	<i>Vernonia leopoldi</i> (Sch. Bip. ex Walp.) Vatke	Asteraceae	Sh
10	<i>Vepris dainellii</i> (Pic. Serm.) Kokwaro	Rutaceae	T

4.1.2 Forest structure

4.1.2.1 Species density

A total of 4313 individuals ($\text{dbh} \geq 2.5 \text{ cm}$) representing 69 species, 64 genera, and 39 families were recorded in sampled plots. In terms of density, a total 1477 individuals ha^{-1} was recorded. The majority (77%) of the individuals were in the smaller (2.5-12.6 cm) diameter class. The stem density (number of individuals) and number of species consistently decreased with increasing dbh classes (Fig. 5a and b). The proportions of individuals as shrubs and trees in total density were 63.8% and 36.2 %, respectively. The densities of the individuals varied between 0.34 - 283.6 individuals ha^{-1} , with the mean density (Mean $\pm$ S.E) of 21.4 ± 5.1 individuals ha^{-1} . The highest density was recorded for *Dracaena afromontana* (283.6 individuals ha^{-1}), followed by

Chionanthes mildbraedii (132.9 individuals ha⁻¹), *Syzygium guineense* subsp. *afromontanum* (131.8 individuals ha⁻¹), *Pouteria adolfi-friederici* (101.7 individuals ha⁻¹). *Maytenus gracilipes* (87.3 individuals ha⁻¹) and *Landolphia buechananii* (60.3 individuals ha⁻¹). These six species together accounted for 44% of the total stem density ha⁻¹. Species having the least stem densities or in low abundances were *Grewia ferruginea*, *Senna petersiana*, and *Solanecio mannii* with 0.34 individuals ha⁻¹ each.

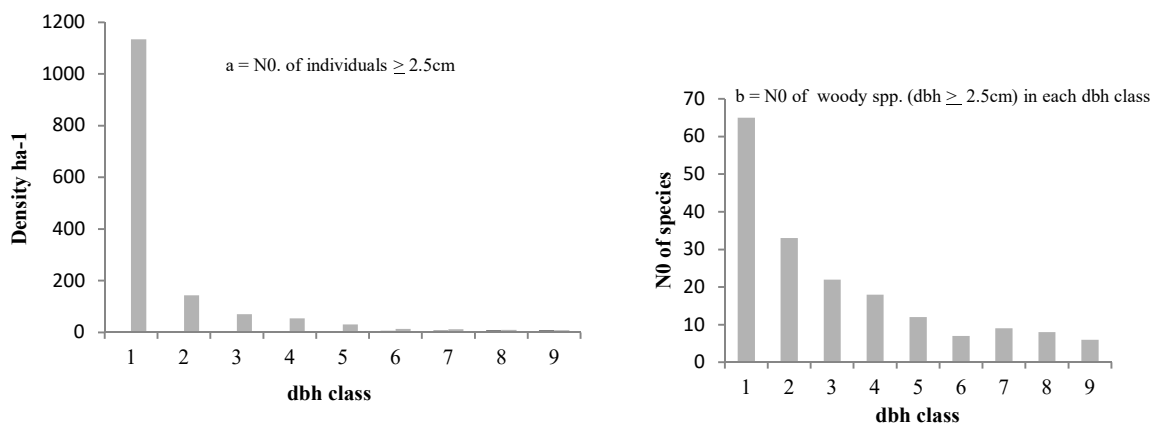


Figure 5 Distribution of individuals of woody species (dbh $\geq$ 2.5 cm) in different dbh classes

4.1.2.2 Species frequency

The frequencies of the sampled species varied between 1.4 - 67.1%. The highest frequency was recorded for *Dracaena afromontana*, *Pouteria adolfi-friederici* and *Syzygium guineense* subsp. *afromontanum* (67.1% each). The top ten species accounted for 52% of the total frequency. The most frequent species belonged to Dracaenaceae, Myrtaceae, and Sapotaceae families. About 53 (76.8%) of species were in the lowest Raunkier's frequency class A (0-20%) (Fig. 6). It was found that species showing the highest densities were also the most frequent and were in class D (61-80%) frequency.

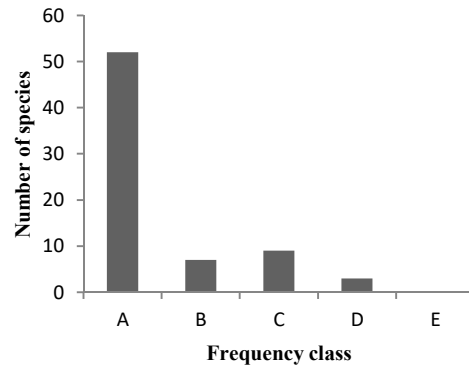


Figure 6 Distribution of species in different Raunkier's frequency classes

4.1.2.3 Species height

The heights of the sampled woody species varied between 1.5 and 45 m, with a mean height of 4.2 m. The majority of individuals were in the first (1.5-5 m) height class (Fig. 7). The numbers of individuals consistently decrease along increasing height classes. The first and second height classes alone accounted for 62% of the total individuals. Spearman's correlation revealed a significant correlation between height and dbh of woody individuals ($r = 0.65$, $p < 0.05$) (Table 2). The number of species also consistently decreased with increasing height classes.

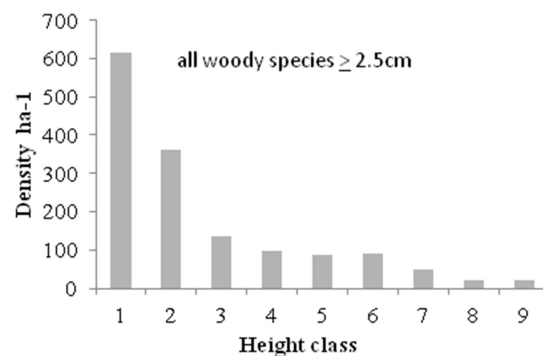


Figure 7 Distribution of individuals in different height classes

Table 2 Correlation between dbh and height of woody species

			dbh	height
Spearman's rho	dbh	Correlation Coefficient	1.000	0.650**
		Sig. (2-tailed)	.	0.000
		N	69	69
	height	Correlation Coefficient	0.650**	1.000
		Sig. (2-tailed)	.000	0.00
		N	69	69
**. Correlation is significant at the 0.001 level (2-tailed).				

4.1.2.4 Species basal area

In terms of basal area, the total basal area of woody species ($\text{dbh} \geq 2.5 \text{ cm}$) in JWF was $62.7 \text{ m}^2 \text{ ha}^{-1}$. The basal area varied between 0.01 and $30.2 \text{ m}^2 \text{ ha}^{-1}$, with a mean basal area of $0.91 \text{ m}^2 \text{ ha}^{-1}$. The species showing the largest basal areas were *Pouteria adolfi-friederici* ($30.2 \text{ m}^2 \text{ ha}^{-1}$), *Syzygium guineense* subsp. *afromontanum* ($8.1 \text{ m}^2 \text{ ha}^{-1}$), *Ficus sur* ($5.0 \text{ m}^2 \text{ ha}^{-1}$) and *Croton macrostachyus* ($4.3 \text{ m}^2 \text{ ha}^{-1}$). These four species accounted for 75.8 % of the total basal area, while the majority (65 species) contributed only 24.2% to the total basal area. The basal areas (dominance) were found significantly correlated with stem density ($r = 0.75$, $N = 69$, $p < 0.05$). Trees with the largest dbh were *Pouteria adolfi-friederici* (207 cm), *Schefflera abyssinica* (170 cm), *Ficus sur* (152.9 cm) and *Croton macrostachyus* (124.2 cm).

4.1.2.5 Species importance value index (IVI)

The IVIs of all sampled woody species ($\text{dbh} \geq 2.5 \text{ cm}$) varied between 0.17 to 37.7 (Appendix 3). Species with the highest IVI were *Pouteria adolfi-friederici* (37.7), *Syzygium guineense* subsp. *afromontanum* (23.6), *Dracaena afromontana* (20.5), *Chionanthes mildbraedii* (15.9), and *Croton macrostachyus* (12.3) (Table 3). The important value index of the majority (63.8%) of species were generally low (< 2).

Table 3 Ecologically the most important species in the forest

Names	Growth forms	Relative frequency	Relative density	Relative dominance	IVI
<i>Pouteria adolfi-friederici</i> (Engl.) Baehni	T	0.63	6.89	30.15	37.67
<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>afromontanum</i> F. White	T	6.63	8.93	8.08	23.64
<i>Dracaena afromontana</i> Mildbr.	Sh	0.63	19.20	0.69	20.52
<i>Chionanthus mildbraedii</i> (Gilg & Schellenb) Stearn	Sh	5.95	9.00	0.99	15.94
<i>Croton macrostachyus</i> Del.	T	4.87	3.13	4.28	12.28
<i>Ficus sur</i> Forssk.	T	3.79	2.57	5.04	11.40
<i>Maytenus gracilipes</i> (Welw. ex Oliv.) Exell subsp. <i>argota</i> (Loes.) Sebsebe	Sh	4.47	5.91	0.35	10.73

4.1.2.6 Population structure

The proportion of individuals of woody species ($\text{dbh} \geq 2.5 \text{ cm}$) was considerably high in the first dbh class and sharply dropped in the second, with a subsequent decrease towards the last class. This shows many small-sized and relatively few medium to large sized individuals are found in the forest. Similarly, the dbh size class distribution of species showed a characteristic decline in numbers of species with increasing dbh class. In sum, the distribution of individuals of all woody species in different dbh classes together showed a definite pattern of inverted J-shaped pattern (Fig. 8).

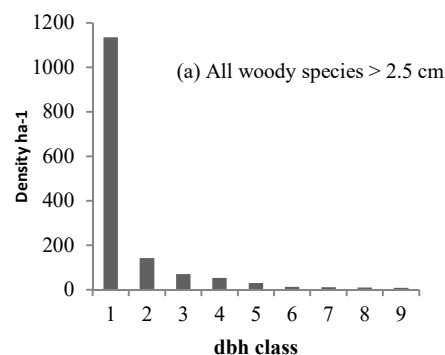


Figure 8 Distribution of individuals in different dbh classes of all woody species

The analysis of tree population structure, however, depicted in general three distribution patterns of individuals (Fig. 9a to f). In the first pattern (reverse J-shape), there were many individuals in the first dbh (2.5-12.5 cm) class, followed by a few individuals or discontinuous occurrence towards the last dbh (> 80 cm) classes (Fig.9a-d). This group includes *Ficus sur*, *Pouteria adolfi-friederici* and *Syzygium guineense* subsp. *afromontanum*, which showed many individuals in the first dbh size classes followed by a few individuals in the remaining classes. Species such as *Albizia schimperiana*, *Allophylus abyssinicus*, *Croton macrostachyus*, *Ilex mitis*, *Macaranga capensis*, *Millettia ferruginea* and *Vepris dainellii* showed many individuals in the first dbh size with decreasing individuals towards intermediate classes showing reverse J-shape but completely absent from larger classes (Fig. 9b). *Apodytes dimidiata*, *Ekebergia capensis*, *Maytenus addat*, *Olea capensis* subsp. *hochstetteri*, *Olea welwitschii*, and *Prunus africana* showed many individuals in the first class followed by irregular and decreasing occurrence towards intermediate class but absent from the last classes (Fig. 9c). Species like *Albizia gummifera*, *Bersama abyssinica*, *Celtis africana*, *Cassipourea malosana*, and *Ehretia cymosa* showed many individuals in the first dbh class with few individuals in the second showing reverse J-shape pattern but completely absent in the intermediate and last classes (Fig.9 c-d). In the second pattern (spread pattern) (Fig.9e), there were few individuals in intermediate classes but completely absent from first and last dbh classes. This was depicted by *Polyscias fulva* and *Cordia africana*. The last pattern exhibited by *Schefflera abyssinica* in which few individuals appeared in the last dbh class but completely absent from the first and intermediate dbh classes (Fig.9f).

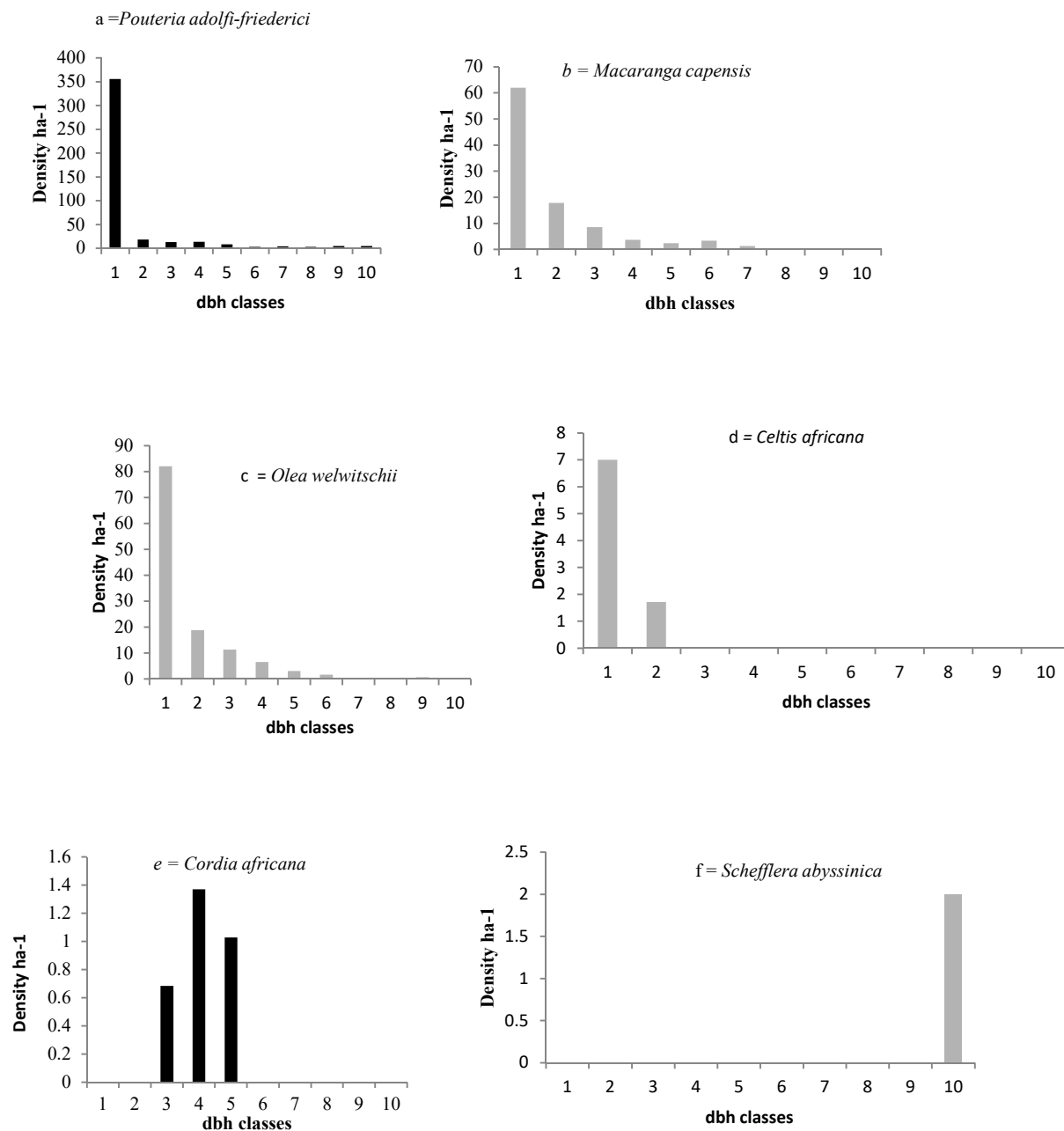


Figure 9 Distribution of individuals of tree species in different dbh classes (a-f)

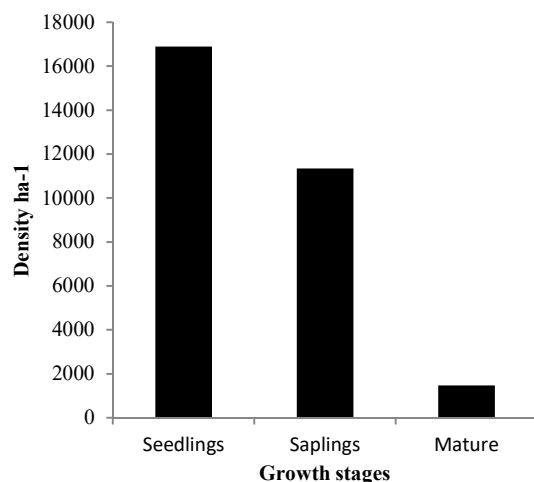
4.1.2.7 Natural regeneration

The regeneration status of woody species was determined based on their seedling and sapling densities. Of the 69 woody species ($\text{dbh} \geq 2.5$ cm), 58 species belonging to 55 genera and 37

families were represented either in seedlings or in the saplings growth phase. Of these species, 40 were present in seedling and sapling phases, nine were present in only one (either seedling or sapling) phase, and 11 were absent from both seedling and sapling phases. Two species namely, *Calpurnia aurea* and *Rhamnus prinoides* were absent from the adult phase ($\text{dbh} \geq 2.5 \text{ cm}$). The Fabaceae and Rubiaceae families contributed the highest number (5 species each) to the juvenile individuals.

The seedlings densities varied between 7 and 4199 individuals ha^{-1} , with a total density of 16924 individuals ha^{-1} . Similarly, the sapling density ranged from 7 to 2459 individuals ha^{-1} , with a total density of 11219 individuals ha^{-1} . The mean seedling and sapling densities were (Mean $\pm$ SE), (352 ± 97.7) and (229 ± 61.4) individuals ha^{-1} , respectively. The overall population structure of seedlings, saplings, and mature individuals showed a reverse-J shape distribution pattern (Fig. 10). The highest seedlings and saplings were recorded for *Landolphia buehariana*, followed by *Vepris dainellii*, and *Dracaena afromontana*. These three species accounted for 47.6% of the total seedlings and 40.7% saplings densities showing high regeneration potential of these species in the forest.

The lowest seedling and sapling densities (7 individuals ha^{-1} each) were recorded for *Albizia schimperiana*, *Croton macrostachyus*, *Ehretia cymosa*, *Ekebergia capensis*, *Ficus sur*, *Flacourtia indica*, *Gouania longispicata*, *Keetia gueinzii*, *Ocimum urticifolium*, *Phyllanthus limmuensis*, *Pittosporum viridiflorum* and *Croton macrostachyus*.



NB: Seedlings (height < 1m); Saplings (dbh < 2.5 cm); Mature (dbh > 2.5cm)

Figure 10 Distribution of individuals of woody species of different growth phases

Comparison of the juveniles with mature tree revealed that, of 25 tree species in sampled plots, 14 (56%) were represented at both seedling and sapling stages; seven (28%) were missed from seedling and nine (36%) missed from sapling growth phases. Trees such as *Albizia gummifera*, *Bersama abyssinica*, *Olea welwitschii*, *Pouteria adolfi-friederici*, *Prunus africana*, *Syzygium guineense* subsp. *afromontanum*, and *Vepris dainellii* had exhibited the highest seedling density, followed by sapling and mature. On the other hand, *Cordia africana*, *Cyathea manniana*, *Maytenus addat*, *Polyscias fulva*, *Schefflera abyssinica* were represented neither in seedlings nor in saplings phase.

4.1.3 Plant community

4.1.3.1 Classification of plant community

Hierarchical agglomerative cluster analysis classified plots into five community types (I, II, III, IV, V) as visualized in the dendrogram (Fig. 11).

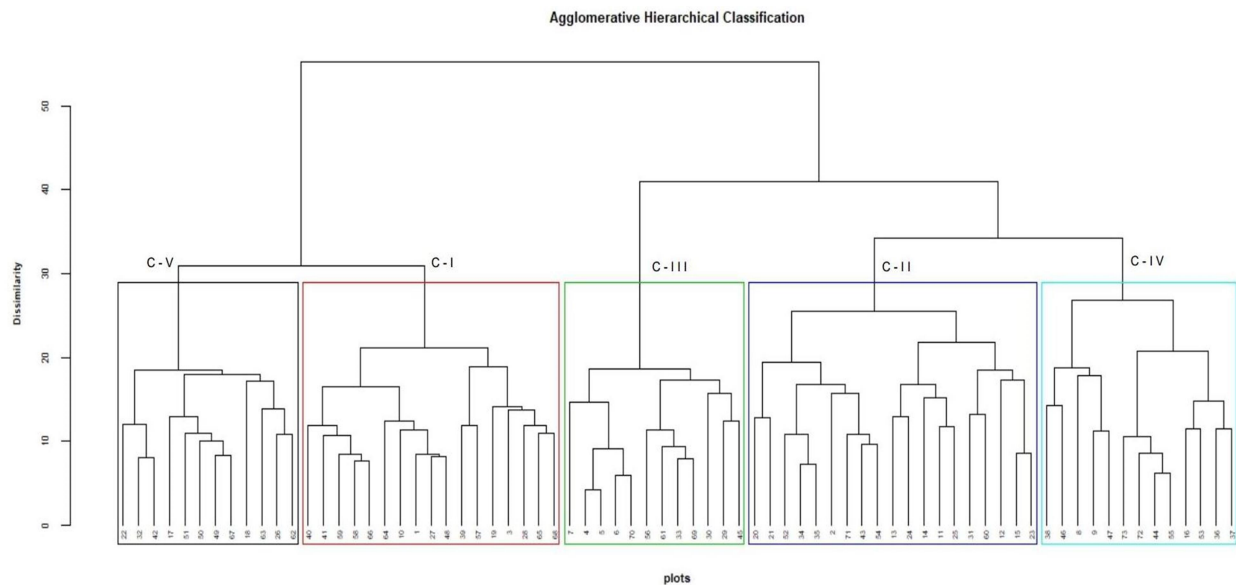


Figure 11 Dendrogram showing plant community types in JWF

(CI = *Cyperus fischerianus* - *Apodytes dimidiata* Community, CII = *Dracaena afromontana* - *Hippocratea pallens* Community, CIII = *Ficus sur* - *Olea welwitschii* Community, CIV = *Desmodium repandum* - *Cordia africana* Community and CV = *Chionanthus mildbraedii* - *Pouteria adolfi-friederici* Community).

Each plant community was named by the first two characteristic species with high indicator value (IV) and low p-value. The community types are described below:

Cyperus fischerianus - *Apodytes dimidiata* (community I)

The characteristic tree and shrub species with significant indicator values were *Apodytes dimidiata*, *Cassipourea malosana*, *Buddleja polystachya*, *Dombeya torrida*, and *Hypericum quartinianum*. In the herb layer, *Cyperus fischerianus*, and *Adiantum poiretii* had shown

significant indicator values. Other trees and shrubs found in this community include *Croton macrostachyus*, *Ficus sur*, *Macaranga capensis*, *Allophylus abyssinicus*, *Chionanthus mildbraedii*, *Erythrococca trichogyne*, *Justicia schimperiana*, *Nuxia congesta*, and *Rhus glutinosa*. *Embelia schimperii*, *Gouania longispicata*, *Keetia gueinzii* and *Landolphia buchananii* were the liana found in this community. The ground layer also included *Bidens macroptera*, *Coleochloa abyssinica*, *Hyparrhenia cymbaria*, *Impatiens hochstetteri*, and *Vernonia wollastonii*. Trees such as *Apodytes dimidiata* and *Cassipourea malosana* were the emergent tree in this community. The average altitudinal range of characteristic species of this community was between 2350-2500 m.

Dracaena afromontana - *Hippocratea pallens* (Community II)

The characteristic species with significant values were *Dracaena afromontana* and *Hippocratea pallens*. The tree and shrub layer of this community included *Syzygium guineense* subsp. *afromontanum*, *Croton macrostachyus*, *Ehretia cymosa*, *Maytenus addat*, *Brucea antidysentrica*, and *Chionanthus mildbraedii*. *Embelia schimperii*, *Gouania longispicata*, *Jasminum abyssinicum*, *Landolphia buchananii*, and *Urera hypselodendron* were lianas found in this community. In the herb layer, *Cyperus fischerianus*, *Hypoestes triflora*, *Impatiens hochstetteri*, *Justicia ladanooides*, *Kyllinga odorata*, *Phaulopsis imbricata*, and *Panicum hochstetteri* were recorded. This community was found between 2248-2327 m altitudinal ranges.

Ficus sur - *Olea welwitschii* (Community III)

The characteristic species of this community were *Ficus sur* and *Olea welwitschii*. This community encompasses many other trees, shrubs, and herbs. The trees and shrubs were *Albizia schimperiana*, *Bersama abyssinica*, *Croton macrostachyus*, *Ekebergia capensis*, *Polyscias fulva*,

Syzygium guineense subsp. *afromontanum*, *Vepris dainellii*, *Clausena anisata*, *Canthium oligocarpum*, *Lepidotrichilia volkensii*, *Maytenus gracilipes*, and *Galiniera saxifragae*. *Embelia schimperi*, *Gouania longispicata*, and *Landolphia buchananii* were among the lianas found in this community. Herbaceous species found in this community were *Ageratum conyzoides*, *Crotalaria gillettii*, *Cynoglossum amplifolium*, *Elatostema monticolum* and *Panicum hochstetteri*. This community was found between 2170-2230 m altitudinal ranges.

Desmodium repandum - *Cordia africana* (Community IV)

The characteristic species with significant indicator values were *Desmodium repandum*, *Cordia africana*, *Millettia ferruginea*, *Allophylus abyssinicus*, *Maesa lanceolata*, *Dalbergia lactea*, *Coffea arabica*, *Hypoestes triflora*, *Panicum hochstetteri*, *Phaulopsis imbricate*, and *Setaria poiretiana*. Other associated trees and shrubs found in this community were *Albizia gummifera*, *Ficus sur*, *Celtis africana*, *Dalbergia lactea*, and *Grewia ferruginea*. The liana of this community included *Clematis hirsuta*, *Combretum paniculatum*, *Rubus apetalus*, and *R. niveus*. The herbaceous layer was composed of *Achyranthes aspera*, *Cyperus fischerianus*, *Impatiens hochstetteri*, *Pilea rivularis*, and *Pteridium aquilinum*. This community was found between 2080-2250 m.

Chionanthus mildbraedii - *Pouteria adolfi-friederici* (community V)

Chionanthus mildbraedii and *Pouteria adolfi-friederici* showed significant indicator value in this community. Other associated trees and shrubs found in this community included *Bersama abyssinica*, *Croton macrostachyus*, *Macaranga capensis*, *Abutilon longicuspe*, *Acanthus eminens*, *Dracaena afromontana*, *Justicia schimperiana*, *Maytenus gracilipes* subsp. *argota*, *Ocimum urticifolium*, and *Solanecio gigas*. The lianas found in this community were *Clematis hirsuta* and

Mucuna melanocarpa. The ground layer of this community encompasses *Dichrocephala integrifolia*, *Isodon ramosissimus*, *Hypoestes forskoolii*, *Panicum hochstetteri*, *Pennisetum trachyphyllum*, and *Solanecio mannii*. This community type was found between 2205-2310 m elevations.

Table 4 listed indicator species with significant indicator values in each community. The indicator values indicate the degree to which species are associated with the various clusters /plant community types.

Table 4 Synoptic table showing significant indicator value (%) in each plant community type

Name	C-I	C-II	C-III	C-IV	C-V	p-value
<i>Cyperus fischerianus</i> A. Rich.	47	0.11	0.01	0.07	0.03	0.006
<i>Apodytes dimidiata</i> E. Mey. ex Arn.	44	0.29	0.04	0.00	0.00	0.003
<i>Cassipourea malosana</i> (Baker) Alston	36	0.02	0.03	0.00	0.02	0.022
<i>Hypericum quartinianum</i> A. Rich.	31	0.00	0.00	0.00	0.00	0.020
<i>Dombeya torrida</i> (J. F. Gmel.) P. Bamps	23	0.00	0.00	0.00	0.02	0.039
<i>Adiantum poiretii</i> Wikstr.	20	0.00	0.00	0.00	0.00	0.039
<i>Buddleja polystachya</i> Fresen.	19	0.01	0.00	0.00	0.00	0.046
<i>Dracaena afromontana</i> Mildbr.	0.12	35	0.16	0.00	0.13	0.010
<i>Hippocratea pallens</i> Planch. ex Oliv.	0.00	24	0.10	0.00	0.00	0.041
<i>Ficus sur</i> Forssk.	0.03	0.00	32	0.32	0.00	0.028
<i>Olea welwitschii</i> (Knobl.) Gilg & Schellenb.	0.02	0.13	29	0.00	0.06	0.044
<i>Desmodium repandum</i> (Vahl) DC.	0.00	0.01	0.01	79	0.01	0.001
<i>Cordia africana</i> Lam.	0.00	0.00	0.00	72	0.00	0.001
<i>Setaria poiretiana</i> (Schult.) Kunth	0.00	0.01	0.01	70	0.03	0.002
<i>Millettia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	0.00	0.00	0.02	65	0.00	0.001
<i>Maesa lanceolata</i> Forssk.	0.03	0.01	0.00	45	0.06	0.008
<i>Allophylus abyssinicus</i> (Hochst.) Radlk.	0.01	0.02	0.04	40	0.03	0.014
<i>Hypoestes triflora</i> (Forssk.) Roem. & Schult.	0.01	0.00	0.00	38	0.01	0.005
<i>Phaulopsis imbricata</i> (Forssk.) Sweet	0.00	0.00	0.00	37	0.02	0.009
<i>Coffea arabica</i> L.	0.00	0.00	0.00	25	0.00	0.046
<i>Rubus niveus</i> Thunb.	0.00	0.00	0.00	22	0.00	0.047
<i>Chionanthus mildbraedii</i> (Gilg & Schellenb) Stearn	0.00	0.07	0.33	0.00	41	0.004
<i>Pouteria adolfi-friederici</i> (Engl.) Baehni	0.09	0.28	0.09	0.00	37	0.001

Signf. : $p = 0.001^{***}$; 0.01^{**} ; 0.05^{*}

4.1.3.2 Plant community-environment relationships

Redundancy Analysis (RDA) elucidated the relationships between plant community types and environmental factors (Fig. 12). The length of the two arrows indicates the strength of the influence of environmental variables (altitude and slope) on the distribution of species along environmental variables. Plots 19, 39 and 68 were correlated with altitude and slope. Characteristic species associated with these plots were *Apodytes dimidiata*, *Buddleja polystachya*, *Cassipourea malosana*, *Dombeya torrida*, and *Hypericum quatinianum*. The results revealed that the distribution of these species is influenced and significantly correlated with altitude and slope. Species in plots 34, 36 and 37 were negatively correlated with environmental variables. *Canthium oligocarpum*, *Chionanthes mildbraedii*, *Combretum paniculatum*, *Dracaena afromontana*, *Landolphia buchananii*, *Olea welwitschii*, *Pouteria adolfi-friederici* and *Vepris dainellii*. The ordination biplot displayed the three eigenvalues that measured the maximum separation (variation). The RDA eigenvalues (variance) for the first three axes were 7.6, 4.6, and 1.6, respectively. The first two RDA ordination axes together explained 12.2% of the total variation in species distribution (Table 5). Monte Carlo permutation tests revealed that altitude and slope significantly ($p < 0.001$) influenced the distribution of species. The result further showed that the influence of aspect on species the distribution in JWF was not significant (Table 6). Furthermore, the Mantel test based on Pearson's product-moment confirmed the existence of significant correlation ($r = 37$, $p < 0.001$) between species distribution and environmental variables.

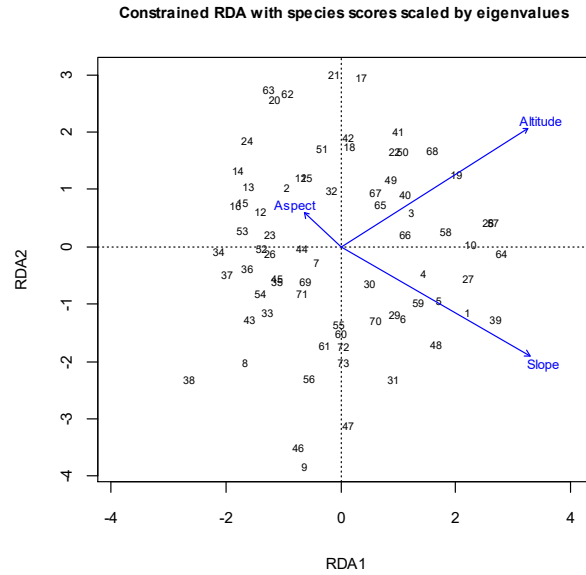


Figure 12 RDA ordination showing sites constrained by environmental variables

Table 5 RDA axis (eigenvalues) showing variations explained by environmental variables

	RDA1	RDA2	RDA3
Eigenvalues	7.687	4.558	1.596
Proportion Explained	0.555	0.329	0.115
Cumulative Proportion	0.555	0.885	1.000

Table 6 Environmental variables and their significance

Variables	Df	Sums of Sqs	Mean Sqs	F. Model	R ²	Pr (> F)
Slope	1	1.386	1.386	6.358	0.076	0.001 ***
Aspect	1	0.370	0.370	1.696	0.020	0.060 .
Altitude	1	1.399	1.399	6.414	0.077	0.001 ***
Residuals	69	15.045	0.218		0.827	

Signif. codes: 0.001 '***'

4.1.3.3 Species diversity in identified communities

The values of species richness, diversity, and evenness of each community were shown in Table 7. The overall species richness, diversity, and evenness were 125, 3.7, and 0.8, respectively. The mean value of species richness varied between 50 and 79. The highest species richness (79

species) was recorded in community I, while the lowest (50 species) was recorded in community V. Shannon diversity of plant communities varied between 3.15 and 3.57; evenness varied between 0.81 and 0.84. Analysis of variance (ANOVA) showed no significant variation in species richness ($p = 0.19, p > 0.05$) and Shannon diversity ($p = 0.07, p > 0.05$) between plots of community types, while evenness showed significant difference between plots of different community types. ($p = 0.02, p < 0.05$).

Table 7 Plant diversity in different plant communities

Community	Richness	H'	Shannon Evenness
I	79	3.57	0.82
II	61	3.34	0.81
III	52	3.15	0.82
IV	58	3.43	0.85
V	50	3.29	0.84

4.1.4 Diversity of medicinal and wild edible plants in JWF

The study found that JWF is home to a number of ethnobotanically useful plant species. The local people utilize these species for various livelihood needs. This study documented 102 species having medicinal and food values. These species belong to 54 families and 91 genera. Of the total, 79 species were medicinal, 12 were WEPs, and 11 species were both medicinal and WEPs (Appendix 4). The forms of these species were herbs (35 %), shrubs (33 %), trees (22 %) and lianas (11 %).

Assessment of medicinal and WEP species in sampled floristic plots identified a total 57 medicinal and/or edible plant species. In order to understand the stock and ecological roles of these species in the forest, floristic attributes (density, frequency basal area, importance value index) of woody medicinal and WEPs having dbh ≥ 2.5 cm were assessed and presented in Appendix 5.

The total density of medicinal and WEPs in sampled plots was 738.68 ha⁻¹, which comprise about 50% of total stem density in sampled plots. The frequency of medicinal and WEPs varied between 1.37-67.1%. The total basal area was 22.7 m² ha⁻¹, which comprises 36% of total basal areas of all woody species (dbh ≥ 2.5 cm) in sampled plots. The importance value index varied between 0.17- 23.6. The highest density, frequency, basal area, and importance value index (IVI) were recorded for *Syzygium guineense* subsp. *afromontanum*, *Chionanthus mildbraedii*, and *Croton macrostachyus* in descending order. These species are among the dominant species in JWF. The results further revealed that some medicinal and WEPs had significant ecological dominance and importance in JWF. Spearman correlation analysis was performed to investigate the correlation between ecological importance and cultural importance/use diversity of medicinal and WEPs in JWF. The analysis confirmed that there exist a strong correlation between the ecological importance value index (IVI) and cultural importance of medicinal and WEPs (Table 8). This revealed that species showing high IVI have also high cultural importance.

Table 8 Spearman's correlations between ecological importance and cultural importance

Importance values	CI	UV	IVI
CI	1.00		
UV	0.768**	1.00	
IVI	0.867**	0.885**	1.00

**significant at 0.001

Assessment of medicinal and WEPs across plant community types also found rich medicinal and WEPs. The richness of medicinal and WEPs was highest (34 species) in *Cyperus fischerianus* - *Apodytes dimidiata* (community I), followed by *Dracaena afromontana* - *Hippocratea pallens* (Community II) (with 29 species) and *Desmodium repandum* - *Cordia africana* (Community IV)

(with 27 species). The lowest richness was recorded in *Chionanthus mildbraedii* - *Pouteria adolfi-friederici* (community V) (with 20 species). Some of the medicinal plants and WEPs found in the plant communities are commonly found and distributed across most plant communities. These species include *Achyranthes aspera*, *Bersama abyssinica*, *Brucea antidysentrica*, *Croton macrostachyus*, *Embelia schimperi*, *Ficus sur*, *Millettia ferruginea*, *Syzygium guineense* subsp. *afromontanum* and *Vepris dainellii*. Others such as *Bidens macroptera*, *Buddleja polystachya*, *Ocimum urticifolium*, *Rubus apetalus*, and *R. niveus* were restricted to one or two plant community types (Table 9).

Table 9 Distribution of medicinal and WEPs having high use report and their community types

Scientific name	Use	Family	Habit	Community types
<i>Bersama abyssinica</i> Fresen.	M	Melanthiaceae	T	All community
<i>Brucea antidysentrica</i> J. F. Mill.	M	Simaroubaceae	Sh	All community
<i>Buddleja polystachya</i> Fresen.	M	Loganiaceae	Sh	I, V,
<i>Croton macrostachyus</i> Del.	M	Euphorbiaceae	T	All community
<i>Drymaria cordata</i> (L.) Schultes	M	Caryophyllaceae	H	I, II, III
<i>Ehretia cymosa</i> Thonn.	M	Boraginaceae	T	III, V
<i>Embelia schimperi</i> Vatke	FM	Myrsinaceae	Liana	I, II, III, V
<i>Ficus sur</i> Forssk.	F	Moraceae	T	I, II, IV
<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	M	Acanthaceae	Sh	I, II
<i>Maesa lanceolata</i> Forssk.	M	Myrsinaceae	Sh	I, III, IV
<i>Millettia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	M	Fabaceae	T	III, IV, V
<i>Ocimum urticifolium</i> Roth	M	Lamiaceae	Sh	II
<i>Rubus apetalus</i> Poir.	F	Rosaceae	Liana	IV
<i>Rubus niveus</i> Thunb.	F	Rosaceae	Liana	IV
<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>guineense</i>	FM	Myrtaceae	T	All community
<i>Vepris dainellii</i> (Pic. Serm.) Kokwaro	FM	Rutaceae	T	All community

4.1.5 Local people's perception towards the conservation of JWF

Participants of group discussions expressed that JWF is viewed as the main source of their livelihood needs. JWF is important not only to the villagers around the forest but also to the people found in the district because it is the source moisture and a favorable climate. The participants further expressed that JWF is the source of food, medicine, and water among other ecosystem services. In view of its importance, all interviewed informants have expressed their interest and willingness to safeguard the forest, which they inherited its management from their fathers. According to the participants, the forest has been protected by local communities from fire, illegal cutting of timber trees and encroachment (Fig. 13a-c).

Despite the community's conservation efforts, there are some illegal activities in the forest. Among these, cutting trees for timber and for making beehive resulted in the loss of mature trees. Trees such as *Cordia africana* and *Pouteria adolfi-friederici* have been selectively harvested for timber while *Olea welwitschii* has been fallen for its aromatic bark, which is used for making beehive. Moreover, there was expansion of coffee farms into the forest (Fig. 13a & b).

Efforts towards co-management of the forest

In view of conservation, the government (Oromia Forest and Wildlife Enterprise) and the community around the forest agreed to protect and manage the forest from anthropogenic and natural disturbance. The enterprise has demarcated the forest to implement the PFM. Accordingly, the forest parts were categorized into blocks of defined sizes. For example, on 10-20 ha, about 90-120 households were organized to manage the forest. As incentive, the enterprise agreed to develop infrastructure that can benefit the communities around the forest. Moreover, it had promised to create job opportunity to the local community. However, all interviewed

informants reported that there are claims from the people for lack of implementation of the agreement, which placed the issue of implementation of Participatory Forest Management (PFM) under question. Besides, some farmers claimed their farmlands that had become part of the forest during the previous regime. However, there was no timely response to the demands of local people from the government. These might restrain the full participation of local communities on the co-management of the forest and might negatively affect the ongoing conservation efforts.



Figure 13 Expansion of coffee farms (a & b) and timber extraction in the JWF (c)

4.2 Ethnobotanical study of medicinal plants

4.2.1 Medicinal plants and current usage status

The study found a total of 162 medicinal plant species belonging to 65 families and 135 genera. Of these, 71 (43.8%) medicinal plants were reported for treatment of human health problems, 58 (35.8%) for both human and livestock and 33 (20.4%) for only livestock health problems. The families with greater number of medicinal plants were Asteraceae Fabaceae Solanaceae and Lamiaceae in descending order. The highest proportion of the documented medicinal plants were herbaceous (77, 47.5%) in growth form followed by shrubs (45, 27.8%), trees (27, 16.7%) and lianas (13, 8%) growth forms.

In terms of usage, the majority (92%) of informants reported that they relied on both traditional and formal healthcare services. Some 8% of the informants reported that they use only modern medicine due to fear of side effects of medicinal plants. The diversity of reported medicinal plants and informants usage responses indicate that medicinal plants are still used by the majority of the rural population. However, about 54% of the informants perceived decreasing number of medicinal plant users; 30% have felt an increasing number of users; 13% have felt no change; some informants could not respond on the number of users over the years.

4.2.2 Medicinal plants for human health problems

4.2.2.1 Diversity and distribution

The ethnobotanical study found a total of 129 species belonging to 108 genera and 60 families that used for the treatment of human health problems. The families to which the highest number of medicinal plants belong were Asteraceae (21 species), Fabaceae (10 species), Solanaceae and

Lamiaceae (9 species each) (Fig. 14). The majority 41 (68%) of the families were represented by one species. Of the 129 species, 71 (55 %) medicinal plants were reported only for the treatment of human health problems, while the remaining 58 (45 %) were reported to treat both human and animal health problems. The documented medicinal plants comprise some species endemic to Ethiopia (Table 10).

Information on all documented medicinal plants, which includes the scientific names, local names, growth forms, plant parts used, treated health conditions and application of plant remedies are listed in (Appendix 6).

Table 10 Medicinal plants endemic to Ethiopia found in sampled KEBELES

Scientific name	Family name	Local name	Habits
<i>Amorphophallus gallaensis</i> (Engl.) N. E. Br.	Araceae	QICUU	H
<i>Crassocephalum macropappum</i> (Sch. Bip. ex A. Rich.) S. Moore	Asteraceae	QORICHA DHIITOO	H
<i>Echinops longisetus</i> A. Rich.	Asteraceae	QABARICHO	Sh
<i>Lippia adoensis</i> Hochst. ex Walp.	Verbenaceae	KUSAAAYEE	Sh
<i>Millettia ferruginea</i> (Hochst.) Bak.	Fabaceae	SOOTALLOO	T
<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Asteraceae	TIMBATIMBO	Sh

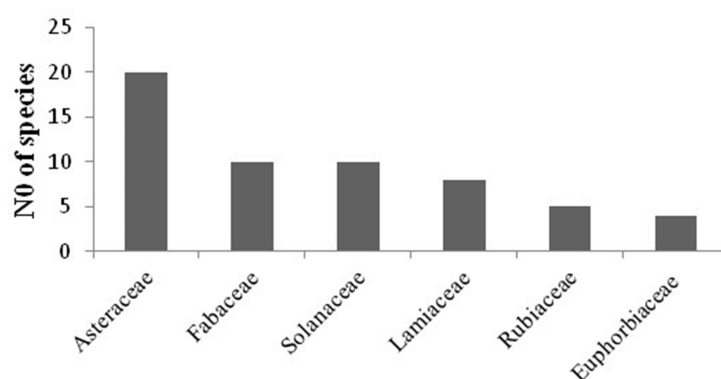


Figure 14 Families with the highest number of medicinal species

According to informants, the recorded medicinal plants were found in different habitat types. These include forest, farmlands/borders, woodland, pasturelands, and reverine habitats. The altitudinal ranges of the habitats were between 1600 m to 2400 m (a.s.l). A greater number of the medicinal plants were gathered from habitats found between 2000-2200 m (a.s.l). It was also noted that many of the species were reported in more than one habitat within these altitudinal ranges. The habitats harboring the highest proportion of medicinal plants were forests (34%), followed by farmlands/borders (33%), roadsides (10%) and homegardens (9%) (Fig. 15). Some of the species were commonly reported for more than one habitats. These include *Ageratum conyzoides*, *Bersama abyssinica*, *Croton macrostachyus*, *Justicia schimperiana* and *Salvia nilotica*. These species have shown a broader range of altitudinal distributions. Species such as *Capparis tomentosa*, *Combretum molle*, *Echinops amplexicaulis*, *Securidaca longepedunculata*, *Stereospermum kunthianum*, *Warburgia ugandensis*, and *Ximenia americana*, were found in woodlands. These species were reported more frequently by informants found in lower altitudes in *Comberetum-Terminalia* woodland vegetation. Very few species such as *Adiantum poiretii*, *Chionanthus mildbraedii*, *Cyperus fischerianus*, *Galiniera saxifraga*, *Pavetta oliveriana*, and *Vepris dainellii* have been found in forest habitats.

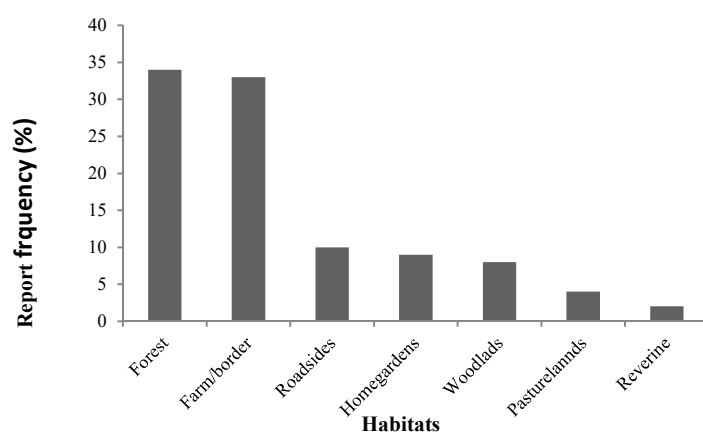


Figure 15 Proportion of medicinal plants habitats

4.2.2.2 Growth forms and parts used as medicine

Herbs make up the highest proportion 65 (50%) of the growth forms of medicinal plants used for treatment of human health problems, followed by shrubs 33 (25.6%), trees 20 (15.5%) and lianas 11 (8.5%). Medicinal plant parts used for the preparation of remedies were leaves, roots, barks, fruits, flowers, seeds, stems and above ground parts. However, 51% of the informants reported the use of leaves for herbal preparations followed by roots 28% (Fig. 16).

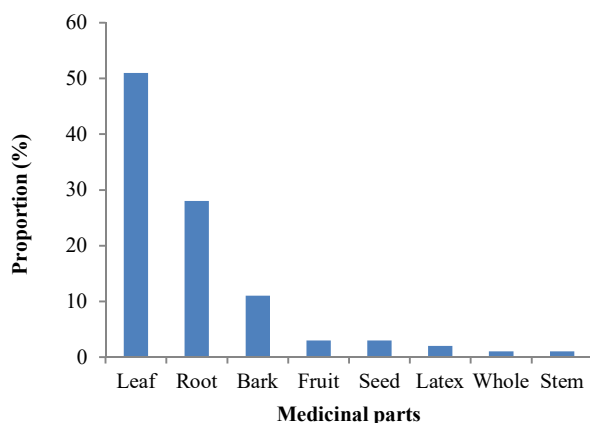


Figure 16 Proportion of medicinal plant parts used as remedies for human health problems

4.2.2.3 Human health problems and medicinal plants usage consensus

The local communities in the study area have been confronted with various health problems. Most of these health problems have been reported to be treated using medicinal plants alongside of conventional medicine. The health problems commonly treated by medicinal plants were stomachache, snakebites, rabies, migraine, fever, febrile and wounds. In total, 45 human health problems were treated using medicinal plants. Detail applications of the plant remedies are indicated in Appendix 6. These were grouped into eleven major categories based on affected organs or features of the health problems. The number of health problems grouped under each

category ranged from 2 to 8 health problems. The number of medicinal plants reported for the treatment of the above-mentioned health problem ranged from 3 to 47 species. The highest number of taxa (47 species) and usage reports was reported for category of neurological health problems and the lowest number of taxa (3 species) was reported for category of reproductive health problems. The level of informants' agreement on medicinal plant use for each health problem category was determined using the factor of informant consensus (*Fic*). The highest *Fic* values suggests high agreements on medicinal plants reported for skeletal (*Fic* = 0.95) and gastrointestinal (*Fic* = 0.92) health problem categories (Table 11). The high reports and consensus values might also indicate a high prevalence of the health problems in the study area.

Table 11 Major human health problem categories and factor of informant consensus values

Health problem categories	N0 of health problems/conditions	Report frequency (<i>Nur</i>)	N0 taxa (<i>Nt</i>)	Nur-1	Nur-Nt	Fic
Skeletal (broken bone, swelling of leg, backache)	3	59	4	58	55	0.95
Gastrointestinal (stomachache, diarrhea, amoebiasis, bloat, vomit)	4	194	16	193	178	0.92
Neurological (migraine, rabies, epilepsy, evil spirit, evil eye, circling sickness)	6	336	47	335	289	0.86
Worms (taeniasis, worms, leech)	3	25	5	24	20	0.83
General malaise (fever, febrile, sudden illness, malaria, swellings)	5	136	28	135	108	0.80
Dermatological health problems (bleeding wound, dandruff, hemorrhoids, fire burn, ectoparasite, sore, tinea corporis, wart)	8	120	25	119	95	0.80
Auricular, dental, neck and optical health problems (toothache, meningitis, stabbing of ear and eye health problems)	4	150	33	149	117	0.79
Antidote (poisonous, snakebite, spider poison)	3	110	25	109	85	0.78
Liver and kidney (jaundice, kidney problem)	2	18	5	17	13	0.76
Reproductive health problems (Menstruation, gonorrhea)	2	9	3	8	6	0.75
Respiratory, burning in chest and throatic problem (cough, influenza, chest burn, persistent cough, tonsillitis)	5	39	13	38	26	0.68

Specific human health problems showing the highest number of medicinal plant use report were rabies, stomachache, migraine, febrile, toothache, and bleeding wound. These health problems have shown the highest report and informant consensus (Table 12) indicating more agreement on the use of medicinal plants reported for these problems and also indicates the higher occurrence of these health problems.

Table 12 Top ten common health problems with the highest report and informant consensus values

Health problems	Nur	Nt	Nur-1	Nur - Nt	Fic
Bone fracture	49	1	48	48	1.00
Stomachache	177	11	176	166	0.94
Rabies	187	18	186	169	0.91
Bleeding wound	63	8	62	55	0.89
Migraine	120	16	119	104	0.87
Febrile	110	15	109	95	0.87
Circling sickness	44	6	43	38	0.88
Toothache	106	20	105	86	0.82
Snakebite	70	13	69	57	0.83
Spider poison	57	11	56	46	0.82

The specific health problems were treated using different number of medicinal plants. Health problems treated with the highest number of medicinal plants were toothache (20 species), followed by rabies (18 species), migraine (16 species) and febrile (15 species). The results further show that the use of many different medicinal plants for the same health problems by the same or different informant(s) might show the presence of medicinal plants knowledge richness in the area. This richness helps local people to use alternative medicinal plants, which might reduce harvesting pressure or dependence on single species. However, the results revealed that medicinal plants use report frequencies and consensus vary among the reported species. *Pentas schimperiana* was reported for bone fracture ($Fic = 1.00$) and $FL = 100\%$. It is the only

medicinal plant used widely for maintenance of bone fracture. *Ehretia cymosa* and *Loxogramme abyssinica* had shown the highest consensus values for treatment of toothache. *Phytolacca dodecandra* had shown the highest consensus value for treatment of rabies, followed by *Datura stramonium*, *Justicia schimperiana* and *Dracaena steudneri*. *Ocimum lamiifolium* and *Echinops longisetus* had shown the highest informant consensus for treatment of migraine (Table 13).

Table 13 Ethnomedicinal plants with high fidelity values on specific health problems

Specific health problem	Medicinal plant	Np	N	FL (%)
Toothache	<i>Ehretia cymosa</i> Thonn.	18	18	100
Bone fracture	<i>Pentas schimperiana</i> (A. Rich.) Vatke	49	49	100
Toothache	<i>Loxogramme abyssinica</i> (Baker) M. G. Price	17	18	94
Febrile	<i>Ocimum urticifolium</i> Roth	32	37	86
Migraine	<i>Ocimum lamiifolium</i> Hochst. ex Benth.	49	57	86
Rabies	<i>Phytolacca dodecandra</i> L'Hérit.	36	43	84
Migraine	<i>Echinops longisetus</i> A. Rich.	57	70	81
Rabies	<i>Datura stramonium</i> L.	17	21	81
Stomachache	<i>Clerodendrum myricoides</i> (Hochst.) Vatke	15	19	79
Febrile	<i>Salvia nilotica</i> Jacq.	18	23	78
Stomachache	<i>Securidaca longepedunculata</i> Fresen.	16	21	76
Taeniasis	<i>Embelia schimperi</i> Vatke	13	17	76
Bleeding wound	<i>Croton macrostachyus</i> Del.	63	84	75
Rabies	<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	22	33	67
Rabies	<i>Dracaena steudneri</i> Engler	31	52	60

Some medicinal plants have multiple therapeutic values. Medicinal plants with the highest number of therapeutic uses were *Echinops longisetus* (eight uses), followed by *Croton macrostachyus* and *Capparis tomentosa* (seven uses each).

4.2.2.4 Dosage forms and application of remedies

The remedies used for treatment were prepared from fresh (64%), dried or fresh (34%) and dried (2%) medicinal plant materials. According to informants, fresh plant parts are more potent in healing than dried materials. Drying might reduce or affect the content of bioactive compounds in medicinal plants. Such information needs further investigation on the effect of drying on bioactive content of the plants. Dried medicinal plants were used rarely for scarce medicinal plants, which were not locally available or which were applied by smoke/or fumigation. It was found that most (87%) of the remedies were prepared from single species or plant part. In many cases, more than one plant parts of the same species were used in preparation of different remedies. The remedies were processed and applied in various forms depending on the types of health problems. These include juice or sap and aroma from crushed/smashed/ rubbed/chewed parts, infusion/liquid extract, concoction, heating plant parts, smoking, steam bath, and latex. The quantity of remedies varied depending on the treated health problems and age of users. There were no standardized measurements for measuring dosage. However, traditionally informants estimate the required amounts using spoon and cup (full, half or one fourth of a cup), depending on the age, the physical condition of the users, and the type of treated health problems.

The most common mode (44%) of application of the remedies was drinking, followed by crushing/smashing and inhaling or adding drops (14%). Smoke inhalation and steam bath were the least reported methods of remedy applications (Fig. 17). Remedies such as infusions, concoctions, chewing and swallowing juice were, generally reported for internal health problems and bone fracture. Crushed remedies were applied on a bleeding wound, fire burns, and other dermatological problems. Steam baths and smoke inhalations were applied for fever, migraine,

and toothache. The major ingredients used for the preparation of remedies were, largely salt followed by, butter, coffee, milk, honey, garlic and ginger. Other ingredients used rarely included barley soup, sugar, pancake, lumen, yoghurt, hot pepper, vaseline, sugar cane, and ash. The use of these additive substances in herbal remedies is believed either to reduce adverse effects or to improve the flavor of the remedies or to enhance the healing potential of the remedies.

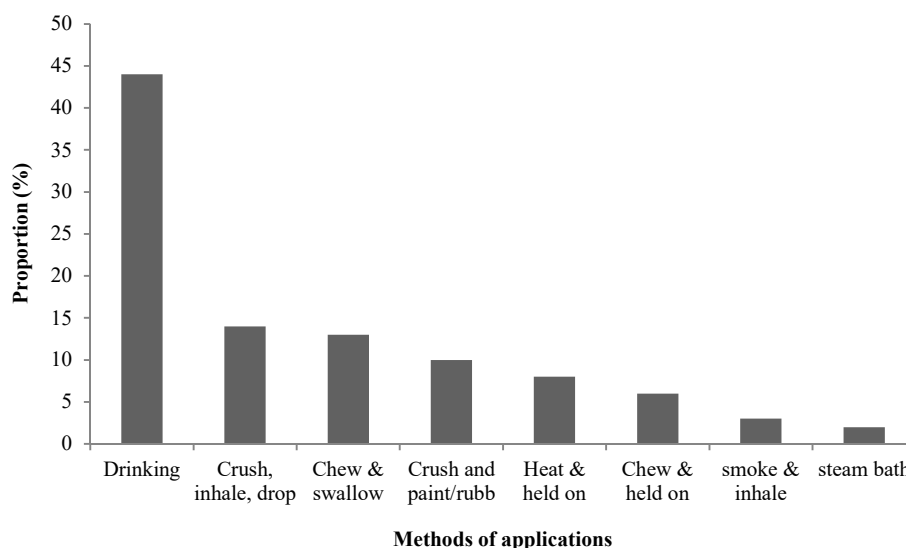


Figure 17 Mode of applications of remedies

The remedies used for various internal and external health problems were administered through different routes. Most of the preparations (60%) were prescribed orally, followed by nasal (16%), dermal (15%), optical (6%), and auricular (3%) applications. Remedies were taken once for most of the health problems while for some such as dandruff, epilepsy, gonorrhea, hemorrhoid, persistent cough, spider poison, and tinea corporis, it was taken until the health conditions improved.

4.2.3 Ethnoveterinary plants and usage

4.2.3.1 Diversity of ethnoveterinary plants

A total of 91 medicinal plants belonging to 84 genera and 49 families were documented as useful in the treatment of various livestock health problems. Of the 91 medicinal plants, 58 (64%) were employed for both human and livestock, while 33 (35.5%) species were used for the treatment of only livestock health problems. Since many species were used for both human and animal health problems, the species-rich families were more or less similar (Fig. 18). Asteraceae, Fabaceae, Euphorbiaceae, and Rubiaceae together contributed 33% species to the total ethnoveterinary plant species. The majority (32, 65%) of the families were represented by one species. Ethnoveterinary medicinal plants and their applications for management of animal health problems are presented in Appendix 7

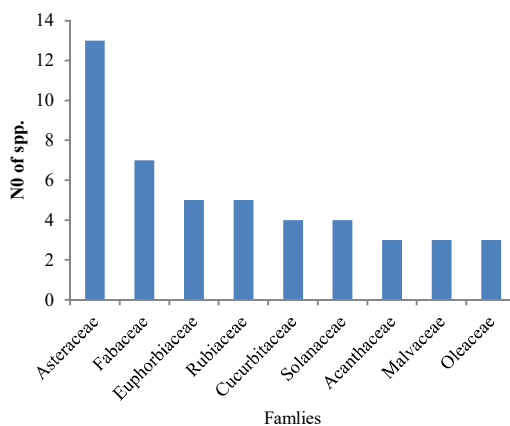


Figure 18 Families having high proportion of ethnoveterinary plants

The habitat and altitudinal distributions of ethnoveterinary medicinal plants are more or less similar to those medicinal plants reported for human use. Forest/forest margin, farm/borders, and homegardens were the most commonly reported habitats of ethnoveterinary plants. Most of the ethnoveterinary medicinal plants were also found between 2000-2200 masl altitudinal ranges.

4.2.3.2 Growth forms and parts used as medicine

As in the case of ethnomedicinal plants, the ethnoveterinary medicinal plants were composed of largely (40, 44%) by herbs, followed by shrubs (22, 24%) and trees (19, 20.9%) and lianas 10 (11%). The most commonly used ethnoveterinary plant part was roots (45, 38%), followed by leaves (39, 33%), and barks (19, 16%) (Fig. 19).

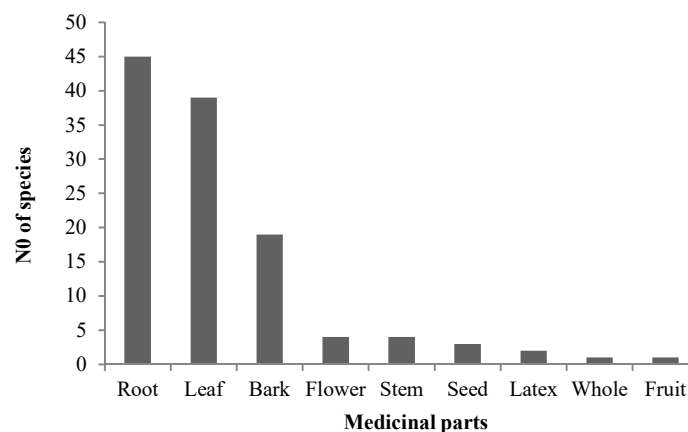


Figure 19 Proportion of ethnoveterinary medicinal plant parts

4.2.3.3 Livestock health problems and medicinal plants usage consensus

The study has identified a total of 31 health problems affecting domestic animals in the study area. Of these, 18 (58 %) were affecting only cattle, while the remaining 13 (42%) were affecting different animals including cattle, sheep, equines, and dogs. The health problems were grouped into eleven health problem categories. These were skeletal health problems, neurological, antidote, general malaise, optical, dermal, gastrointestinal, liver case, worms, reproductive and respiratory health problems. These categories encompass one to eight specific health problems. The health problem category with more number of specific health problems was general malaise

(8 health problems). The highest medicinal use was reported for general malaise, followed by neurological, antidote, and skeletal health problems. The factor of informant consensus (*Fic*) values of the ethnoveterinary health problem categories ranged between 0.53 and 0.96. Medicinal plants reported for skeletal category showed the highest factor of informant consensus values (*Fic* = 0.96). Optical and neurological also showed high medicinal plants use report and high factor of informant consensus (Table 14). The highest factor of informant consensus values suggest more agreement on the use of medicinal plants reported for these major health problem categories. Furthermore, the highest *Fic* values might suggest more prevalence of these health problems in the study area.

Table 14 Major animal health problem categories and factor of informant consensus

Major categories	N0 of health problems	N _t	N _{ur}	Nur-1	N _{ur} -N _t	Fic
Skeletal	2	3	55	54	52	0.96
Optical	1	4	29	28	25	0.89
Neurological	2	26	195	194	169	0.87
General malaise	8	55	235	234	180	0.77
Antidote	1	18	70	69	52	0.75
Dermal	2	6	18	17	12	0.71
Gastrointestinal	4	6	17	16	11	0.69
Liver case	1	3	6	5	3	0.60
Reproductive	5	13	31	30	18	0.60
worms	2	4	8	7	4	0.57
Respiratory	3	9	18	17	9	0.53

The results revealed that the health problems were treated using diverse medicinal plants. A high proportion of ethnoveterinary plants were reported for general malaise (55 species), followed by neurological category (26 species) and antidote (18 species) (Fig. 20). These results suggested that people in different localities might experiment different medicinal plants against a common health problems and acquired medicinal knowledge on different species.

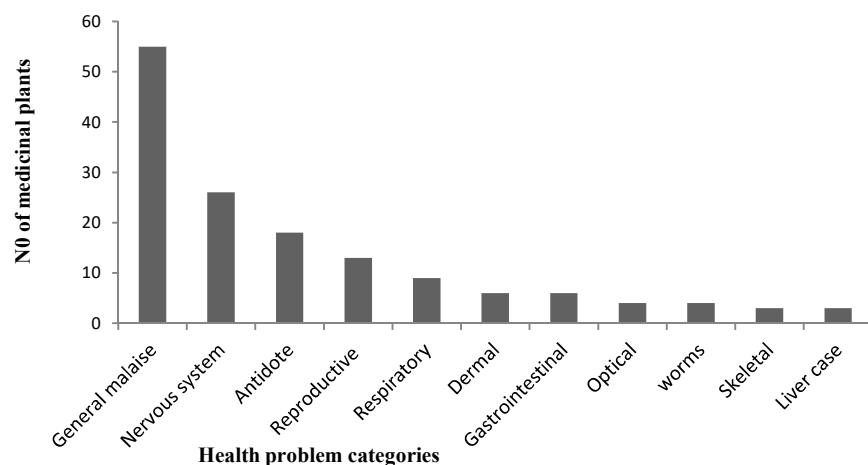


Figure 20 Proportion of ethnoveterinary plant species used for major health problem categories

Some of the specific health problems in each major category showed high medicinal plants use report and hence showed high factor of informant consensus (Table 15). The highest ethnoveterinary plant uses were reported for bone fracture, eye problem, rabies, babesiosis, and snakebite indicating high agreement on the use of reported medicinal plants. These health problems were treated using a number of different medicinal plants.

Table 15 Specific health problems with high factor of informant consensus

Health problem	Major categories	N_t	N_{ur}	$N_{ur}-1$	$N_{ur}-N_t$	<i>Fic</i>
Bone fracture	Skeletal	1	49	48	48	1.00
Eye problem	Optical	4	29	28	25	0.89
Rabies	Neurological	23	187	186	164	0.88
Babesiosis	General	13	82	81	69	0.85
Blackleg	General	16	58	57	42	0.74
Snakebite	Antidote	18	67	66	49	0.74

Of the reported ethnoveterinary plants, some were more known for the treatment of certain health problems and showed high usage consensus. Informant consensus analysis revealed a high

informant consensus on the use of *Buddleja polystachya* (FL = 100%) for treatment eye problem in cattle and *Pentas schimperiana* (FL = 100%) for the treatment of broken bone. Two species, *Mucuna melanocarpa* (FL= 91%) and *Piper capense* (FL= 83%) showed high informant consensus for the treatment of emaciation. Similarly, three species, *Phytolacca dodecandra* (FL= 84%), *Datura stramonium* (FL= 81%) and *Justicia schimperiana* (FL= 67%) showed high informant consensus values for the treatment of rabies (Table 16).

Table 16 Fidelity level values of ethnoveterinary plants commonly reported against specific health problems

Scientific name	Diseases treated	N0 of report	Total report frequency	FL (%)
<i>Buddleja polystachya</i>	Eye disease	20	20	100
<i>Schefflera abyssinica</i>	Blackleg	11	11	100
<i>Mucuna melanocarpa</i>	Emaciation	20	22	91
<i>Phytolacca dodecandra</i>	Rabies	36	43	84
<i>Piper capense</i>	Emaciation	10	12	83
<i>Datura stramonium</i>	Rabies	17	21	81
<i>Justicia schimperiana</i>	Rabies	22	33	67

The results further revealed that of the total 91 species, 58 (64%) had single therapeutic values while 33 (36%) had multiple or more than one therapeutic values (Fig. 21). Ethnoveterinary plants with more than three therapeutic use reports were *Dracaena steudneri* with four therapeutic uses, followed by *Albizia schimperiana*, and *Croton macrostachyus* with three therapeutic uses each.

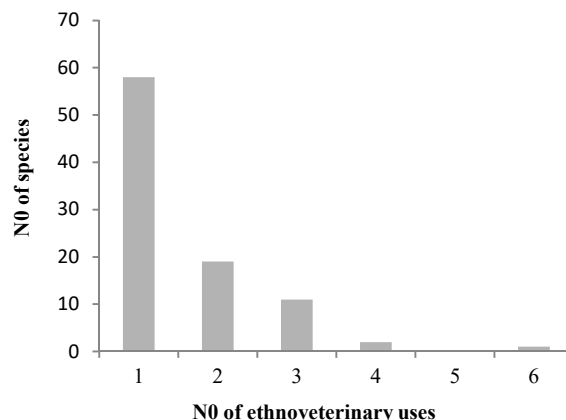


Figure 21 Proportion of ethnoveterinary plants and number of therapeutic uses

4.2.3.4 Preparations of remedies and routes of applications

The preparation of remedies and dosage depends on the type of health problems being treated. The greater proportion (62%) of the ethnoveterinary plant remedies were prepared from fresh plant materials, while 38% were prepared from either fresh or dried materials. Remedies were prepared, mainly by crushing and soaking in water in the form of infusion (57%), followed by concoction (30%), sap or juice (12%) and latex (1%). For health problems such as wound and sore, remedies were crushed and tied on or painted on affected part/organ. The dosages of ethnoveterinary remedies were estimated using plastic bottle for internal health problems. Accordingly, one-third, half or full plastic bottle is measured before applications. The most (82%) frequent method of application of remedies was drenching, followed by dropping (7%), painting or tie on (6%), and feeding (5%). The ethnoveterinary remedies were drenched or fed and applied largely (90%) through mouth. Nasal (5%), dermal (3%) and optical (2%) were the least routes used for application of remedies.

4.2.4 Ethnobotanical knowledge on medicinal plants

The study found a rich ethnobotanical knowledge about the use of medicinal plants in the study area. Evidently, the present study documented a great diversity of medicinal plants used for human and veterinary healthcare. The interviewed informants reported that medicinal plants are part of their culture. The ethnomedicinal knowledge and associated healing practices have been maintained and held among local communities. The majority (90%) of informants reported that they learned the medicinal use of certain plants from their own families. Few informants mentioned that they also learned from neighbors and friends. Two traditional healers additionally reported that they were able to learn from morphological appearance plants. For example, one of the two healers acquired therapeutic value of *Plantago palmata* from resemblance of its leaves with one of snake varieties locally known as 'BUTI'. Mature leaves of *Plantago palmata* have many spots on it and resemble BUTI (spotted snake). Another healer reported that he acquired therapeutic value of *Dregea schimperi*, from its shape, which resembles another snake variety locally known as 'MARATA'.

The study further assessed the distribution of knowledge of medicinal plants among social and geographic variables and found a significant variation among some of the variables. Accordingly, the numbers of medicinal plants known and reported by male and female informants was significantly ($p < 0.01$) different indicating the effect of gender on possession of knowledge of medicinal plants (Table 17). Similarly, healers knew significantly more medicinal plant species ($p < 0.01$) than non-healers. The results further showed that there were significant variations in knowledge among age groups of informants. ANOVA revealed a significant ($p < 0.01$) difference between informants below and above 25 years old. Older informants (> 25 years) tend to know more medicinal plants and their uses than younger informants, indicating a

positive correlation between age and medicinal plant knowledge. Similarly, the study found significant knowledge variation ($p < 0.01$) between informant residing closest forest and those far away from forest. On the other hand, the study found an insignificant difference ($p = 0.30$, $p > 0.05$) in medicinal plant knowledge between informants who attended and who not attend formal education. Similarly, there was no statistically significant difference in medicinal plant knowledge ($p = 0.32$, $p > 0.05$) between informants residing closer to formal health centers and those found far away from the centers. An insignificant variation ($p = 0.23$; $p > 0.05$) was also found among informants residing in different agroecological zones. These results suggest that possession of medicinal plant knowledge in the study area was not correlated with accessibility to formal health centers or formal education and agroecological settlement. In sum, the study found that gender, healing profession, age, and proximity to forest had a significant contribution to variation in knowledge of medicinal plants.

Table 17 Medicinal plant knowledge variables and level of significance

Variables		Mean reported MPs	P-value
Gender	Male	8.89 ± 0.44	$p < 0.00$; $p < 0.01$
	Female	6.09 ± 0.37	
Experience	Healer	10.34 ± 0.58	$p < 0.00$; $p < 0.01$
	Non-healer	6.44 ± 0.32	
Age	< 25 year old	5.06 ± 0.38	$p < 0.00$; $p < 0.01$
	between 25 ≤ 50 years	8.97 ± 0.45	
	> 50 years	9.80 ± 0.83	
Education	Formal education	7.70 ± 0.43	$p = 0.30$
	no formal education	8.40 ± 0.48	
Distance from health center	≤ 1 hr walk	7.61 ± 0.49	$p = 0.32$; $p > 0.05$
	> 1 hr walk	8.25 ± 0.44	
Distance from forest	≤ 2 hr walk	9.15 ± 0.48	$p < 0.001$; $p < 0.01$
	> 2 hr walk	7.02 ± 0.43	
Agroecology	Lowlands	8.02 ± 0.74	$p = 0.23$; $p > 0.05$
	Midlands	7.47 ± 0.47	
	Highlands	8.76 ± 0.57	

Sig. code: $p < 0.01^{**}$, 0.05^{*}

Multiple linear regression analysis identified age, healing profession, gender, and proximity to JWF as predictor variables of medicinal plant knowledge possession. The analysis revealed that these predictor variables together accounted for 34.7% ($R^2 = 0.347$) of the total variation in medicinal plant knowledge possession among informants (Table 18).

Table 18 Multiple Linear Regression indicating the effect of age, healing profession, proximity to JWF, and gender on possession of medicinal plant knowledge

Model	ANOVA				
R^2	Sum of Squares	df	Mean Square	F-value	p-value
0.172	2.595	1	2.595	44.114	0.000 ^a
0.276	4.183	2	2.091	40.676	0.000 ^b
0.317	4.823	3	1.608	33.121	0.000 ^c
0.347	5.307	4	1.327	28.594	0.000 ^d

Predictors (R^2): a = age; b.= age & healing profession ; c= age, healing profession & proximity to JWF; d.=all (age, healing profession & proximity to JWF, gender)

4.2.5 Medicinal plant use similarity

The number of medicinal plants reported in the study sites varies between 46 and 75 species. The study found many commonly known and used medicinal plants. Medicinal plants use similarity index among the study sites varied between 0.31 and 0.70. The highest use similarity was found between Siba Silase and Aarbu Abagada ($S_s = 0.70$) which reflect the presence of many shared medicinal plants between the two sites. The least similarity observed between Shimala Illu and Aydobi ($S_s = 0.31$), which indicates a low number of shared medicinal plants (Table 19). The highest similarities found between study sites/KEBELEs, which are geographically located closer to each other and which have similar agroecological settings or environments. These are sites shared borders with JWF, which is the source of about 50% of medicinal plants reported in this study. Furthermore, geographic proximity might create a greater opportunity for the exchange of medicinal plant knowledge through various social networks. Medicinal plants shared commonly

among most of the study sites were *Brucea antidysentrica*, *Capparis tomentosa*, *Croton macrostachyus*, *Datura stramonium*, *Dracaena steudneri*, *Drymaria cordata*, *Justicia schimperiana*, *Ocimum lamiifolium*, and *O. urticifolium*.

Table 19 Sorensen's similarity index showing medicinal plants use similarity among study KEBELEs

	AB	AD	AL	DQ	GR	AA	HC	HT	SD	SI	SK
AD	0.48										
AL	0.50	0.51									
DQ	0.55	0.55	0.56								
GR	0.56	0.54	0.59	0.64							
AA	0.47	0.47	0.56	0.60	0.59						
HC	0.48	0.50	0.45	0.53	0.55	0.48					
HT	0.51	0.49	0.53	0.55	0.50	0.53	0.39				
SD	0.59	0.52	0.55	0.62	0.67	0.57	0.58	0.55			
SI	0.32	0.31	0.37	0.37	0.35	0.41	0.51	0.33	0.42		
SK	0.42	0.38	0.50	0.47	0.47	0.67	0.46	0.41	0.49	0.40	
SS	0.46	0.50	0.56	0.58	0.62	0.70	0.58	0.56	0.62	0.49	0.56

NB: (AB = Aybeda; AD = Aydobi; AL = Aleku; DQ = Didu Qoce; GR = Gaba Robi; AA = Aarbu Abagada; HC = Haro Coroqa; HT = Haro Tumsa; SD = Siba Dalo; SI = Shimela Ilu; SK = Siba Kopi; SS = Siba Silase)

4.2.6 Medicinal plant market

The study found a few medicinal plants sold at marketplaces. According to interviewed informants, the tradition of selling plants as medicine is less common. The availability and accessibility of traditional healers around rural village residential areas might have contributed to the lack of market for selling medicinal plants. The commonly reported marketable medicinal plants were *Piper capense*, *Olea europaea* subsp. *cuspidata* (stem and bark) (bark) (Fig. 22a, b) and *Echinops longisetus* (root). Market surveys have also found the sale of ethnoveterinary remedies prepared from *Schefflera abyssinica*, *Stereospermum kunthianum* and *Brucea antidysentrica* for treatment of trypanosomiasis, diarrhea, and skin diseases (Fig. 22c). According to the vendor, the price of his remedies was not attractive (not more than five ETB)

per prescription. On the other hand, the sale of *Echinops longisetus* has declined due to over-exploitation and loss of the species.



Figure 22 Medicinal plants sold at Bube marketplace

(a. *Olea europaea* subsp. *cuspidata*, b. *Piper capense*, c. remedies prepared from *Schefflera abyssinica*, *Stereospermum kunthianum*, *Brucea antidysentrica*) (Photo by Kebu Balemie, Oct. 2015)

4.2.7 Use diversity of medicinal plants

Medicinal plants are an important source of subsistence and raw material to various domestic uses. The study found that medicinal plants in the study area were used to support a wide range of livelihoods, and particularly as a source of food, timber, fuel, fodder and other services to the local communities. Of the total 162 medicinal plants (human and veterinary), 128 (79%) species have a range of multiple values to local communities. They have been the source of firewood, construction, food, forage, and a number of other material cultures to rural communities. From the use value analysis, a total of 14 non-medicinal use categories were documented (forage, fuel wood, shade, construction and crafts, farm implements, household utensils, food, rope, rituals, beehive, fattening, fragrance, soap, beverage). The number of uses per species ranged from 1-8, with an average number of two uses per species. The species with the highest use diversity were *Cordia africana*, *Phytolacca dodecandra*, *Syzygium guineense* subsp. *afromontanum*, *Croton macrostachyus*, *Olea europaea*, and *Pittosporum*, each with eight uses.

The contribution of medicinal plants to various use categories varies among the use categories. From the use value analysis, medicinal plants have shown the highest contribution to forage value (28%), followed by fuel wood (21%), shade (15%) and construction and crafts (11%), while the remaining (25%) contribution was shared among other uses (farm implements, household utensils, food, rope, rituals, beehive, fattening, fragrance, soap, beverage). Figure 23 depicted the relative contributions of medicinal plants to the major use categories. The highest contribution of medicinal plants to forage was because this use category includes bee forage, which includes many flowering plants. Similarly, the higher contribution of medicinal plants to fuel wood, construction and crafting might be due to the fact that these categories of use involve the use of all woody plants.

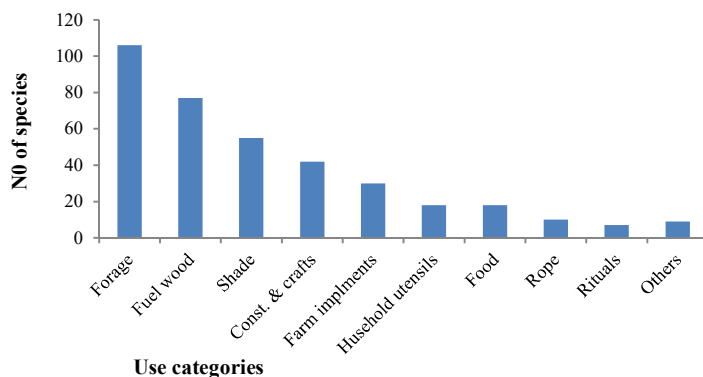


Figure 23 Contribution of medicinal plants to different ethnobotanical use categories

The cultural importance index (CI) and the use-value (UV) of top 29 medicinal plants having over five use categories were determined using cultural importance and use-value indices (Table 20). The cultural importance values ranged from 0.06 to 4.1. It shows the relative contribution of each species to different use categories. Similarly, the use-values of medicinal plants varied between 0.05 and 3.78. The most culturally important medicinal plants that had the highest

cultural importance index and use-values was *Syzygium guineense* subsp. *afromontanum* (CI = 4.13, UV = 3.78). The timber of *S. guineense* subsp. *afromontanum* is mainly used for technology and craft (CI = 1.85) or as firewood (CI = 0.70) than for medicinal value (CI = 0.02). This means *S. guineense* subsp. *afromontanum* is known to a few respondents as medicine and hence their lower cultural importance for medicinal value. The second culturally important and useful species was *Croton macrostachyus* (CI = 1.67, UV= 1.42). This species has frequently been reported as fuel wood, shade tree, and bee forage. The species with the highest CI and UV are the most important socially as it comprises the greatest number of use values. The species with the highest CI and UV were woody species (trees, shrubs) in growth forms. Generally, the results confirmed that medicinal plants provide not only healthcare services but also many additional social and ecological values. The diversity of uses or values might reflect the diversity of ethnobotanical knowledge. These values might help in understanding local plant resource use, which in turn help for sustainable use planning.

Table 20 Cultural importance and use diversity of medicinal plants with more than five use categories

Scientific name	Local name	Cons	FW	Health	Shade	Forage	Others	CI	UV
<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>afromontanum</i> F. White	BADESSA	1.85	0.70	0.02	0.64	0.02	0.89	4.13	3.78
<i>Croton macrostachyus</i> Del.	BAKANIISA	0.16	0.32	0.35	0.29	0.27	0.28	1.67	1.42
<i>Carissa spinarum</i> L.	AGAMSA	0.00	0.02	0.05	0.02	0.02	0.48	0.59	0.52
<i>Justiscia shimperiana</i> Hochst. ex Nees) T. Anders.	DHUMUGAA	0.06	0.17	0.17	0.05	0.06	0.04	0.57	0.40
<i>Brucea antidysenterica</i> J. F. Mill.	QOMANYOO	0.04	0.13	0.17	0.06	0.08	0.00	0.49	0.34
<i>Phytolacca dodecandra</i> L'Hérit.	ANDODE	0.01	0.03	0.19	0.04	0.03	0.12	0.42	0.34
<i>Ehretia cymosa</i> Thonn.	ULAAGAA	0.05	0.07	0.09	0.07	0.04	0.08	0.40	0.31
<i>Warburgia ugandensis</i> Sprague	BIFTII	0.05	0.09	0.10	0.06	0.05	0.02	0.36	0.26
<i>Ocimum urticifolium</i> Roth	ANCABII/HA NCABII	0.02	0.10	0.13	0.01	0.06	0.02	0.33	0.21
<i>Cordia africana</i> Lam.	WADDEESSA	0.02	0.01	0.02	0.01	0.00	0.23	0.31	0.11
<i>Securidaca longepedunculata</i> Fresen.	XABANA'II	0.02	0.08	0.08	0.04	0.04	0.03	0.29	0.23
<i>Albizia schimperiana</i> Oliv.	MUKA ARBAA	0.05	0.05	0.05	0.04	0.03	0.04	0.26	0.21

<i>Trichilia dregeana</i> Sond.	UUYA	0.03	0.04	0.06	0.04	0.03	0.04	0.24	0.20
<i>Cassipourea malosana</i> (Baker) Alston	LOKO	0.16	0.02	0.02	0.01	0.01	0.01	0.23	0.05
<i>Ximenia americana</i> L.	HUDHA	0.01	0.05	0.06	0.03	0.04	0.04	0.22	0.16
<i>Bersama abyssinica</i> Fresen.	LOLCHIISAA	0.04	0.06	0.06	0.03	0.02	0.01	0.22	0.16
<i>Pittosporum viridiflorum</i> Sims	SOLEE	0.01	0.04	0.05	0.04	0.05	0.03	0.22	0.16
<i>Olea europaea</i> L.	EJERSA	0.04	0.05	0.04	0.05	0.01	0.03	0.22	0.18
<i>Schefflera abyssinica</i> (Hochst. ex A. Rich.) Harms	GATAMA	0.03	0.06	0.03	0.00	0.05	0.03	0.21	0.29
<i>Prunus africana</i> (Hook. f.) Kalkm.	HOMII	0.04	0.04	0.06	0.03	0.01	0.03	0.20	0.24
<i>Vernonia auriculifera</i>	REEJJII BADDAA	0.00	0.06	0.08	0.02	0.03	0.01	0.20	0.12
<i>Podocarpus falcatus</i> (Thunb.) R. B. ex. Mirb.	BIRBIRSA	0.04	0.03	0.04	0.03	0.01	0.04	0.19	0.15
<i>Maesa lanceolata</i> Forssk.	ABAYII	0.02	0.04	0.05	0.03	0.02	0.03	0.19	0.14
<i>Entada africana</i> Guill. & Perr.	AMBALTA	0.03	0.03	0.05	0.01	0.03	0.02	0.17	0.16
<i>Millettia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	SOOTALLOO	0.03	0.05	0.05	-0.03	0.02	0.02	0.13	0.15
<i>Ritchiea albersii</i> Gilg.	DANQARICH O	0.01	0.02	0.02	0.02	0.02	0.01	0.10	0.09
<i>Buddleja polystachya</i> Fresen.	ANFARE	0.01	0.02	0.08	0.02	0.02	0.00	0.16	0.08
<i>Ficus exasperata</i> Vahl	BALAAAN SOFII	0.00	0.01	0.02	0.01	0.00	0.01	0.06	0.05

4.2.8 Factors affecting the availability of medicinal plants

Field observations and informants' responses showed that the natural vegetation cover of the study area has been dwindling in many places. Interviewed informants identified five principal factors responsible for the declining availability or scarcity of medicinal and other wild plant resources. These were agricultural expansions, deforestation, overharvesting, overgrazing, and drought/climate change. Most of these factors are interrelated and inter-dependent. Pairwise comparison identified agricultural expansion, followed by deforestation, overgrazing, and overharvesting as top factors for the declining availability and loss of medicinal plants (Table 21). According to informants, agricultural expansion into forests, pasturelands, and woodlands is increasing from time to time. These have altered the habitats of many wild plants including that of medicinal species.

Table 21 Pairwise ranking of threat factors

Factors	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	I ₈	I ₉	I ₁₀	I ₁₁	I ₁₂	Total score	Rank
Agricultural expansion	3	4	3	4	4	4	4	4	2	3	4	3	42	1
Deforestation	2	1	3	3	1	3	2	2	3	4	3	4	31	2
Over-grazing	3	2	0	2	3	0	3	3	3	2	2	1	24	3
Over-harvesting	2	2	2	1	2	2	1	1	1	1	1	1	17	4
Drought	0	1	2	0	0	1	0	0	1	0	0	1	6	5

This study found that forests are the main source of medicinal plants. The loss of forest vegetation thus has a direct impact on the abundance and availability of forest sheltered medicinal plants. Furthermore, the shrinking of pastureland due to agricultural expansion brought grazing pressure on natural vegetation, particularly herbaceous species. Over-harvesting of some medicinal plants such as *Echinops longisetus*, *Pentas schimperiana*, and *Securidaca longepedunculata* have seriously affected the availability of these species. In particular, uprooting makes the worst condition for *Echinops longisetus* and *Securidaca longepedunculata*. During field visits, it was very hard to find these species for herbarium sample collections. In view of increasing pressure on local plant resources, interviewed informants reported the need to conserve *Datura metel*, *Dracaena steudneri*, *Echinops longisetus*, *Euphorbia schimperiana*, *Gomphocarpus semilunatus*, *Olea europaea* subsp. *cuspidata*, *Passiflora caerulea*, *Pentas schimperiana*, *Phytolacca dodecandra*, *Pittosporum viridiflorum*, *Podocarpus falcatus*, *Salvia nilotica*, *Securidaca longepedunculata*, and *Warburgia ugandensis*. These species were found rare or few in number where they were recorded.

4.2.9 Conservation status of medicinal plants

A total of 54 (34%) medicinal plants were managed traditionally by interviewed informants on farmlands (58%) and in homegardens (42%). These include shrubs (16 species), trees, and herbs (14 species each). Of the conserved species, 14 (26.9%) were reported to be locally threatened or rare. These include *Datura metel*, *Dracaena steudneri*, *Echinops longisetus*, *Ocimum lamiifolium*, *Ocimum urticifolium*, *Olea europaea* subsp. *cuspidata*, *Phytolacca dodecandra*, and *Pittosporum viridiflorum*. According to the interviewed informants, most of the managed species spontaneously grow by themselves or not cultivated. Most informants stated that the cultivation of wild species is difficult unless they grow naturally by themselves. Others reported that they do not cultivate medicinal plants because the medicinal plants known to them are available in their surroundings. Some informants (healers) on the other hand, reported that they do not cultivate due to secrecy.

4.3 Ethnobotanical study on wild edible plants

4.3.1 Diversity and distribution

The ethnobotanical study documented a total 39 wild edible plant species belonging to 27 families and 31 genera. A list of WEPs species along with their mode of consumption is presented in Appendix 8. The Moraceae, Myrtaceae, and Solanaceae families were represented by three species each. These families contributed 24% WEP species to the total WEPs. The majority (70%) of the families were represented by single species. In terms of growth forms, 30.7% of the wild edible plants were herbaceous followed by, shrubs and trees 28% each and liana 12.8%. Of the documented WEPs, six species have not been recorded in previous ethnobotanical studies. These species are *Acanthus pubescens*, *Bidens macroptera*, *Discopodium penninervium*, *Pteridium aquilinum*, *Rubus niveus* and *Rumex nepalensis*. The documented

WEPs have also encompassed two endemic species namely, *Amorphophallus gallaensis* and *Vepris dainellii*.

The habitats or sources of WEPs were forests and margins, farmlands and borders, homegardens, wooded grasslands, pasturelands, and riverine habitats. However, forests and forest margins sheltered the highest proportion (50%) of WEPs, followed by farmlands and borders (31.7%) and homegardens (13.4%) (Fig. 24). *Bridelia micrantha*, *Embelia schimperi*, *Ficus sur*, *Rubus apetalus*, and *Syzygium guineense* subsp. *afromontanum* were among WEPs largely reported for forest habitat and forest margins. *Amorphophallus gallaensis*, *Caylusea abyssinica*, *Coffea arabica*, *Discopodium penninervium*, *Ehretia cymosa*, *Pteridium aquilinum*, *Rumex abyssinicus*, *Rumex nepalensis*, *Senna petersiana* and *Solanum nigrum* were reported for farmlands/borders. A number of WEPs distributed in more than one types of habitat. Their abundance, however, varies from place to place. These species when they occur outside their natural habitats, for example, outside forest or woodlands, they occur as single or with a few individuals.

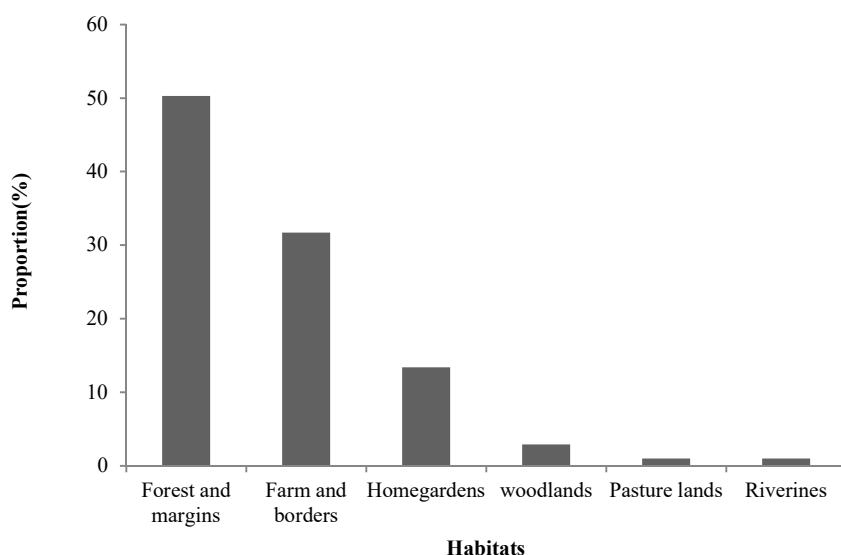


Figure 24 Distribution habitats of wild edible plants

4.3.2 Wild edible parts and mode of consumption

The edible parts were fruits, leaves, roots, seeds, nectar, bulbs, and stem. Of these, fruits make up the highest proportion 25(58.1%) of the edible parts, followed by leaves 10 (23.3%), seed 4(9.3%), root 2(4.7%), stem and nectar (1 each, 2.3%). The most widely consumed WEPs for their fruits were *Carissa spinarum*, *Ficus sur*, *Rubus apetalus*, *Rubus niveus*, and *Syzygium guineense* subsp. *afromontanum*, *Syzygium guineense* subsp. *macrocarpa*, and *Ximenia americana* (Fig. 25a, b).

There were various wild edible plant part usage forms. Most 23 (59%) of the wild edibles were consumed fresh/raw. They have been collected and consumed without further processing. This was followed by consumption after cooking in which 10 (24%) and boiling 3 (8%) species were recorded.

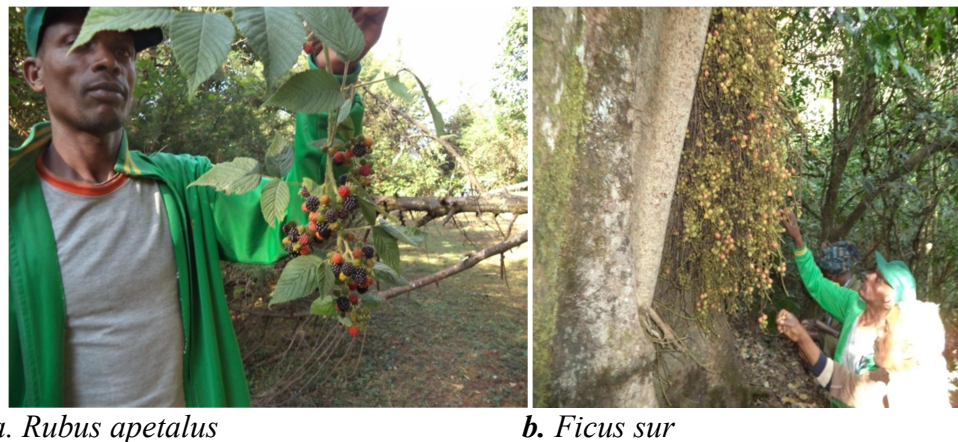


Figure 25 Commonly used wild edible fruits found in JWF (Photo by Kebu Balemie, Feb. 2015)

4.3.3 Preference, consumption and seasonality of wild edible plants

The gathering and consumption of wild edible plants have been common practice in the study. Interviewed informants reported that wild edibles are consumed in different times to reduce starvation and/or suppress thirst during a long stay in the field, as a snack with no thirst or

starvation, and to cope up with seasonal food shortages/famine. The results revealed that 15 (38.5%) of the WEPs were consumed by all age and both genders during normal times as a snack, 16 (41%) were consumed only by children, and 8 (20.5%) species were consumed during seasonal food shortages at the household level. Consumption was based on taste, food shortage, accessibility, and nutraceutical values. Most (56%) of informants reported taste, followed by food shortage (31%) as principal factors for consumption of WEPs. Some (8.3%) of informants reported the consumption of one WEPs for its nutraceutical value. Accessibility and ease of collection (4.7%) was another reported factor, which affect consumption. The wild edibles consumed by all age and gender groups during both normal and food shortages were fruits of *Carissa spinarum*, *Rubus apetalus*, *R. niveus*, *Syzygium guineense* subsp. *afromontanum*, *S. guineense* subsp. *guineense*, *S. guineense* subsp. *macrocarpum*, and *Ximenia americana*. These species have relatively palatable taste and consumed both in normal times and during famine season. WEPs such as *Acanthus pubescens*, *Bridelia micrantha*, *Ehretia cymosa*, *Ficus vasta*, *Momordica foetida*, *Phoenix reclinata*, and *Physalis peruviana* were consumed by children. These species are less tasty and ignored by older people. Wild edibles such as *Caylusea abyssinica*, *Pteridium aquilinum*, *Rumex abyssinicus*, *R. nepalensis*, *Dioscorea praehensilis* and *D. schimperiana* were consumed at the household level only during seasonal food shortages or during a famine. These are green leafy edibles and tubers, which are consumed by poor households. Women and children were more responsible for the gathering and processing of these food plants. *Caylusea abyssinica* is consumed as nutraceutical during normal seasons irrespective of gender and age. However, it is consumed by poor households as gap filler during food shortage.

Furthermore, informants explained that WEP collection varied widely among the species depending on seasonal availability of edible parts and availability of grain food at home. The availability peak season of green leafy edible such as *Caylusea abyssinica*, *Pteridium aquilinum*, *Rumex abyssinicus*, and *R. nepalensis* were often between July and September. Most of WEP parts such as fruits, seeds, and nectar are available between January and June. Edible fruits of *Rubus apetalus*, *R. niveus*, and *Ficus sur* were available between January and February. Similarly, fruits of *Carissa spinarum*, *Syzygium guineense* subsp. *afromontanum*, *Syzygium guineense* subsp. *macrocarpa* and *Ximenia americana* were available between May and June and their consumption is limited to these months. Preference of species varies according to agroecological settlement. For example, WEPs naturally occurring in lowlands were preferred more by communities of these areas. In connection to the mode of consumption, the WEPs were consumed in a variety of ways: most (23, 59%) of the WEPs required no processing or preparations for consumption. Almost all fruits, seeds and nectar were gathered for immediate consumption without further processing. Informants asserted that fruits and seeds are consumed during a long stay in field for agriculture, tending cattle and long travel. About 10 (26%) of leafy edibles require prior cooking for consumption; three species (8%) were consumed after boiled; two species (5%) were consumed either in processed or unprocessed form; one species (3%) was used in local bevarage. These include seeds of *Senna petersiana*, which were eaten raw or drunk after processing it in the form of watery juice. Similarly, fruits of *Piper capnse* can be eaten raw by children, and can also be used as a spice in the sauce. Two (5%) species *Dioscorea praehensilis* and *D. schimperiana* were consumed in boiled form, and one species *Rhamnus prinoides* is used in local beer.

4.3.4 Ethnobotanical knowledge of wild edible plant

Wild edible plants (WEPs) have been known and used by local communities in the study area. The documented WEPs are indicators of ethnobotanical knowledge, which includes identification of WEPs, parts used, methods of uses, tastes, preferences, seasonality, phenology, and habitat location of WEPs. The ethnobotanical knowledge on WEPs was assessed based on the uses and number of wild edible plants known and described by informants. Accordingly, the WEPs known and reported by the male and female informants' were (Mean $\pm$ SE) (5.40 ± 0.21) and (4.96 ± 0.22), respectively. Analysis of variance (ANOVA) indicates no significant difference ($p = 0.93$, $p > 0.05$) between gender in WEPs knowledge. Similarly, the WEPs known by informants who have attended and not attended formal education were insignificantly ($p = 0.58 > 0.05$) different. Similarly, the numbers of WEPs known by and reported by different age groups were not significantly different ($p = 0.34$, $p > 0.05$). Proximity to the forest and agroecological variations has not also affected the possession of WEPs knowledge. Overall, the total numbers of wild edible species known and reported by the different age categories, gender, and educational background, agro-ecology and distance from the forest were not significantly different among informants (Table 22).

Table 22 Distribution of ethnobotanical knowledge among informants with different social and geographic backgrounds

Variables		Mean of reported WEPs	P-value
Gender	Male	5.40 ± 0.21	$p = 0.93; p > 0.05$
	Female	4.96 ± 0.22	
Age	< 25 year old	5.33 ± 0.33	$p = 0.34; p > 0.05$
	between 25 ≤ 52 years	5.46 ± 0.26	
	> 52 years	4.73 ± 0.43	
Distance from forest	≤ 2 hr walk	5.59 ± 0.26	$p = 0.17; p > 0.05$
	> 2 hr walk	5.08 ± 0.26	
Education	Formal education	5.36 ± 0.23	$p = 0.58; p > 0.05$
	no formal education	5.14 ± 0.32	
Agroecology	Lowlands	5.65 ± 0.38	$p = 0.17; p > 0.05$
	Midlands	4.97 ± 0.24	
	Highlands	5.60 ± 0.32	

4.3.5 Pairwise ranking of selected wild edible plants

Pairwise comparison ranked *Syzygium guineense* subsp. *afromontanum* first with the total score of 42, followed by *S. guineense* subsp. *macrocarpum* and *S. guineense* subsp. *guineense* (Table 23). These species were found to have more sugary taste and preferred by the majority of informants who reported the edibility of the species.

Table 23 Pairwise ranking of wild edible fruits

WEPs	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	I ₈	I ₉	I ₁₀	I ₁₁	I ₁₂	Totaal	Rank
<i>Ximenia americana</i>	2	0	4	1	2	2	2	1	3	4	4	4	29	1
<i>S. guineense</i> subsp. <i>afromontanum</i>	1	1	2	3	2	3	4	4	2	2	2	2	28	2
<i>S. guineense</i> subsp. <i>macrocarpa</i>	0	3	3	3	2	3	1	1	2	0	2	3	23	3
<i>S. guineense</i> subsp. <i>guineense</i>	4	4	1	3	0	2	2	3	0	1	1	0	21	4
<i>Carissa spinarum</i>	3	2	0	0	4	0	1	1	3	3	1	1	19	5

4.3.6 Nutritional profile of selected WEPs fruits

Proximate content

The mean percentage of ash varied between 2.94% for *Syzygium guineense* subsp. *afromontanum* and 9.61% for *Ximenia americana*. The percentage of crude protein content was highest (13.96%) in *Ximenia americana* and least (2.94%) in *S. guineense* subsp. *afromontanum*. The percentage of crude fat was considerably high in *Carissa spinarum* (17.79%) whereas relatively low (below 4.58%) in other analyzed fruits. Crude fiber is highest in *S. guineense* subsp. *guineense* (Table 24).

Mineral content

This analysis was carried out for the content of sodium (Na), potassium (K) and phosphorus (P) in wild edible fruits. The analysis found the highest potassium content (4352.17mg/100 g) in *X. americana*, followed by *S. guineense* subsp. *guineense* (2276.81mg/100 g). Similarly, the highest sodium content was found in *S. guineense* subsp. *afromontanum* (23.98 mg/100 g) and the lowest found in *C. spinarum* and *X. americana* (7.99 mg/100 g each). Furthermore, the analysis found the highest phosphorus content (183.5 mg/Kg) in *X. americana*, followed by *S. guineense* subsp. *guineense* (143.2 mg/Kg).

Vitamin C content

The Vitamin C content of the fruits varied between 2.32 to 19.70 g/100g. The highest content was found in *X. americana* (19.70 g/100g), followed by *C. spinarum* (14.08 g/100g). One-way ANOVA found significant ($p = 0.00$; $p < 0.05$) variations in ash, crude fat, crude fiber, and phosphorus among analyzed fruits. ANOVA with LSD test *post-hoc* analysis, however, identified the content of some parameters that are significantly different. Accordingly, crude fat

content in *S. guineense* subsp. *guineense* and *X. americana* was not significantly different ($p = 0.096$, $p > 0.05$). Similarly, there was no significant difference ($p = 0.132$, $p > 0.05$) in crude fiber content between *S. guineense* subsp. *afromontanum* and *S. guineense* subsp. *guineense*; also no significant difference ($p = 0.369$, $p > 0.05$) in crude fiber content between *S. guineense* subsp. *afromontanum* and *C. spinarum*.

Overall, the analysis revealed that wild edible fruits are a potential source of nutrients, which could contribute to food and health security of rural communities. Although there were some quantitative variations, all the fruits analyzed contained proximate, minerals, and vitamin. The consumption of these fruits definitely contributes to nutritional needs of local communities.

Table 24 Nutritional profile of some wild edible fruits

Parameters	<i>Carissa spinarum</i>	<i>Syzygium guineense</i> subsp. <i>afromontanum</i>	<i>Syzygium guineense</i> subsp. <i>guineense</i>	<i>S. guineense</i> subsp. <i>macrocarpa</i>	<i>Ximenia americana</i>	p-value
Ash (%)	4.56 ± 0.02	2.94 ± 0.03	5.47 ± 0.02	5.15 ± 0.10	9.65 ± 0.07	$p = 0.67$, $p > 0.05$
Crude fat (%)	17.78 ± 0.16	2.49 ± 0.11	4.34 ± 0.03	3.06 ± 0.01	4.58 ± 0.00	0.000
Crude fiber (%)	18.84 ± 0.34	19.77 ± 0.34	21.48 ± 1.37	28.22 ± 0.53	9.31 ± 0.13	0.000
P mg/Kg	115.42 ± 0.47	80 ± 0.36	143.15 ± 0.39	76.15 ± 0.39	183.53 ± 0.20	0.000
Crude protein (%)	6.27	6.46	6.82	6.27	13.96	
Na mg/100g	19.98	7.99	11.98	19.98	7.99	
K mg/100g	1757.89	2117.46	2276.81	1757.89	4352.17	
Vitamin C (mg/100 g)	8.08	14.08	12.23	8.08	19.7	

4.3.7 Challenges to consumption of WEPs

Informants reported that the number of people consuming WEPs has decreased now compared to the past. Many of the plants reported in this study are less frequently consumed or their consumption has declined. According to informants, deliberate search for WEPs from wild/ or field has declined even during food shortages. Informants reported various factors for declining

WEP consumption. About 41% of the informants reported the availability of grain foods for this declining of consumption; 26% reported neglect due to poor taste and fear of side effects after consumption; 16.5% reported lack of knowledge; 9% reported loss of species from an area; 7.6% reported accessibility of species, labor and time requirement for harvesting and processing; 5% reported fear of social stigma upon gathering and consumption. With increasing alternative sources of income such as off-farm labor, people are able to buy grain food and domesticated fruits and decline to rely on WEPs collected during a famine. In this study, younger individuals were expected to report a greater number of WEPs than do older informants. However, the results showed no variation in WEPs knowledge possession between the younger and older informants.

4.3.8 Marketability of WEPs

The study found that 18% of the recorded WEPs were reported to be marketable. The highest marketability report was for *S. guineense* subsp. *afromontanum*, *S. guineense* subsp. *macrocarpa*, and *Ximenia americana*, respectively. Informants further explained that in the past these species were sold by children and few women. These species were not available now in marketplaces. Informants suggested that low prices and decreasing fruit availability (accessibility) might discourage the sale of these wild edible fruits. According to the informants, some of these marketable edible fruits are consumed by wild animals such as baboons and birds or they might be dropped and decayed. As a result, adequate quantity might not be obtained for sale. The species available on market were harvested from stands in their own farms and/or gardens. These include *Aframomum corrorima*, *Piper capense* and *Rhamnus prinoides*.

4.3.9 Use diversity and cultural importance of WEPs

The study showed that WEPs have many other uses than food. About 95% of WEPs have more than one use category. These include construction and crafts, medicine, fuel wood, forage, shade, and others (baking, walking stick, rope, cosmetics, rituals, etc.). The WEPs had the highest contribution to the shade use category (21 species) followed by technology and crafts (19 species) and fuel wood (18 species), respectively (Fig. 26). Most of the WEPs reported for their shade. The main shade trees are *Cordia africana*, *Ehretia cymosa*, *Ficus sur*, *F. vasta*, *Syzygium guineense* subsp. *afromontanum*, *S. guineense* subsp. *guineense*, *S. subsp. macrocarpa*, and *Vepris dainellii*. Some of the main shade trees were also reported under technology and crafts for construction, farm implements, hand tools, and various household utensils. The most reported species for uses under technology and crafts categories were *Cordia africana* and *Syzygium guineense* subsp. *afromontanum*. Forage was another category of use, comprising 18 WEP species.

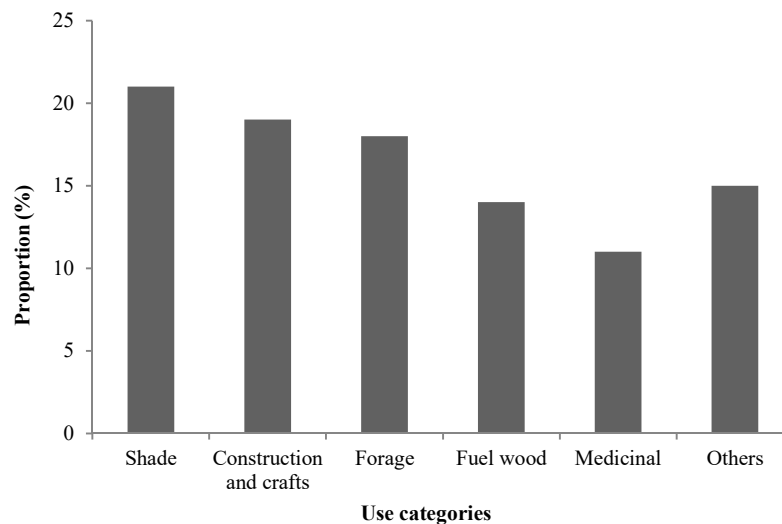


Figure 26 Proportion of WEPs in different use categories

The cultural significance of the top ten WEPs reported by most informants is shown in Table 25. *Syzygium guineense* subsp. *afromontanum* scored the highest cultural importance values (CI = 3.78), followed by *Cordia africana* (CI = 1.27) and *S.* subsp. *macrocarpa* (CI = 0.95), respectively. Cultural importance values reveal the relative importance of a species in each category of use. Species with high cultural importance therefore means that these species contribute greatly to the livelihoods of local communities.

Table 25 Cultural importance values of WEPs with more number of use categories

Name	construction & crafts	Fuel wood	Health	Forage	Environmental	others	Cultural importance (CI)
<i>Syzygium guineense</i> subsp. <i>afromontanum</i>	1.87	0.71	0.02	0.3	0.65	0.23	3.78
<i>Cordia africana</i>	0.51	0.19	0.02	0.11	0.2	0.24	1.27
<i>Syzygium guineense</i> subsp. <i>macrocarpa</i>	0.4	0.23	0	0.06	0.23	0.03	0.95
<i>Ficus sur</i>	0.3	0.21	0.01	0.1	0.21	0.02	0.84
<i>Ximenia americana</i>	0.1	0.11	0.06	0.03	0.08	0.03	0.4
<i>Syzygium guineense</i> subsp. <i>guineense</i>	0.1	0.11	0	0.06	0.08	0.03	0.38
<i>Phoenix reclinata</i>	0.17	0.03	0.01	0.04	0.07	0.09	0.44
<i>Carissa spinarum</i>	0.07	0.11	0.01	0.03	0.03	0.02	0.27
<i>Morus nigra</i>	0.04	0.03	0.01	0.03	0.00	0.02	0.13
<i>Caylusea abyssinica</i>	0.01	0.00	0.06	0.03	0.00	0.00	0.10

4.3.10 Threats to and conservation practices of WEPs

Informants stressed that factors affecting the availability of WEPs were the same as those affecting medicinal plants and the results of pair comparisons were the same. Various human activities have threatened the rare and other wild edible plants. In this, the expansion of agricultural land, deforestation and harvesting are among the main threats to plant diversity, including WEPs.

With regard to conservation, some farmers have made efforts to manage and conserve WEPs. These farmers maintained some WEPs on their own lands for various reasons. The results indicated that interviewed farmers are managing 18 WEPs. The highest proportion of informants reported the management of *Syzygium guineense* subsp. *afromontanum* and *Cordia africana* (Table 26). The managed species were not planted; instead, they grew up by themselves in their farmlands, homegardens/or homesteads, forest patches, and pasture lands. It was reported that 9 (32%) of the managed species were managed in homegardens; 8 (29%) species in farmlands including coffee farm, 7 (25%) species in forest patch and 4 (14%) species in pasture lands. These management efforts should be encouraged and promoted among the public so that more useful and threatened species can be rescued from local extinction. Local people should be supported such as by provision of seedlings, especially that of trees and shrubs. In terms of conservation demand, most informants have expressed their interest in the conservation of the following species: *Syzygium guineense* subsp. *macrocarpa*, *Carissa spinarum*, *S. guineense* subsp. *afromontanum*, *S. guineense* subsp. *guineense*, *Ximenia americana*, *Cordia africana*, *Phoenix reclinata*, and *Ficus sur*. In many cases, these wild plants grow on marginal areas with minimal management effort.

Table 26 WEPs maintained by some farmers in the study areas

Scientific name	Report frequency	Proportion (%)	Place of conservation
<i>Syzygium guineense</i> . subsp. <i>afromontanum</i>	61	36	FL, Hg
<i>Morus alba</i>	28	17	Hg, FL
<i>Cordia africana</i>	25	15	FL, F
<i>Carissa spinarum</i>	9	5	FL, F, Hg, GL
<i>Phoenix reclinata</i>	8	5	H
<i>Caylusea abyssinica</i>	6	4	GL
<i>Syzygium guineense</i> subsp. <i>macrocarpa</i>	5	3	FL, F
<i>Senna petersiana</i>	5	3	GL
<i>Pteridium aquilinum</i>	4	2	Hg, F
<i>Dioscorea praehensilis</i>	3	2	Hg
<i>Ensete ventricosum</i>	3	2	Hg
<i>Ritchiea albersii</i>	2	1	F
<i>Ficus sur</i> Forssk.	2	1	F
<i>Ximenia americana</i>	2	1	FL, Hg
<i>Bidens macroptera</i>	2	1	GL
<i>Rumex abyssinicus</i>	1	1	FL
<i>Rubus niveus</i>	1	1	F
<i>Piper capense</i>	1	1	FL

NB: F = forest; Hg = homegarden; FL = farmland; GL = grazing land

CHAPTER FIVE

5. DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Discussion

5.1.1 Floristic study of JWF

5.1.1.1 Floristic diversity and composition

The floristic study has documented a total of 237 species, with the most species-rich family being Fabaceae, followed by Asteraceae, Acanthaceae, Lamiaceae, and Poaceae. These families were also reported to be dominant in many other studies such as in Bonga Forest, Yayu forest, Berhane-Kontir Forest, Maji Forest, and Harena Forest (Feyera Senbeta, 2006), in Kontom Forest (Fekadu Gurmessa *et al.*, 2013), in Belete Forest (Kflay Gebrehiwot and Kitessa Hundera, 2014), in Wondo Genet Afromontane Forest (Mamo Kebede *et al.*, 2013) and in Gera Forest (Yohannes Mulugeta *et al.*, 2015). These families are also among the dominant families of the Ethiopian flora (Ensermu Kelbessa and Sebsebe Demissew, 2014). For instance, the Fabaceae (678) and Asteraceae (472) families had, respectively the highest number of species in Flora of Ethiopia and Eritrea (Ensemu Kelbessa and Sebsebe Demissew, 2014). The Fabaceae is also among the dominant families in tropical forests in Africa and Neotropics (Gentry, 1988). Furthermore, families such as Rubiaceae, Euphorbiaceae, and Moraceae are among the most species-rich families in tropical forests (Gentry, 1988). Feyera Senbeta (2006) reported a similar result among five moist Afromontane forests of Ethiopia. The dominance and wider distribution of these families, in general, could be attributed to their efficient and successful dispersal mechanisms and adaptation to a wide range of ecological conditions. The most abundant and dominant species in JWF were *Dracaena afromontana*, *Chionanthes mildbraedii*, *Syzygium guineense* subsp. *afromontanum* and *Pouteria adolfi-friederici*, *Maytenus gracilipes* and

Landolphia buchanani in descending order. These species are characteristic to moist Afromontane forests of Ethiopia (Friis, 1992).

In terms of endemism, the JWF consists of 10 endemic plants. The number of endemics found in this study relatively comparable with those reported in other moist Afromontane forests. Dereje Denu (2006) reported 13 endemic species from Gura ferda forest, Feyera Senbeta (2006) recorded from Berhane-Kontir and Bonga 14 species each. Species such as *Millettia ferruginea* subsp. *ferruginea* and *Vepris dainellii* are shared among most other moist Afromontane forests (Dereje Denu, 2006; Feyera Senbeta, 2006; Fekadu GurMESSA *et al.*, 2013; Yohannes Mulugeta *et al.*, 2015). Among the endemics in JWF, *Bothriocline schimperi*, *Lippia adoensis*, *Millettia ferruginea* subsp. *ferruginea*, *Maytenus addat*, *Solanecio gigas*, *Vepris dainellii*, and *Vernonia leopoldi* were reported in the IUCN Red List of threatened plants under different threat categories (Vivero *et al.*, 2005).

In terms of ethnobotanical importance, JWF encompasses over 100 medicinal and WEPs used in the study area. This witnessed that, in addition to the source of other ecosystem services, JWF forest is the source of the diverse array of culturally important species that contribute to livelihoods.

The floristic study has further found a number of species, the distribution of which was not included in the Flora of Ethiopia and Eritrea for Wollega floristic region. Similar findings were reported in Kontom Forest (Fekadu GurMESSA *et al.*, 2013) and Gerged Forest (Tamene Yohannes, 2016). This is in line with Friis (2009) who reported that the Wollega floristic region is generally underexplored and many species from this floristic region have not been included in

the Flora of Ethiopia and Eritrea. The present information thus contributes to enriching the flora database of the country. Moreover, the finding suggests the need for more exploration in unexplored parts of this floristic region.

5.1.1.2 Floristic affinity of JWF with some Afromontane forests

The Afromontane forests of Ethiopia are known to encompass high species diversity because of the fact that they are located within the high rainfall zone and altitudinal gradient. In comparison with other forests, the number of species documented in this study compares well with some forests in other parts of Ethiopia. Most of the previous studies undertaken on the moist Afromontane and dry Afromontane forests have documented a comparable number of species. For example, Ermias Lulekal *et al.* (2008) documented 211 species in Mana Angetu; Tadesse Woldemariam (2003) documented 220 species in Yayu forest; Mamo Kebede *et al* (2013) recorded 240 species in Afromontane natural forest of Wondo Genet. Some studies, on the other hand, reported lower numbers compared to that of JWF. For example, Fekadu Gurmessa *et al.* (2013) documented 180 species in Komto moist Afromontane forest; Kflay Gebrehiwot and Kitessa Hundera (2014) reported 157 species in Belete moist Afromontane forest; Yohannes Mulugeta *et al.* (2015) recorded a total of 132 species in Gera moist forest. Other studies have reported a higher number of species; for example, Feyera Senbeta (2006) recorded 285 species from Boga, 374 from Konter-Berhan, and 289 from Harena moist Afromontane forests. The differences in recorded floristic diversity among tropical forests could be due to the size of the forests, objectives of the studies, sampling intensity and geologic history (Peter, 1996). Moreover, studies showed that anthropogenic disturbance and habitat heterogeneity could have contributed to variation in floristic diversity among forests (Feyera Senbeta, 2006). Despite the variation in richness, the studies generally witnessed that the moist Afromontane forests of

Ethiopia are home to a great diversity of plants including endemic and economically important species.

In terms of floristic resemblance, JWF showed 7 to 39% floristic affinities with other compared moist Afromontane and dry Afromontane forests in Ethiopia (Table 27). Similarity index revealed that JWF revealed a high floristic similarity (0.39) with Agama MAF. In a similar comparison, Feyera Senbeta *et al.* (2014) found 42 to 50% similarity values between five moist Afromontane forests of Ethiopia. The high floristic affinity of JWF with other forests might be due to similarity in environmental factors that could potentially influence the distribution of species. The least similarity was found with dry Afromontane forest. The high floristic affinity of JWF with other forests might be due to more similarity in environmental factors, which could potentially influence the distribution of species. The least similarity was found with Bale Mountain dry Afromontane forest (0.07). The low similarity values indicate more variations in environmental factors between the compared forests (0.07). The low similarity values indicate more variations in environmental factors between the comparative forests.

Table 27 Sorensen's similarity (Ss) between JWF and some moist Afromontane and dry Afromontane forests of Ethiopia

Compared forest	Vegetation type	N0 of compared spp.	a	b	c	Ss	Sources
Agama	MAF	150	75	162	75	0.39	Admasu Addi <i>et al.</i> , 2016
Kumuli	DAF	133	69	168	64	0.37	Gideon Woldemariam <i>et al.</i> , 2016
Gura ferda	MAF	196	81	156	115	0.37	Dereje Denu, 2006
Wondo Genet	MAF	243	87	150	156	0.36	Mamo Kebede <i>et al.</i> , 2013
Belete	MAF	155	66	171	89	0.34	Kflay Gebrehiwot and Kitessa Hundera, 2014
Chilimo	DAF	214	73	164	141	0.32	Teshome Soromessa and Ensermu Kelbessa, 2014
Feyera Senbeta	MAF	651	143	94	557	0.31	Feyera Senbeta, 2006
Densa	DAF	158	58	179	100	0.29	Ermias Lulekal, 2014
Hugumburda-Gratkassu	DAF	326	60	177	266	0.21	Leul Kidane, 2015
Bale Mountain	DAF	223	16	221	207	0.07	Haile Yineger <i>et al.</i> , 2008

Jorgo Wato Forest has shared many characteristic species to moist Afromontane forests (Friis, 1992). These include *Coffea arabica*, *Cyathea manniana*, *Dracaena afromontana*, *Olea welwitschii*, *Schrebera alata*, *Polyscias fulva*, *Pouteria adolfi-friederici*, *Schefflera abyssinica*, and *Vepris dainellii*. In terms of dominant characteristic species, different moist Afromontane forests harbor various dominant species. For example, *Dracaena afromontana*, *Chionanthes mildbraedii*, and *Pouteria adolfi-friederici* are dominant in JWF; *Coffea arabica*, *Schefflera abyssinica*, *Polyscias fulva*, *Croton macrostachyus*, *Millettia ferruginea*, *Vepris dainellii*, *Prunus africana*, *Galiniera saxifrage*, and *Olea welwitschii* are dominant species in Gera Forest (Yohannes Mulugeta *et al.*, 2015). In others such as Berhane-Kontir Forest, *Dracaena fragrans*, *Eugenia bukobensis*, *Whitfieldia elongata* and *Argomuelleria macrophylla* are the dominant species (Feyera Senbeta, 2006). The dominance of different species in different moist Afromontane forests reflects variability in environmental factors that uniquely favor the successful establishment and adaptation of dominant species in each forest.

Similarly, JWF shares a number of species such *Acacia abyssinica*, *Allophylus abyssinicus*, *Apodytes dimidiata*, *Bersama abyssinica*, *Brucea antidysenterica*, *Buddleja polystachya*, *Calpurnia aurea*, *Cassipourea malosana*, *Celtis africana*, *Ehretia cymosa* *Ekebergia capensis* with dry Afromontane forests. These species might have adapted to a wide range of environmental conditions or due to similar environmental factors shared between JWF and the other Afromontane forests.

5.1.1.3 Forest structure

Density

Distribution of woody individuals ($\text{dbh} \geq 2.5 \text{ cm}$) across different dbh classes showed the highest proportion of stem density ha^{-1} in the lowest dbh classes. Similar findings have been reported in Fekadu Gurmessa *et al.* (2012) in Kontom Forest; in Abreham Assefa *et al.* (2013) in Masha Forest, in Kflay Gebrehiwot and Kitessa Hundera (2014), in Belete Forest, and in Yohannes Mulugeta *et al.* (2015) in Gera Forest. Many tree and shrub individuals in lower dbh class indicate that the forest is generally under healthy regeneration. The total density reported in this study ($1477 \text{ stem ha}^{-1}$) and many other studies vary across forests. For example, Ermias Lulekal (2014) found $1138 \text{ stems ha}^{-1}$ of woody individuals ($>2\text{cm}$) for Dense Forest, Kflay Gebrehiwot and Kitessa Hundera (2014) reported a lower density value ($760.95 \text{ stems ha}^{-1}$) for the woody individuals ($\text{dbh} > 3.5 \text{ cm}$) in Belete Forest and Yohannes Mulugeta *et al.* (2015) reported 1778 ha^{-1} of woody individuals ($> 10 \text{ cm}$) in Gera Forest. One of the visible reasons for the difference in stem densities among different forests is variation in dbh limit considered during surveys. Apart from this, stem density can be affected by many factors including disturbance, competition, site productivity, size of the studied forests as well as topographic, edaphic and climatic factors. For example, several studies have reported decreasing stem density with increasing intensity of disturbance (Sagar *et al.*, 2003; Nath *et al.*, 2005; Feyera Senbeta *et al.* 2014).

Frequency

The frequency analysis revealed that most of the species recorded in the plots were in the lowest Raunkiaer's (1934) frequency class (class A). The low frequency of most species indicates that many species in JWF are either clumped or rare or not uniform in their distribution. On the other hand, few species were in the higher frequency classes (B, C, and D). These means that

individuals of few species uniformly distributed in many parts of the forest. Species in Class D for example, with frequency between 61-80% are present in most parts of the plots. High frequency of occurrence indicates high reproductive capacity and adaptation to a wide range of niches. Frequency often used to detect changes in vegetation composition over time. The low frequency of most species is a characteristic feature of tropical forest (Gaston, 1994; Feyera Senbeta *et al.*, 2014). According to Partel *et al.* (2005), the low frequency or restricted distribution of species could be due to a combination of species biological or ecological characteristics and anthropogenic disturbance.

Basal areas

The structural analysis further showed that most of the woody species in the sampled plots contributed only 24.2% to the total basal area ($62.7 \text{ m}^2 \text{ ha}^{-1}$), while few species contributed 75.8% to the total basal area. The basal areas of individuals vary among different Afromontane forests. Feyera Senbeta *et al.* (2014) reported total basal areas ranging between 46 and $54 \text{ m}^2 \text{ ha}^{-1}$ in five moist Afromontane forests. Kflay Gebrehiwot and Kitessa Hundera (2014) reported the total basal area of $103.5 \text{ m}^2 \text{ ha}^{-1}$ for Belete moist Afromontane forest. Nath *et al.* (2005) reported a basal area of $98.58 \text{ m}^2 \text{ ha}^{-1}$ in tropical wet evergreen forest. Tesfaye Bogale *et al.* (2017) reported a total basal area of $87.49 \text{ m}^2 \text{ ha}^{-1}$ for Berbere moist Afromontane forest. The species contributing the highest basal area to the total basal area also vary among different Afromontane forests. Many reasons can be given for the variations in basal among different tropical forests. Density and size (age) of woody species are strongly correlated with basal areas. Forests with many individuals and many large sized individuals might have high total basal area (Sahu *et al.*, 2008). Variations in dbh limits considered during survey could also result in the variation of basal areas. Furthermore, site productivity, competition, and disturbance factors have been

suggested reasons for the difference in basal areas among forests (Sagar *et al.*, 2003; Feyera Senbeta *et al.*, 2014). The differences in the basal area among study plots of the same forest could also be observed due to differences in altitude, species composition, the age of woody species, and disturbances (Sahu *et al.*, 2008). Removal of larger or aged trees could have a direct impact on the total basal area.

Importance value Index

Importance Value Index (IVI) has been developed for understanding the dominance and ecological success of a species in a particular plant community. It gives an insight into the abundance and occurrence of each species within plant communities (Kent and Coker, 1992). The present study found very few species with the highest IVIs. These include *Pouteria adolfi-friederici*, *Syzygium guineense* subsp. *afromontanum*, *Dracaena afromontana*, *Chionanthes mildbraedii*, and *Croton macrostachyus*. The highest IVIs signify their ecological dominance in terms of space, resource use and many other ecological functions. These species have also exhibited high ecological dominance in Belete Forest (Kflay Gebrehiwot and Kitessa Hundera, 2014) and Bonga Forest (Feyera Senbeta, 2006). The dominance of species in geographically different forests indicates their successful adaptation to a wide range of habitats (Feyera Senbeta, 2006). Species dominance often related to the availability of a suitable niche and disturbances (Kadavul and Parthasarathy, 1999). Ecologically dominant species are less sensitive to anthropogenic disturbances (Feyera Senbeta, 2006). Ecologically dominant species have a major controlling influence based on their number, size, or productivity. Such species influence the energy flow and are capable of influencing physical environment of other species; they protect and provide shelter to the organisms. This is a characteristic feature observed in many tropical forests (Gaston, 1994). In contrast, low ecological importance, indicate species least ecological

roles (Feyera Senbeta, 2006). Species with low dominance could easily be vulnerable to extinction and might warrant an immediate conservation action.

Population structure and regeneration status

Plant population structure shows whether the population has a stable distribution of individuals that allows continuous regeneration to take place (Rao *et al.*, 1990). Accordingly, size class distributions of woody individuals have been used to describe the population structure of given vegetation type (Khan *et al.*, 1987; Peter, 1996). In particular, the diameter distribution of tree individuals has been used to represent the population structure of a forest (Rao *et al.*, 1990; Peter, 1996). Although long-term demographic data on population trends is required, diameter size class distribution has been considered as indicator of changes in population structure and species composition of a forest (Newbery and Gartlan, 1996; Peter, 1996). The patterns of distribution across the dbh classes also help to interpret the regeneration status of vegetation (Saxena and Singh, 1984; Peter, 1996), which plays a key role for sustainable use and conservation planning. Furthermore, size-class distribution gives information about the past disturbance, which can be used to estimate the future trend of a population of a particular species (Demel Teketay, 1997). Several studies have used size class distribution to view population and determine regeneration status forests and forest species (Tadesse Woldemariam, 2003; Feyera Senbeta, 2006; Ermias Lulekal *et al.*, 2008; Getachew Tesfaye, 2008; Kflay Gebrehiwot and Kitessa Hundera, 2014; Tesfaye Bogale *et al.*, 2017).

In the present study, the population structure of all woody individuals ($\text{dbh} \geq 2.5 \text{ cm}$) together exhibited an inverse-J shape pattern. Most of the individuals ha^{-1} were found in the lower dbh classes, with a gradual decrease towards the larger classes. Such pattern was reported in various

studies conducted on Afromontane forests such as Yayu Forest (Tadesse Woldemariam, 2003), Hareenna, Bonga, Berhane-Kontir, Maji and Yayu Forests (Feyera Senbeta, 2006), Belete forest (Kflay Gebrehiwot and Kitessa Hundera, 2014) and Berbere Forest (Tesfaye Bogale *et al.*, 2017). Many tropical forests exhibited numerous individuals in smaller diameter classes and very few individuals in higher diameter classes. Such distribution is characteristic of a stable population (Hall and Bawa, 1993; Teketay, 1997).

The population structure of individual trees, however, exhibited different patterns. Most of the trees showed many individuals in the first dbh class, but differ in number and occurrence of individuals towards the last classes. Among the tree species in this group, *Pouteria adolfi-friederici* and *Syzygium guineense* subsp. *afromontanum* showed many individuals in the first dbh class but few individuals towards the larger dbh classes indicating inverse-J shape pattern. Such a pattern is generally indicative of active regeneration and stable population (Teketay, 1997; Feyera Senbeta, 2006; Getachew Tesfaye, 2008). Other studies (e.g. Feyera Senbeta, 2006; Tesfaye Burju *et al.*, 2013) also found a greater number of individuals for lower dbh classes and gradual decline or missing towards the higher dbh classes.

The result further revealed that two trees (*Cordia africana* and *Polyscias fulva*) had some individuals in the intermediate dbh classes with missing in the first and last dbh classes. The other pattern depicted by *Schefflera abyssinica* was the presence of some individuals in the last dbh class and absence from first and intermediate classes. Individuals of these species are lacking from the first dbh classes and thus showed population structure deviating from a reverse-J pattern. According to Khan *et al.* (1987) and Hall and Bawa (1993), such a pattern indicates a

lack of recruitment and may indicate unhealthy population structure. The lower number or missing of individuals in different size classes suggests the presence of various disturbance factors to the forest or species (Saxena and Singh, 1984). In Jorgo Wato Forest, timber trees had been logged by the government during the previous military regime and by individuals during transisional government (1992-93) (Pers. comm. with elders). *Pouteria adolfi-friederici* and *Cordia africana* were the main timber species, which suffered logging. Still, now these tree species are illegally harvested preferably for their timber. In ethnobotanical part of this study, *Cordia africana* has revealed high cultural importance value. This witnessed that this species is harvested for a wide variety of multipurpose, which might affect population structure and endanger the species. Other species such as *Olea welwitschii* tree trunk is selectively and illegally being fell-down for its bark (having good aroma) for making a beehive. Different species were also seen illegally harvested from the forest for construction and farm implements. These agree with Yohannes Mulugeta *et al.* (2015) who reported similar pressure on *Olea welwitschii* and other illegal harvesting activities in Gera forest. Age-related and other natural disturbance could result in the fall of large trees, which occurred in most natural forests. *Schefflera abyssinica*, for example, was falling in the forest in many places. Although the frequency of fall varies among trees/shrubs, such natural disturbances may also contribute to the low or missing number of individuals at larger dbh classes.

The population structure of seedlings and saplings has also been considered as indicators of a forest's regeneration status (Saxena and Singh, 1984; Khan *et al.*, 1987). Such information contributes to the sustainable use and management of forests (Peter, 1996). In JWF, the overall density of seedlings was greater than that of saplings, which was much greater than mature

woody species indicating the presence of healthy recruitment in the forest. However, assessment of seedlings and saplings of individual tree species, found different regeneration status. Among the trees, *Albizia gummifera*, *Bersama abyssinica*, *Olea welwitschii*, *Pouteria adolfi-friederici*, *Prunus africana*, *Syzygium guineense* subsp. *afromontanum*, and *Vepris dainellii* had exhibited greater density of seedling than sapling, which in turn exhibited greater individuals than mature ones. Of the shrubs, *Landolphia buechananii*, and *Dracaena afromontana* had exhibited the highest seedlings and saplings densities ha⁻¹. These species have shown continuous establishment of seedlings and saplings. The presence of high numbers of seedlings, saplings, and young trees in a given population often, indicates successful regeneration (Saxena and Singh, 1984; Khan *et al.*, 1987; Feyera Senbeta, 2006; Getachew Tesfaye, 2008). The higher seedlings and saplings densities found in the present study can be attributed to several factors including the availability of suitable niche for germination and growth. Such factors may be edaphic conditions, shade tolerance of seedlings, canopy gaps and adequate number of seeds coupled with low or no seed predators. For example, Peter (1996) reported that canopy gaps play a major role in tropical tree establishment and growth.

Other tree species such as *Cordia africana*, *Maytenus addat*, *Polyscias fulva*, and *Schefflera abyssinica* were absent at seedling and sapling stages. The absence of the juveniles suggests that these species are suffering from declining population. They may not be sustaining themselves and may be at risk in the future. Similar findings have been reported for these species in Yayu Forest (Tadesse Woldemariam, 2003), in Wondo Genet Forest (Mamo Kebede *et al.*, 2013), in Jibat Forest (Tefaye Burju *et al.*, 2013), in Masha Forest (Abrham Assefa *et al.*, 2013) and in Gera Forest (Yohannes Mulugeta *et al.*, 2015). The absence of seedlings and saplings of these

species was partially attributed to the absence of a favorable environment for germination seeds and growth of seedlings. Factors such as lack of light due to a canopy, soil conditions and biotic factors (seed predators, poor seed dispersal, competition, and pathogen) may contribute to the absence of seedlings and saplings. In addition, selective harvesting of mature *Cordia africana* could particularly reduce the number of stems capable of producing reproductive material to sustain the population. Tadesse Woldemariam (2003) further suggested that seeds of pioneer species such as *Cordia africana* require pre-germination disturbance. In the case of *Schefflera abyssinica*, seeds require tree forks and or places that are rich in plant detritus and where water can easily reach the seeds to germinate. *Schefflera abyssinica* seedlings therefore prefer to grow on other plants and not observed on the ground (Ensermu Kelbessa and Teshome Soromessa, 2008). *Polyscias fulva* was also among the trees that showed lack of regeneration and needed further investigation into seed germination conditions. In line with regeneration, studies reported that abiotic and biotic factors are responsible for lack of regeneration of trees in forests (Augsburger, 1984; Nath *et al.*, 2005). Getachew Tesfaye (2008) further identified and reported that understory light environment, seedling herbivory, and human disturbances are among the major factors affecting regeneration. In addition, Feyera Senbeta (2006) suggested that poor regeneration could occur because most trees do not produce enough seed due to age or there may be seed depletion due to predators.

5.1.1.4 Plant community and environment relationship

Classification of natural vegetation into plant communities is important to understand factors affecting site productivity, regeneration, species composition, and management need of communities. In this study, the Jorgo Wato Forest is classified into five community types. Each plant community type was characterized by characteristic or indicator species that were able to

characterize the habitat of their community. Beside characteristic species, each community encompasses species commonly distributed across the communities. It is believed that the distribution of species is governed by several environmental factors. In the present study, the influence of altitude and slope were found significant. Furthermore, RDA ordination showed significant influence of altitude and slope on species distribution across plant community types. Although the influence of topographic variables (altitude, slope) appears significant, many other environmental variables such as soil nutrients, pH, canopy gap and other factors explain the variations in some species distribution. The distribution of many other species remained unexplained or unconstrained by environmental variables. This is in line with Clark *et al.* (1998) who reported topographic variables (altitude, slope, aspect) as an important environmental factor that causes spatial variation in tropical forest structure. Various studies on moist Afromontane forests in Ethiopia also reported significant correlations between topographic (altitude, slope, aspect) variables and species distribution (Kumelachew Yeshtela and Tamrat Bekele, 2002; Mamo Kebede *et al.*, 2013; Feyera Senbeta *et al.*, 2014; Admasu Addi *et al.*, 2016). Topographic variations bring variation in soil properties, solar radiation, temperature, moisture, microclimate, humidity, evaporation, and plant performance (Chapin *et al.*, 1987) which affects species distribution patterns and composition. However, the level or strength of the influence of environmental factors varies in different forests.

The study further found varied number of species in the identified plant community types. The highest species richness (79 species) was recorded in community I. The richness included a wealth of medicinal and WEPs used by local communities in the study area. The highest richness of this community could be explained partly by altitude and canopy gaps. Some of the plots of this community are located at higher altitudes and had little canopy compared to the others. Plant

communities in the different forest vegetation of Ethiopia have also shown a wide variation in species richness (Mamo Kebede *et al.*, 2013; Feyera Senbeta *et al.*, 2014; Admasu Addi *et al.*, 2016). Species richness among plant communities could vary due to habitat heterogeneity such as variation in site productivity (soil properties), canopy gaps, aspect, slope, altitudinal gradient, and disturbance (Denslow, 1987; Vilhar *et al.* 2015). Gaps due to mild disturbance can create higher richness resulting in different composition compared to closed canopy forests at different scales (Denslow, 1987). The low disturbance that opens the canopy may allow seedling to be established and light-demanding species to grow (Denslow, 1987; Vilhar *et al.*, 2015). In addition, intermediate disturbances could help the arrival and establishment of new species in disturbed forests (Feyera Senbeta, 2006). On the other hand, gaps due to severe disturbance may contribute to lower species richness and affect species composition (Sagar *et al.*, 2003).

The results further showed that JWF's Shannon diversity is high (between 3.15 and 3.57). Environmental factors like altitude, slopes and other environmental factors could have also contributed to the variation in species diversity between plant community types. Many researchers reported Shannon diversity values ranging from 1.54 to 4.18 for moist Afromontane forests in Ethiopia (Mamo Kebede *et al.*, 2013; Fekadu Gurmessa *et al.*, 2013; Feyera Senbeta *et al.*, 2014; Yohannes Mulugeta *et al.*, 2015; Admasu Addi *et al.*, 2016). The larger H' values (> 3.0) indicate the greater diversity of the species and the more stable the communities. Thus, the diversity values obtained in the present study fit within the reported range. Shannon evenness values are also quite high in the identified plant community types. These values indicate that most individuals in the community types are distributed equitably among the species. The evenness values found in this study are closely comparable to similar works in other moist

Afromontane forests such as those reported for Bonga Forest (Feyera Senbeta, 2006) and Wondo Genet Forest (Mamo Kebede *et al.*, 2013). High equitability is often reported in less disturbed or undisturbed forests (Sagar *et al.*, 2003).

5.1.2 Medicinal plants and usage

5.1.2.1 Medicinal plants used for human health problems

Diversity and distribution

The results have shown that the flora of the study area is composed of a great diversity of medicinal plants used for the treatment of a wide range of human health problems. The families richest in medicinal species are also among the 12 world flowering plant families, which are known to encompass the highest proportion of medicinal plants (RBG, 2017). Previous ethnobotanical studies in Ethiopia (e.g. Moa Megersa *et al.*, 2013; Getnet Chekole, 2017) have also documented a number of medicinal plants belonging to these families. A number of species in Lamiaceae, Asteraceae, Solanaceae, and Fabaceae constitute secondary metabolites such as essential oils, antibacterial, and antifungal products (Joudi and Bibalani, 2010). Lamiaceae family in particular is known for its aromatic compounds, which have aroma-therapeutic values. Thus, families represented by the highest number of medicinal plants can be considered as a target group in search for drug compounds.

In terms of distribution, a high proportion of medicinal plants were distributed in the forest, followed by farmland/borders and roadsides. Several studies (e.g. Peter, 1996; Thomas and Baltzer, 2002; Montagnini and Jordan, 2005; Primack and Corlett, 2005; Gibson and Gibson, 2007) reported that tropical forests are home to a large number of useful species, including medicinal plants, most of which remain undiscovered (Farnsworth and Soejarto, 1991;

Mendelsohn and Balick, 1995). Compared to other habitats, forests are structurally complex, have a heterogeneous niche, and often they get some level of protection from local communities. These together may have contributed to the high diversity of medicinal plants in forests. The high diversity of farmland/borders in medicinal plants could be attributed to human activities, which could favor the dispersal of propagules, especially of weedy and herbaceous medicinal plant species. This observation agrees with Mirutse Giday *et al.* (2009), who found farmlands as a source of a larger number of medicinal plants. These findings suggest that habitats such as forest/forest margins and farmlands/farm borders could be considered as target areas during collections of medicinal plants germplasms. Furthermore, the results showed that many of the medicinal plants were found in more than one habitat type. Wider habitat distribution of species could increase the availability and accessibility of the species for public use. From a conservation point of view, species found in different habitats are under less harvesting pressure compared to those that are locally restricted.

Growth forms and parts used as medicine

The result showed that medicinal plants reported for human healthcare were predominantly comprise herbs, followed by shrubs. This observation is consistent with previous ethnomedicinal plant studies in Ethiopia (Mirutse Giday *et al.*, 2009; Ermias Luleka *et al.*, 2013; Moa Megersa *et al.*, 2013). Herbaceous species are available naturally in almost all habitats including in forests. The greater availability in many habitats turn may be related to their short life cycle and seed dispersal, respectively, which are short and easily dispersed reproductive parts. On the other hand, increasing deforestation and expansion of agriculture contribute to increasing scarcity and inaccessibility of woody species (trees, shrubs) while favoring the growth of many weedy herbaceous plants, including medicinal species. It is assumed that the more available the plant

taxa in an area, the greater the likelihood of being used by local people (Campos and Ehringhaus, 2003). A similar reason could be given for predominant use of herbs. On the other hand, terms such as ‘herbs’ and ‘herbal medicine’ might suggest the greater availability of drug compounds more in herbs than do in other growth forms. Furthermore, herbs are smaller sized, easily harvested, processed and applied compared to other growth forms. These could be another reason for a higher proportion of herbs in documented medicinal plants.

With regard to medicinal parts, almost all parts of medicinal plants are used in the preparation of remedies. However, leaves and roots have been the most commonly used in the preparation of remedies. Previous ethnobotanical studies undertaken in Ethiopia (e.g. Mirutse Giday *et al.*, 2010; Moa Megersa *et al.*, 2013) also reported increased use of roots and leaves in traditional healthcare. Similar studies outside Ethiopia have reported the most frequent use of leaves and roots in their herbal medicines (Maroyi, 2011; Luseba and Tshisikhawe, 2013). Different reasons could be given for the frequent use of a particular part. In some cases, several medicinal plants or parts are used for the same medicinal purposes. In such a case, users may choose the most readily available, harvestable and applicable parts. These may contribute to increased use of a particular part. For example, the most frequent use of parts such as leaves might be related to ease of harvesting, preparation, and application. From scientific point of view, leaves are the main photosynthetic plant organ where many secondary metabolites are produced and temporarily stay before their translocation to permanent storage organ. Whatever the reasons behind this, the more frequent use or preference of a specific plant part/s may indicate the presence of bioactive compounds, which should be considered as a target in the search for bioactive compounds. In line with this, Evans (2009) argued that the most frequent use or a long

history of plant or plant parts use might suggest that this plant or plant parts are not toxic to human health.

In view of conservation, the most frequent use of roots and barks, especially from woody and slow-growing species is a concern because it is considered to be destructive; it could threaten and endangered species' survival (Cunningham, 1993; Hamilton, 2004). Species such as *Echinops longisetus*, *Securidaca longepedunculata*, and *Warburgia ugandensis* are being harvested for their roots in the present study areas and have become vulnerable to extinction locally. *Echinops longisetus* is already reported in IUCN Red List of threatened species under Least Concerned (LC) threat category (Vivero *et al.*, 2005). Although further assessment and evaluations are required, *Securidaca longepedunculata* and *Warburgia ugandensis* are under threat and need conservation attention. Similar experiences were reported from other parts of Ethiopia (Mander *et al.*, 2006) and elsewhere around the world (Maroyi, 2011; Hong *et al.*, 2015).

Health problems and application of medicinal plant remedies

Medicinal plants documented in this study were reported to treat a wide range of health problems. These include broken bones, wounds, rabies, febrile, migraine, stomachache, and toothache and these showed high informant consensus values, which might indicate more prevalence of the health problems in the study area. High informant consensus value might also indicate more agreement among informants on the medicinal plant species reported for treatments of the health problems. These health problems were also among common health problems in many parts of Ethiopia and have been treated by medicinal plants (Kebu Balemie *et*

al., 2004; Haile Yineger *et al.*, 2008; Mirutse Giday *et al.*, 2009; Miruste Giday *et al.*, 2010; Getnet Chekole, 2017).

It was found that most of the health problems were treated by more than one medicinal plants. Health problems treated with the highest number of medicinal plants were stomachache, rabies, snakebite/venom, toothache, migraine and febrile. The use of different plant species for the same application might increase treatment options. For example, when a particular plant is not available due to various reasons such as seasonality or accessibility, the alternative species could be used for the treatment. The availability of different medicinal plants for the same treatment also contributes to health security by enabling individuals to choose the most effective remedies. The presence of alternative remedies might also reduce harvesting pressure on medicinal plants.

It was found that some medicinal plants have shown high use reports and high informant consensus values indicating the existence of high usage agreement among local communities for the treatment of certain health problems. Medicinal plants with high use reports and informant consensus values can be considered culturally significant species (Heinrich *et al.*, 1998). These were *Croton macrostachyus*, *Echinops longisetus*, *Capparis tomentosa*, *Dracaena steudneri*, and *Ocimum lamiifolium*. These species including a number of medicinal plants such as *Ehretia cymosa*, *Pentas schimperiana*, *Loxogramme abyssinica*, *Croton macrostachyus*, *Ocimum urticifolium*, and *O. lamiifolium* had also shown high use report and high informant consensus. The high consensus (fidelity values) might indicate the high healing potential of these species in the treatment of a particular health problem. Besides, plants having high fidelity values might

suggest the presence of phytochemical compounds in the plant parts (Mirutse Giday *et al.*, 2007; Tabuti *et al.*, 2012) and need further phytochemical and pharmacological studies.

Many of the medicinal plants showing high use report have also shown medicinal applications in different parts of Ethiopia. Among these, *Phytolacca dodecandra* has long been one of the most popular medicinal plants used traditionally for numerous ailments such as anti-helminthes, eczema, gonorrhea, abortion, malaria, rabies, and liver disease (Jansen, 1981; Fekadu Fullas, 2001). *P. dodecandra* was also reported for treatment of leech, helminthes, and skin disease in Ankober District (Ermias Lulekal *et al.*, 2014), for gonorrhea in Wayu Tuka (Moa Megersa *et al.*, 2013), for malaria in Wonago (Fiseha Mesfin *et al.*, 2009). *Brucea antidysenterica* had been reported for treatment of various health problems cancer, diarrhea, evil eye, leishmaniasis, rabies, wound, skin disease (Jansen, 1981; Fekadu Fullas, 2001), dysentery, haemorrhoids, weight loss, fever, and diarrhea (Asmare Amuamuta *et al.*, 2014). The same source reported the use of *Securidaca longepedunculata* for treatment of a cough, gonorrhea; leprosy, syphilis, and taeniasis (Fekadu Fullas, 2001). Another most frequently used species was *Embelia schimperi* which had been earlier reported for treatment of tapeworms and roundworms (Jansen, 1981), for gastrointestinal complaints (Mirutse Giday *et al.*, 2009), for gastrointestinal and parasitic ailments (Ermias Lulekal *et al.*, 2013). The same source reported the highest use report of *Ocimum lamiifolium* for treatment of febrile, *Croton macrostachyus* for dermatological health problems. *C. macrostachyus* was also reported for many other health problems including bleeding wound (Jansen, 1981; Dawit Abebe and Ahadu Ayehu, 1993; Fekadu Fullas, 2001). *Croton macrostachyus* was also found to be useful as anti-malaria, diarrhea, and blackleg (Mirutse Giday *et al.*, 2007). Leaves of *Datura stramonium* was reported for treatment of cough,

fever, asthma and skin disorder (Debnath and Chakraverty, 2017). *Justicia schimperiana* had been reported for treatment of malaria, pellagra, digestive disturbances, drying and peeling of skin (Jansen, 1981), and for lice, diarrhea, jaundice, and liver disease (Fekadu Fullas, 2001). *Dracaena steudneri* had been reported for the treatment of wound and *Pentas schimperiana* reported for epilepsy in Wonago (Fiseha Mesfin *et al.*, 2009). In general, most of the medicinal plants reported in this study were ethnomedicinally reported elsewhere for treatment of various health problems. The cross-cultural medicinal applications of these species suggest the presence of bioactive compounds and recommended for phytochemical screening and pharmacological testing. On the other hand, the most frequent usage (high fidelity) and the greater therapeutic uses might suggest conservation concern. Species having high fidelity and therapeutic values might be under the focus of many users (collectors) and might face local extinction risk if they are rare and restricted in distribution (Cunningham, 1993; Hamilton, 2004).

Preparations and mode of administration

The preparation of remedies was mainly from freshly harvested plant parts, while the use of dried plant parts was less common. According to informants' view, fresh materials are more potent in healing than the dried ones. They thought that medicinal plants might lose medicinal value upon drying. The predominant use of fresh materials has been reported in different studies in Ethiopia (Kebu Balemie *et al.*, 2004; Haile Yinger *et al.*, 2008; Fiseha Mesfin *et al.*, 2009; Mirutse Giday *et al.*, 2009). From scientific perspectives, many factors including plants growth stage and storage period after harvest are believed to affect the phytochemical constituents of plants. In line with this, Raya *et al.* (2015) found a higher amount of phytochemical compounds in young plant parts compared to mature parts. This reflects that phytochemical content might decrease with increasing plant maturity and support the use of fresh material in most traditional

medicine. The same source also found that prolonged storage of plant parts reduced their phytochemical contents. Thus, although further investigations on different parts of species are needed, the use of fresh materials in the traditional herbal preparations has possible scientific evidence. On the other hand, the higher proportion of fresh material in preparation of remedies indicates availability and accessibility of medicinal plants in the study area.

In most of the herbal preparations, a single species or plant part was employed while in some multiple plant parts or species were employed. Various authors suggested that the use of more than one plant species to prepare a remedy for ailments is attributed to the additive or synergistic effects and thereby enhances the healing power of the remedies (Dawit Abebe and Ahadu Ayehu, 1993; Dawit Abebe, 2001; Mirutse Giday *et al.*, 2009; Hong *et al.*, 2015). It could also serve as buffer to reduce the side effects of the remedies. Another reflection on the use of multiple plants or parts possibly adds anti-health factor or toxicity, which could aggravate the side effects of remedies. In the above two reflections or suggestions, there could be possibilities depending on species used, dosages and types of diseases.

The herbal remedies were prepared in various forms, largely juice or sap followed by infusion and concoction. This might be related to the greater number of reported internal health problems, which often treated through oral application of remedies. The oral application was the most frequently used route, followed by dermal application. Mirutse Giday *et al.* (2009) suggested that oral application is often preferred to permit rapid physiological reaction and speeds up healing. This needs further comparative investigation. Instead, the more common use of oral application

might be due to the more reported number of internal health problems, which involve the oral application of remedies.

The results further showed that different ingredients such as salt followed by butter, coffee, milk, honey, garlic, and ginger were used together with herbal preparations. The use of these additive substances in herbal remedies could be attributed to possible additive effects of the remedies and enhance healing potential of the remedies, or to improve the flavor of the remedies; it could also be used to buffer the remedies and reduce their side effects on human body.

5.1.2.2 Ethnoveterinary plants

Diversity and distribution

The flora of the study area was also rich in ethnoveterinary medicinal plants showing 91 species claimed for use in the treatment of various livestock health problems. A good number of these (64%) were also applied for the treatment of human health problems. This concurs with the fact that ethnoveterinary medicine has, in many societies, developed alongside human ethnomedicine, with practitioners of one being knowledgeable about the other (McCorkle and Mathias-Mundy, 1992). As indicated in the results the number of medicinal plants reported for livestock only is low compared to that of the human. This might be related to variation in number of health problems or it might be related to more emphasis for treatment of human health problems. The ethnoveterinary plants reported in this study have also ethnomedicinal applications in other parts of Ethiopia. For example, 35 ethnoveterinary plants reported in the present study were also documented in Moa Megersa *et al.* (2013) for the treatment of human and livestock health problems; 16 species were in Ermias Lulekal *et al.* (2014); 15 species were in Fiseha Mesfin *et al.* (2009). Some of the ethnoveterinary species were also reported for the

treatment of various human health problems. For example, *Buddleja polystachya* was reported for the treatment of sudden illness in human in Wonago (Fiseha Mesfin *et al.*, 2009). *Schefflera abyssinica* was reported for snakebite in Lebo Kemkem (Getnet Chekole *et al.* 2015). The use of the same plant species for medicinal purposes by people in different geographic areas might suggest the presence of phytochemical substances having curative values in these species. The common use of medicinal plants among people of different culture indicates the inter-cultural sharing of ethnoveterinary plant use knowledge.

The plant families contributing more number of ethnoveterinary medicinal species (Asteraceae, Fabaceae, Euphorbiaceae, and Rubiaceae) are reportedly important in contributing more number of medicinal plant species in Ethiopia (e.g. Fiseha Mesfin *et al.*, 2009; Moa Megersa *et al.*, 2013). The wider use of species belonging to these families could perhaps due to their dominance in the study area. Besides, Asteraceae is among the world's top producers of alkaloids having very potent pharmacological properties (Evans, 2009).

Growth forms and parts used in ethnoveterinary medicine

In terms of growth forms, herbaceous plant comprises the highest proportion of ethnoveterinary medicinal plants. This agrees with many ethnoveterinary research reports (Mirutse Giday and Tilahun Teklehaymanot, 2013). The common use of herbaceous species could be related to their availability and abundance in many habitats and might be related to ease of harvesting. The common use of herbaceous plants as ethnoveterinary remedies was also reported in other studies outside Ethiopia (Tariq *et al.*, 2014; Parthiban *et al.*, 2016).

The medicinal plant parts used in the preparation of ethnoveterinary medicines include almost all parts of plants. However, roots and leaves were the most frequently used parts for treatment of animal health problems. This observation agrees with other ethnoveterinary studies undertaken in Ethiopia (Mirutse Giday and Tilahun Teklehaymanot, 2013; Ermias Lulekal *et al.*, 2014; Gebremedhin Romha *et al.*, 2015). The most frequent usage of roots and leaves in ethnoveterinary medicines was also reported elsewhere outside Ethiopia (Chinsembu *et al.*, 2014; Tariq *et al.*, 2014; Parthiban *et al.*, 2016).

Herbal preparations and mode of application

The result showed that most of the health problems reported in the study area were affecting cattle, which might be due to more occurrences of health problems affecting cattle. Similar findings were reported from Ada'ar District in Afar Region (Mirutse Giday and Tilahun Teklehaymanot, 2013) and in Ankober District in Amhara Region (Ermias Lulekal *et al.*, 2014). The health problems were treated predominantly using fresh plant materials for preparation of remedies. This is in agreement with communities in other parts of Ethiopia with different culture (e.g. Kebu Balemie *et al.*, 2004; Haile Yinger *et al.*, 2008; Gebremedhin Romha *et al.*, 2015) and elsewhere outside Ethiopia (Merwe *et al.*, 2001). Remedies were largely, prepared by crushing the medicinal part (s) and mixing it with water in the form of infusion and then drenching. This finding is in agreement with Merwe *et al.* (2001), Ermias Lulekal *et al.* (2014), Gebremedhin Romha *et al.* (2015) and Parthiban *et al.* (2016). The quantities applied were based on estimation and varied among informants report. Like that of humans, lack of quality and standardized measurements and dosage matters have been the main critiques on the use of ethnoveterinary plants (Maroyi, 2011; Hong *et al.*, 2015)

The remedies were applied mainly through oral, which is commonly used for the treatment of internal health problems. Oral is the widely reported route for the application of not only ethnoveterinary remedies but also human remedies in Ethiopia (Mirutse Giday and Tilahun Teklehaymanot, 2013; Gebremedhin Romha *et al.*, 2015) and outside Ethiopia (Merwe *et al.*, 2001; Chinsembu *et al.*, 2014; Parthiban *et al.*, 2016).

5.1.2.3 Phytochemical and pharmacological basis of medicinal plants

The traditional uses of medicinal plants reported in the present study were justified by scientific findings on their phytochemical contents and pharmacological activities. Many of the medicinal plants including those showing high informant consensus values were found to possess phytochemical and pharmacological properties. Phytochemical screening has confirmed the presence of flavonoids, tannins, saponins, terpenoids, glycosides, sterols, coumarins, quinones and higher fatty acids in different parts of *Stereospermum kunthianum* (Aliyu *et al.*, 2009). These phytochemical compounds provide various therapeutic properties (Evans, 2009). For example, flavonoids were found to exhibit several biological effects such as anti-inflammatory, antimicrobial, antiviral, antiulcer, hepatoprotective, antitumor, and antioxidant activities (Dixon and Pasinetti, 2010). Similarly, tannins have long been recognized to exhibit quite potent antibiotic activities including toxicity for fungi and bacteria (Evans, 2009). Many alkaloids were also documented for their antiproliferative, anti-inflammatory, antioxidant, enzymatic inhibitory and antimicrobial activities (Evans, 2009). Phytochemical screening of *Ocimum lamiifolium* leaf extracts confirmed the presence of tannins, sterols, flavonoids, saponins, terpenoids, and alkaloids (Dawit Abebe *et al.*, 2003; Namulinduwa *et al.*, 2015). Aqueous extracts of leaves, fruits and stem of *Phytolacca docandera* are known to contain alkaloids, steroids, phenols,

triterpenoids in its leaves (Dawit Abebe *et al.*, 2003; Namulinduwa *et al.*, 2015). The berries of *P. docandera* are known to contain saponins, a compound showing molluscicidal properties (Fekadu Fullas, 2001). A crude leaf extract of *Brucea antidysenterica* and *Croton macrostachyus* showed the presence of flavonoids, saponins (Asmare Amuamuta *et al.*, 2014), alkaloids, phenols, triterpenoids and steroids (Seid Mohammed and Ayisha Ahimad, 2015; Abraham Dilnesa *et al.*, 2016). *Brucea antidysenterica* is known to contain potent antileukemic compounds such as quassinoids, bruceantin, and bruceantanol (Fekadu Fullas, 2001).

Similarly, phytochemical screening of *Justicia schimperiana* leaves (Habtamu Abebe *et al.*, 2014) confirmed the presence of alkaloids, polyphenols, flavonoids, glycosides, phytosterols, saponins, triterpenes, and quinines. Phytochemical investigation of *Echinops longisetus* flower head, root, leaf, and stem showed the presence of alkaloids, saponins, phytosterols, polyphenols and carotenoids in the different parts of the plant. Phytochemical investigations in *Embelia schimperi* berries found alkaloid benzoate (Dawit Abebe *et al.*, 2003; Tariku Nefo and Aman Dekebo, 2017). *Ehretia cymosia* was reported to contain alkaloids, terpenoids, and flavonoids (Pascaline *et al.*, 2011). Phytochemical investigations of *Millettia ferruginea* seeds and *Warburgia ugandensis* leaves found the presence of saponins, polyphenols, alkaloids and glycosides (Asfaw Debella *et al.*, 2007). Several alkaloids and tannins have been reported to be present in different parts of *Datura stramonium* (Fekadu Fullas, 2001; Dawit Abebe *et al.*, 2003; Debnath and Chakraverty, 2017). Phytochemical investigations of leaves of *Buddleja polystachya* found flavonoides, alkaloids, terpenoides, cardiac glycosides, oils and saponin compounds (Berhanemeskel Atsbeha *et al.*, 2014).

Many other medicinal plants such as *Achyranthes aspera* (Biruhalem Taye *et al.*, 2011), *Asparagus racemosus*, *Carrisa spinarum*, *Clutia abyssinica*, and *Clerodendrum myricoides*, *Ehretia cymosia* reported in this study were found to contain different phytochemical compounds (Pascaline *et al.*, 2011).

These bioactive compounds have been known for many years to exhibit biological activity, such as effects on the central nervous system (Fekadu Fullas, 2001), antimicrobial, stimulants, pain killer, antitumor, fungicidal, and anthelmintic activity (Pengelly, 2004). The same source noted that flavonoids are known to have antioxidant, antiviral, hepatoprotective, anti-inflammatory, cardiovascular and antihypertensive therapeutic effects (Pengelly, 2004). The pharmacological effects of tannins include astringent, antibacterial, antifungal, antioxidant effects and enzymatic inhibition, prevent bleeding wound, reduce inflammation and swelling (Pengelly, 2004). Similarly, saponins have a range of effects including wound healing, anticancer, anti-inflammatory, antiallergic, immunomodulatory, antiviral, antihepatotoxic, antidiabetic: hypoglycaemic, antifungal, molluscicidal, cardiac activity such as hemolytic, antithrombotic, hypocholesterolemic, anti-stress, sedative, expectorant, diuretic and digestive effects (Pengelly, 2004).

The phytochemicals present in these plants are responsible for pharmacological effects of the reported plants (Evans, 2009). The pharmacological activities of reported medicinal plants against harmful microbes were reported in different literature. Crude extract of *Buddleja Polystachya* leaf has shown anti-inflammatory (Al Ati *et al.*, 21015), cytotoxic potentials and antimicrobial effects (Fawzy *et al.*, 2013). Leaf extracts of *Croton macrostachyus* showed

antibacterial activities against *Staphylococcus aureus* and *Shigella sonnei* (Getnet Chekole *et al.*, 2016). Mirutse Giday *et al.* (2009) found the pharmacological activities of *Croton macrostachyus*, *Embelia schimperi*, *Phytolacca dodecandra*, *Ricinus communis* against helminths and bacteria. Extracts of *Ocimum lamiifolium* leaves had shown significant antiplasmodial and antibacterial effects (Teklit Gebregiorgis and Shalkh, 2015; Atetetgeb Kefe *et al.*, 2016) and against different microbial strains (Ermias Lulekal *et al.*, 2013). Crude extract of *Phytolacca docandera* had shown inhibition against bacterial growth (Biruhalem Taye *et al.*, 2011); seed extracts of *Brucea antidysenterica* had shown a significant effect against Plasmodium parasite (Atetetgeb Kefe *et al.*, 2016); leaf and seed extracts of *Datura stromonium* has shown anti-microbial activities (Debnath and Chakraverty, 2017); crude extracts of *Dracaena steudneri* and *Capparis erythrocarpos* (Kisangau *et al.*, 2009) portrayed the most significant antifungal activity; extracts from *Echinops longisetus* leaf and stem showed strong inhibitory activity against *Staphylococcus aureus*; root and flower extracts had shown lethal activity against earthworms and molluscicidal activity (Hymete *et al.*, 2005). *Embelia schimperi*, *O. lamiifolium* and *Vernonia amygdalina* have been reported to possess antimicrobial effect against different microbial strains (Ermias Lulekal *et al.*, 2013). Embelin compounds found in the berries had shown lethal activity against hookworm larvae (Yared Debebe *et al.*, 2015) and antimicrobial effect against *Staphylococcus aureus* strains (Rondevaldova *et al.*, 2015). The crude extracts of *Millettia ferruginea* seed and *Warburgia ugandensis* leaves demonstrate the stronger larvicidal effect (Asfaw Debella *et al.*, 2007). The antibacterial, antiplasmodial, analgesic, anti-inflammatory, antidiarrhoeal and antioxidant effects of *Stereospermum kunthianum* extract have been experimentally demonstrated (Aliyu *et al.*, 2009; Oloche *et al.*,

2016). Apart anti-microbial and anti-fungal activities, the leaf extracts of *Pentas schimperiana* were found to exhibit high anti-diabetic activity (Tadele Dinku *et al.*, 2010).

Indeed, the presence of diverse chemical compounds in different parts of the reported medicinal plants and antimicrobial activity testing all give significant credibility to the usage of documented medicinal plants traditionally used by local people. The literature on the therapeutic uses, phytochemical and pharmacological investigations on species of high fidelity values showed that ethnobotanical study such as the use informant consensus approach is a suitable method for targeting medicinal plants for drug discovery and pharmacological evaluation against wide range of diseases and disease causing organisms. The results further suggest that the development and use of such local resources would help both the government and the public in many ways: reduce foreign currency expenditure and accessible drug products.

5.1.2.4 Ethnomedicinal plants knowledge

The results revealed that the local people of the study area possess rich knowledge of medicinal and their uses. This shows that ethnomedicinal knowledge has still played an important role in the healthcare of local communities. The medicinal plant diversity and their uses reported in the present study reflect the presence of rich ethnomedicinal knowledge. The results showed that most of the informants acquired the knowledge largely from own families. Besides, two traditional healers reported that they acquired by relating plants morphological observations with treated health problems. This approach of medicinal plant knowledge acquisition is related to the concept known as the Doctrine of Signature. Many traditional healers throughout the world use this approach for the identification of plants and plant parts having therapeutic values (Bennett, 2007). In line with this, Etkin (1986) suggested that the selection of medicinal plants or parts by

users could be initiated in accordance with the belief that certain attributes (e.g. leaf shape or color), which serve to indicate the utility relative to a particular ailment or disease. However, Bennett (2007) considers the Doctrine of Signatures not so effective. Instead, plant physical properties including odor/smell and taste might correlate with the presence of phytochemical attributes (e.g. alkaloids, terpenes).

Although it lacks scientific support, this belief has been widely used around the world by many people having different cultural groups having different cultural backgrounds. The local people including traditional healers, through their empirical observations and long year healing experiments, have been able to ascertain the curative value of their medicinal plants or parts. This local system of knowledge acquisition should not be undermined. It should be considered like other ethnobotanical information for further evaluation of phytochemical properties.

The medicinal plants' knowledge was variably held among some social groups. The study found that the medicinal plants' knowledge was not evenly distributed among some social and geographic variables. Earlier studies (Begossi *et al.* 2002; Byg and Balslev, 2004; Quinlan and Quinlan, 2007; Camou-Guerrero *et al.*, 2008) suggested that several factors have accounted for differences in ethnomedical knowledge. In this study, the numbers of medicinal plants known and reported were positively correlated with informants' age, gender, traditional healing 'profession' and accessibility to forest vegetation. Male informants knew a significantly greater number of medicinal plants and their uses than do female informants ($p < 0.01$). This result agrees with Tesfaye Hailemariam *et al.* (2009) and Hong *et al.* (2015) who found more medicinal plant knowledge among male informants. Camou-Guerrero *et al.* (2008) suggested

that the variation of ethnobotanical knowledge between genders is due to the social division of labor and responsibilities. Males tend to be more responsible for field agricultural activities than do female counterparts who are often limited to home-based activities. This avails more opportunities for interaction with plants of various uses found in agricultural landscapes and natural areas. Furthermore, cultural accounts showed that there has been a gender difference in traditional medicinal practices, in which the majority of healers are males. For example, the transmission of ethnomedicinal knowledge along with a family line favors males (Kleinman, 1980, Mirutse Giday *et al.*, 2009; Hong *et al.*, 2015) often the first-born son. This might create more opportunity for males to be knowledgeable than females.

Similarly, traditional healing experience of traditional healers was positively and significantly associated to medicinal plant knowledge possession, which is consistent with Getnet Chekole *et al.* (2015) and Haile Yineger *et al.* (2008) who found positive association between experience and medicinal plant knowledge possession. Many ethnobotanical notes (Martin, 1995; Cotton, 1996) have reported that ethnobotanical knowledge including that of medicinal plants is mainly the result of long years' observations, learning, and experimentation. The healers' greater medicinal plants knowledge possession could be explained in view of their primary participation in traditional healing practices. They have various experiences and more exposure to many different plants and health problems for which they test and acquire unique knowledge on them than other members of local communities. Age was another factor that showed a significant association with medicinal plants knowledge, which is consistent with ethnomedicinal studies in other parts of Ethiopia as reported in Haile Yineger *et al.* (2008) among Oromo ethnic group in southwestern Ethiopia, in Sheko District southwest Ethiopia (Giday *et al.*, 2010), Mirutse,

in Dek Island (Tilahun Teklehaymanot, 2009), and in Libo Kemkem District (Getnet Chekole *et al.*, 2015). In all these cases, the younger informants (< 25 years) were able to identify and report less number of medicinal plants and their uses than older informants (> 25 years). This finding is consistent with many ethnomedicinal studies done on herbal remedy knowledge distribution among indigenous groups in Ethiopia and outside. For example, Voeks and Leony (2004) and Beltrán-Rodríguez *et al.* (2014) found positive association between age and medicinal plants knowledge in eastern Brazil; Ryan *et al.* (2005) reported similar findings among ethnic communities of Manus island. Indeed, age is naturally assumed to have an association with the acquisition of plant knowledge and older individuals tend to accumulate more knowledge (Byg and Balslev, 2004; Beltrán-Rodríguez *et al.*, 2014) and young generation usually learn from elders.

Accessibility to forest has also contributed to the possession of more medicinal plant knowledge. Informants residing closer to the forest were able to know and report a greater number of medicinal plants. The more the available the species, the more the chance to learn the use of plant species. This agree with Campos and Ehringhaus (2003) who suggested that availability or access to plant diversity in a given location can be attributed to the acquisition of ethnobotanical knowledge and increase use possibilities of plants. Proximity to forest might create ease of harvest where there is knowledge of plant utility.

Multiple linear regression analysis identified age, gender, traditional healing profession, and proximity to forest together as predictors of medicinal plant knowledge possession in the study area. These variables explained 34.7% of the variability in medicinal plants knowledge

possession among informants. The remaining variation in knowledge could be explained by other factors possibly differences in cultural interactions, local networks, attitudes/interest towards knowing medicinal plants. Quinlan and Quinlan (2007) has also found age and gender among predictors of medicinal plant knowledge possession in Caribbean horticultural village.

On the other hand, the results showed that medicinal plant knowledge was not affected by education. This observation agrees with Quinlan and Quinlan (2007), Haile Yineger *et al.* (2008) and Beltrán-Rodríguez *et al.* (2014) who reported an insignificant contribution of education to medicinal plants knowledge possession. In other studies, education is reported among the variables affecting medicinal plant knowledge (Alvarado-guzmán *et al.*, 2009). Formal education possibly leads to a loss of ethnobotanical knowledge where there is an increasing acculturation. It is believed that educated people may seek modern medical treatment more readily than uneducated ones. In the present study, it was found that most of the interviewed informants had attended elementary school in the past but now they have dropped out schooling and engaged in farm activities, which might have reduced the influence of education on ethnobotanical/medicinal plants knowledge through acculturation.

Similarly, there was no significant knowledge difference among informants due to proximity to formal health centers. There has been common believes that the availability of modern healthcare appears to compete with traditional medicinal plant use and result in loss of associated knowledge. Given a choice such as closer to formal health centers, communities would prefer modern treatment to traditional medicine and become less familiar with medicinal plants (Zent and Lopez Zent, 2004). This study, however, found no significant influence on medicinal plants

knowledge possession due to accessibility to health centers. This observation is consistent with Mirutse Giday *et al.* (2009) who reported similar finding in Bench area, southwestern Ethiopia. Agroecological settlement variation was also not contributing to medicinal plant knowledge variation. The numbers of medicinal plants known and reported by informants from different agroecological zones were not significantly different.

5.1.3 Ethnobotany of wild edible plants

5.1.3.1 Diversity and distribution

The documented 39 wild edible plants in the present study provided closely comparable information with the records of previous studies on WEPs of Ethiopia. For instance, Tilahun Teklehaymanot and Mirtuse Giday (2010) documented 38 WEPs used by Kara and Kwego people in lower Omo valley, south Ethiopia. The reported WEPs may be indicative of the presence of rich WEPs and associated indigenous knowledge in the study area. Of the documented WEPs, 32 (82%) were reported in literature Zemedede Asfaw and Mesfin Tadesse (2001) and Ermias Lulekal *et al.* (2011), while six (15 %) are new records. The new records will enrich the existing information of WEPs of Ethiopia documented in Ermias Lulekal *et al.* (2011).

The Myrtaceae, Moraceae, and Solanaceae families contributed more number of WEPs to the total WEPs in the study area. These families are among the top families of Ethiopia's flora (Ensemu Kelbessa and Sebsebe Demissew, 2014). Moreover, Moraceae and Solanaceae are among the top twelve families represented by more number of WEPs in Ethiopia (Ermias Lulekal *et al.*, 2011). The predominant growth form of the WEP was herbs, followed by shrubs, trees and lianas. A similar proportion of WEPs growth forms were reported in previous studies (Zemedede Asfaw and Mesfin Tadesse, 2001; Kebu Balemie, 2014).

The habitats of most WEPs (forest and forest margins, agricultural fields and borders) agreed with Tena Regassa *et al.* (2014) who found more number of WEPs from forests and agricultural lands. In another study, Mersha Ashagre *et al.* (2016) reported the highest number of WEPs from woodland vegetation. The proportion of wild edible plants in particular areas might be associated with the dominance of natural vegetation of that particular study area. For instance, where forest and forest patch are common, a high proportion of WEPs might be sheltered in the forest. Similarly, woodland could be the main source where there were no or less agricultural or forestlands. Many species were found to occur in two or more habitat types. In relation to distribution, there were variations among the species. Some WEPs were restricted to forests or farmlands, or woodlands and others. Some were reported to occur both in and outside their natural occurrence or habitats perhaps due to dispersal, mechanisms or they could be relic species that survived deforestation and agricultural expansion, or they might be domesticated or managed in their private farms. The abundance of such species outside their natural habitat is low or few individuals as seen in the case of *Cordia africana*, which is expected to occur naturally in forest and forest edges. It occurred outside forests in forest remnants as isolated individual tree, around churches, in grassland, cultivated fields, and homegardens. Similarly, *Syzygium guineense* subsp. *afromontanum* is expected to occur in forest and forest edges and riverine vegetation. However, it also occurred in farmlands, farm borders, and homegardens as a single tree. These species can easily disappear with minimal disturbance when they occur or grow outside their natural habitats.

5.1.3.2 Wild edible plant parts and mode of consumption

The finding, in this research, of the fruit to be the most frequently documented edible plant part followed by leaves is in agreement with many other ethnobotanical works in Ethiopia (e.g.

Zemedet Asfaw and Mesfin Tadesse, 2001; Tilahun Teklehaymanot and Mirutse Giday *et al.*, 2010; Ermias Lulekal *et al.*, 2011; Kebu Balemie, 2014). Elsewhere outside Ethiopia, similar results were reported in Ghorbani *et al.* (2012) and Urso *et al.* (2015). The more frequent use and preference to fruits perhaps attributed to the good taste and lack of processing prior to consumption. Other reasons could be greater availability of edible parts might also increase frequent access and encourage consumption. Similar reasons were suggested regarding the frequent and preference of fruits elsewhere around the world (Ju *et al.*, 2013; Urso *et al.*, 2015). Fruits are often rich in water and sugar, they can immediately suppress starvation and thirsty upon consumption.

Most of the leafy edibles reported in the present study were consumed during food shortage and consumed after cooking. This agrees with previous studies reported in Guinand and Dechassa Lemessa (2000), Tilahun Teklehaymanot and Mirutse Giday (2010), Getachew Addis *et al.* (2013) and Kebu Balemie (2014). Similarly, the underground parts (root tubers) were also consumed during food shortages and remove the feeling of thirsty because this plant part is known to be highly energetic.

5.1.3.3 Preference, consumption, and seasonality of wild edible plants

As in many parts of the world, wild plant gathering and consumption has been part of local culture in the study area. This old practice is still maintained among many rural communities in Ethiopia. The reasons for the collection of WEPs were mainly to reduce hunger and/or suppress thirst during field stay and/or to fill the seasonal food gap due to food shortages and rarely used as nutraceuticals. The gathering task and consumption of wild edible plants vary across socioeconomic groups such as age and gender. The proportion of WEPs consumed by various

social groups varies based mainly on the taste quality of edible plants and the availability of adequate grain food at home. The results further revealed that during normal times, 15 (38.5%) of WEPs were consumed by all age and gender groups as snacks; 16 (41%) were consumed solely by children as snack. These are less tasty fruits, seeds, and nectar. The consumption of these species by children during their stay in the field might be due to their limited tolerance to starvation compared to adults and forced to eat by starvation. Some 20% of the WEPs were consumed by households who face seasonal food shortage. These are commonly consumed by the households who lack cash sources to buy grain food during seasonal gaps often between rainy season and upcoming crop harvest. This agrees with Guinand and Dechassa Lemessa (2000), Zemedu Asfaw and Mesfin Tadesse (2001), Tilahun Teklehaymanot Mirutse Giday (2010) and Ermias Lulekal *et al.* (2011) who have reported the roles of WEPs as supplementary during normal times and emergency role during food shortages. In many parts of Africa, a wide range of such species have contributed to local survival strategies at times of severe food shortage (FAO, 1999). Such food plants have a characteristically unpleasant taste, have side effects, often cause stomach complaints, constipation, diarrhea and even intoxication, prolonged harvesting and preparation time (Guinand and Dechassa Lemessa, 2000; Getachew Addis *et al.*, 2013; Kebu Balemie, 2014). In the present study, tubers from *Dioscorea praehensilis* and *D. schimperiana* took long harvesting and processing (boiling) time before consumption.

The gathering and consumption seasons of WEPs vary depending on the availability of edible parts. Fruits and seeds of most WEPs were largely available between January and June while green leafy vegetables were available following rainfall often between July and September. Previous studies have also reported seasonality in gathering and consumption of WEPs (Guinand

and Dechassa Lemessa, 2000; Zemde Asfaw and Mesfin Tadesse, 2001; Kebu Balemie, 2014) with elevated intake particularly severe food shortage as part of survival strategies.

5.1.3.4 Challenges/barriers to consumption of WEPs

Despite their crucial role in food security, various factors have challenged the continued use of many WEPs. A large number of people are still gathering and consuming some popularly used wild species. Overall results, however, revealed that the collection and consumption of WEPs has decreased over the years. Different factors have been reported for the declining collection and consumption of different WEPs. According to most informants, poor taste, fear of health hazards, and people's affordability to buy grain food are all contributing to declining consumption of some WEPs. For example, it is now rare to find people who consume less tasty WEPs such as *Caylusea abyssinica*, *Rumex abyssinicus*, *R. nepalensis*, *Dioscorea praehensilis* and *D. schimperiana*. This applies also to less tasty fruits/seeds such as *Bridelia micrantha*, *Ehretia cymosa*, *Ficus vasta*, and *Momordica foetida*. In line with these challenges, various authors (e.g. Guinand and Dechassa Lemessa, 2000; Getachew Addis *et al.*, 2013; Kebu Balemie, 2014) reported health hazards happened due to consumption of some WEP group. For instance, Getachew Addis *et al.* (2013) reported skin and mouth irritation upon consumption of *Amorphophallus gomboczianus*; joint paralysis due to consumption of *Justicia ladanoides*; various abdominal pains due to consumption of *Ficus vasta*, *Ximenia caffra*, *Balanites aegyptiaca*, *Corchorus tridens*, *Dobera glabra*, and *Tamarindus indica*. In the present study, informants reported that parents advise their children not to consume WEPs because they fear that wild fruits/seeds can be poisoned by poisonous animals and they worried that consumption of such fruits could affect the health of their children.

Social stigma in relation to gathering and consumption of famine food plants has also contributed to the declined consumption of some wild edible plants. Similar challenges were reported in previous studies (e.g. Guinand and Dechassa Lemessa, 2000; and Kebu Balemie, 2014). Other reason for the declined consumption was loss of species. For instance, *Carissa spinarum*, *S. guineense* subsp. *macrocarpa* and *Ximenia americana* are not available now in areas where they were found in the past. The gradual loss of natural vegetation is resulting in the disappearance of many valuable wild species. This observation witnessed that increasing scarcity or loss of plants may enhance the declined uses of the plants and loss of knowledge (Cunningham, 2001). The results showed that the challenges reported in this study have direct or indirect contribution to the declining diversity of the local food system and associated indigenous knowledge. These suggest the need for habitat conservation and preservation of indigenous knowledge.

5.1.3.5 Ethnobotanical knowledge of wild edible plants

Ethnobotanical knowledge possession is influenced by many factors including gender, age, education, social and economic status, roles, and responsibilities in the home and within the community (Martin, 1995; Beltrán-Rodríguez *et al.*, 2014). The present study has found that the numbers of WEPs known and reported by informants of different age, gender, education, and geographic variables were not significantly different ($p > 0.05$), suggesting lack of association between variables (social, geographic) and knowledge on wild edible plants. Although the comparison is difficult, other studies have also found no association between social variables (age, gender, education) and ethnobotanical knowledge of WEPs (Somnasanc and Moreno-black, 2000; Ghorbani *et al.*, 2012). Getachew Addis *et al.* (2013) have also reported a lack of association between age and knowledge of wild food plants. On the other hand, other studies

have found a positive association between age and WEPs knowledge (Tena Regassa *et al.*, 2014).

In the present study, the reasons could be due to the fact that this knowledge is communal; it is not secret; it is shared openly. However, it is assumed that children (younger) who spend more time in the field and frequent users of WEPs and collectors of leafy edibles were expected to know a greater number and use of wild edibles. Despite this assumption, it has been found that parents advise their children not to consume WEPs due to fear of health hazards in relation to consumption. This could have influenced the familiarity of children with the wider spectrum of WEP species used by their parents in earlier days. This in turn could have affected the acquisition of knowledge and consumption of WEPs. Education is often associated with the loss of ethnobotanical knowledge in indigenous communities (Saynes-Vásquez *et al.*, 2013). Formal education is associated with acculturation; it is believed that it detaches children from the natural environment and stay more time in schools consequently leads to gaps in the transfer of ethnobotanical knowledge and hence to ultimate loss. In the context of the present study, it was noted that some of the informants had attended formal education up to secondary school some time ago, but now they dropped out and became farmers. Others currently attending schools were not completely detached from rural settings. Schooling could contribute to the declined use of WEPs where there is complete detachment from the rural environment. Overall, informants reported a general decline in the consumption of WEPs, particularly less tasty food plants. These may have contributed to the insignificant variation of knowledge among informants in WEPs. During interviews, it was noticed that informants, especially the elders, were unable to easily recall and mention the edible species they consumed before. The difficulty of recalling could

indicate the effect of declining uses, which could lead to the loss of indigenous knowledge. This suggests a need for awareness of the roles of indigenous knowledge and the need to preserve ethnobotanical knowledge of WEPs.

5.1.3.6 Nutritional profile of selected wild edible fruits

Nutritional information of WEPs is vital to promote future domestication and wider utilization. The nutritional analysis of wild edible fruits undertaken in this study found varying quantities of investigated nutrients. This finding supports the local use of these species and recognizes the knowledge of local communities. The proximate analysis found the highest content of ash and crude protein in *Ximenia americana*. From a comparative point of view, Mapongmetsem *et al.* (2012) reported lower (< 0.4%) ash value in fruits of *Carissa spinarum* and *Syzygium guineense* subsp. *guineense*; lower protein (2 to 6 %) in *Ximenia americana*, *Carissa spinarum*, *Syzygium guineense* subsp. *macrocarpum*, and *S. guineense* subsp. *guineense*. The same author reported the presence of high levels of vitamin C, flavonoids, polyphenols and antioxidants in *Ximenia americana*. According to Mapongmetsem *et al.* (2012), variation in localities contributed to the difference in nutrient contents. Studies elsewhere (Musinguzi *et al.*, 2007) found a wide array of nutrient contents including moisture, crude protein, vitamin C, retinol, and crude fibers in *Carissa spinarum*. High moisture content was also found in *Syzygium guineense* subsp. *macrocarpum*, and *S. guineense* subsp. *guineense* and *Ximenia americana* (Mapongmetsem *et al.*, 2012).

The analysis of mineral elements further revealed the highest phosphorus (183.53 mg/100g) and potassium (4352.17 Kmg/100g) in *Ximenia americana*. Maximum value of sodium was recorded in *Syzygium guineense* subsp. *afromontanum* (23.98 mg/100g) followed by *Syzygium guineense*

subsp. *macrocarpum* (19.98 mg/100g). Elsewhere a wide array of mineral elements such as sodium, potassium, calcium, magnesium, iron, phosphorus, and crude fibers were found in *Carissa spinarum* (Musinguzi *et al.*, 2007).

Apart from nutritional values, the consumption of such fruits is associated with reduced risk of cardiovascular disease and cancers. For example, *Ximenia americana* has been used in treating various health problems (James *et al.*, 2007). Phytochemical investigation of crude extracts of leaves of *X. americana* found bioactive compounds, which include, mainly, flavonoids, saponins, alkaloids, quinones, terpenoids, phenols, glycosides, and sterols (James *et al.*, 2007). The extracts, especially, aqueous and methanolic extracts *X. americana* leaves had shown antimicrobial, antifungal, anticancer, antitrypanosomal, antirheumatic, antioxidant, analgesic, molluscicide, pesticidal, antipyretic, and antifungal properties, among others (Sarmiento *et al.*, 2015). Similarly, *Carissa spinarum* has also been used in traditional medicine against different health problems (Maobe *et al.*, 2013). The isolated metabolites and crude extract have exhibited a wide range of pharmacological effects, including antioxidants, antimicrobial, antiviral, anticonvulsant, anticancer, antiarthritic, antihelmintic, cytotoxic activity (Maobe *et al.*, 2013). These revealed that wild edible fruits are not only good sources of nutrients but also the source of bioactive compounds. The vitamins, fiber, and minerals present in the diet are necessary for normal growth and metabolism and influence the utilization of other nutrients such as protein. The deficiency of essential vitamins or minerals leads to several physiological disorders and diseases, slowed growth, and a lack of deposition of proteins in tissues (Aberoumand, 2011). Vitamin C, for example, is known to enhance absorption iron, reduce the incidence of cancer and heart diseases, and lower blood pressure (Padayatty *et al.*, 2003). The bulk fiber found in fruits

promotes normal gastrointestinal motility and greatly facilitates the passage of food through the digestive tract, helping to prevent constipation and other related health problems (Aberoumand, 2011). The antioxidants such as polyphenols found in many WEPs play an important role in adsorbing and neutralizing free radicals and supporting proper physiological functions. Overall, the results revealed that the selected wild edible fruits were found to contain important nutrients that could potentially contribute to the nutrient needs of local people. Hence, integration of wild edibles into the diets of household members might thus add crucial vitamins and minerals that are normally deficient, particularly among women, children, and malnourished socioeconomic groups (Cassius *et al.*, 2000; Grivetti and Ogle, 2000). From the current market trend, it might not be difficult to predict the future cost of domesticated fruits, which will not be affordable by many rural poor to buy. Furthermore, future climate changes might affect agricultural production. Planting these indigenous wild fruit species, which can grow on marginal areas with minimal management will improve not only food and nutritional needs but also serve as the source of cash base for households. Therefore, the wild edible fruits that showed rich nutritional values (e.g. *Syzygium guineense* subsp. *afromontanum* *S. guineense* subsp. *guineense*, *S. guineense* subsp. *macrocarp*, *Carissa spinarum* and *Ximenia americana*) can be considered as potential candidates for domestication with the aim to meet household nutritional deficiencies and income generation. These species can easily be adapted to local conditions and benefit farmers in many ways.

5.1.4 Conservation of medicinal and wild edible plants

As in many other parts of Ethiopia (e.g. Kebu Balemie *et al.*, 2004; Tena Regassa *et al.*, 2014; Mersha Ashagre *et al.*, 2016), medicinal and wild edible plants in the study area are collected from wild and are under pressures mainly due to anthropogenic activities such as agricultural

expansions, deforestation, over-grazing, and over-harvesting. Agricultural expansions often destructs habitats and results in the loss of many species at a time. Although the growths of some weedy medicinal plants are favored in agricultural fields, many other species are affected by such land use change. Deforestation often removes woody species, which have also negative impacts on shade-loving forest species mainly herbaceous plants. Field observations witnessed that many forested and other lands such as hilly and valley bottoms, which thought to be covered by natural vegetation, have now become farmlands. These factors are generally considered to be the principal factors for the loss of wild plant resources including those found in forests, woodlands, and pasture lands in Ethiopia (Vivero *et al.*, 2006; Demel Teketay *et al.*, 2010; EBI, 2015). In many places, these factors have disrupted the ecosystem functions and services.

Furthermore, multiple uses of medicinal and wild edible species are among the major causes of local peoples' concern. Over-grazing and over-harvesting were other important factors affecting medicinal and WEPs. In the study area, free grazing is a very common practice; animals can graze medicinal and wild plants that have forage value. Over-grazing of premature individuals of these species might affect the phenology and regeneration status of species. Similarly, over-harvesting has been a common threat to many indigenous medicinal plants in Ethiopia (Mander *et al.*, 2006; Endashaw Bekele, 2007) and elsewhere around the world (Cunningham, 1993; Hamilton, 2004; Maroyi, 2011; Hong *et al.*, 2015). It has a variable effect depending on the parts harvested. For example, destructive harvesting such as uprooting and debarking has a significant impact on regeneration and on the survival of the species (Zemedu Asfaw, 2001; Hamilton, 2004). Regular harvesting of flowers, fruits, and seeds can have also adverse ecological impacts and can influence the natural regeneration of the species (Hamilton, 2004; Gaoue and Ticktin,

2008). The impact of harvesting medicinal plants for domestic use is often insignificant for many species. However, it might be detrimental when it is coupled with other use categories (Cunningham, 1993). In the study area, *Echinops longisetus* and *Securidaca longepedunculata* were reported to be under over-harvesting pressure for domestic use and for sale. These species are harvested harvested for their which is considered destructive. These two species have faced similar problems as with the case of *Taverniera abyssinica* and *Echinops kebericho*, which are highly threatened due to harvesting for sale (Mander *et al.*, 2006). *Echinops longisetus* is already reported in IUCN Red List under least concern threat category. These species will disappear from the wild in near future. It took us greater distances and long hours to find the herbarium samples of some medicinal plants such as *Echinops longisetus*, *Passiflora caerulea*, and *Pentas schimperiana*. Similar challenges were faced to collect *Dioscorea praehensilis*, *D. schimperiana*, and *Syzygium guineense* subsp. *guineense* samples. Occurrence of species such as *Aframomum corrorima* and *Piper capense* in the natural moist forest was very rare due to harvesting impact. In general, some of the observations concur with Hamilton (2004) who reported that herbal collectors walk greater distances for medicinal plants collection that once grew in the vicinity of their homes. In many cases, slow-growing and slow-reproducing species with specific habitat requirements have been the most vulnerable group (Cunningham, 1993; Hamilton, 2004; Heywood and Dulloo, 2006). The decline or loss of species has contributed to their declined uses, which could directly or indirectly affect the health and food security contributions of these species. The declined use might in turn, result in the disruption of the transfer of indigenous knowledge. Thus, the long-term availability of medicinal and wild edible plants is very important not only for continued uses, but also for the preservation of culture associated with the species.

To this end, conservation should be undertaken to ensure their sustainable uses. In this regard, the government and local communities have made efforts to conserve the forests. These efforts contributed to the conservation of diverse medicinal and wild edible plants in Jorgo Wato Forest. The medicinal and WEPs in this forest showed varying abundance. Most of them are rare while few are abundant. *Syzygium guineense* subsp. *afromontanum* was among the abundant medicinal and WEPs. The rare WEPs include *Aframomum corrorima*, *Coffea arabica* (spontaneously wild grown), *Dioscorea praehensilis*, *D. schimperiana*, *Pentas schimperiana*, and *Piper capense*. The rare species need periodic monitoring and strengthening their conservation through the participation of local communities.

In reality, many species exist only as part of ecosystems and cannot survive unless their ecosystems are preserved along with as much as possible biodiversity they contain. Thus, the conservation of species in their natural environment (*in-situ* conservation) has many advantages. It favors the co-existence of different biodiversity; it maintains evolutionary processes of the species, it protects rare and threatened species, it contributes to the preservation of indigenous knowledge associated with the species (Heywood and Dulloo, 2006). *In-situ* conservation of medicinal and wild edible plants also offers sociocultural, economic, and ecological benefits to local communities.

Apart from community and government conservation efforts, individuals, mainly traditional healers have contributed to the conservation of medicinal and WEPs. The harvesting techniques and beliefs followed by traditional healers in the study areas avoid destructive methods such as uprooting, debarking, and prevention of over-exploitation. In many parts of Africa, various

culturally inherited customary practices such as beliefs and social restrictions regulate collection methods, times and quantities of harvested medicinal plants (Cunningham, 1993, 2001) and contribute to the conservation and sustainable use of medicinal plants.

Beside sustainable harvesting practice, individuals have maintained many medicinal and WEPs deliberately left to grow in homegardens and on own lands including farmlands. However, the number of informants who were involved in management was few. In the case of medicinal plants, it may be related to secrecy, lack of awareness of possible species of loss and consequences. In Ethiopia, it is a common practice to manage different plants in homegardens and farmlands. Abiyot Berhanu and Zemedu Asfaw (2014) reported about 137 food plants and 81 medicinal plant species maintained in some selected homegardens in Ethiopia. This witnessed that the contribution of homegarden management in rescuing useful plants is immense. The more the participation of the public on such management, the more the species could be rescued from local extinction.

The conservation efforts by local communities are being supported by government, international organization/donors and NGOs. The protection of forests and establishment of area closure contribute to conservation of plants including medicinal and WEPs. The establishment of *ex-situ* conservation sites such field genebanks and botanic gardens by government and support of international organizations can signify attention given to conservation. However, information on how many threatened or rare species are conserved or rescued from extinction is lacking. In all conservation endeavors, priority should be given to rare, threatened and economically useful species. The utilization of such species should also be promoted through cultivation. Cultivation

is an effective way to decrease the pressure on wild medicinal plants particularly those having high household and market demands. It is also widely viewed as a means for meeting current and future demands (FAO, 1997). Cultivation might be difficult under the farmers' condition for some of the plants because of certain biological features or ecological requirements (slow growth rate, special soil requirements, low germination rates, susceptibility to pests, and incompatibility with conventional crops). In such cases, technical information and support might be required from scientific communities.

5.2 Conclusion

The Jorgo Wato Forest has exhibited high species diversity and can be considered as one of important plant diversity centers in the country with 237 species including 10 endemic species. A number of these species is not reported for Wollega floristic region (WG) in the Flora of Ethiopia and Eritrea. This information suggests the need for more exploration and collection this floristic region to fill information gaps related to distribution of species in Ethiopian flora.

The most abundant and the most frequent species of JWF were *Dracaena afromontana*, *Chionanthes mildbraedii*, *Syzygium guineense* subsp. *afromontanum* and *Pouteria adolfi-friederici*, *Maytenus gracilipes* and *Landolphia buchananii*. The population structure of JWF is composed of many young individuals having lower dbh and height size classes. The proportion of mature individuals is decreasing towards larger size classes. In terms of ecological importance, most of the forest plant species revealed a low importance value index (IVI) indicating rarity or low occurrence of these species. The overall distribution pattern of individuals of most species in the forest showed a reverse J-shape pattern and this indicates a healthy population structure or good regeneration status. However, some tree species (*Cordia africana*, *Polyscias fulva*, and *Schefflera abyssinica*) showed a pattern that deviated from the J-shape pattern indicating unhealthy regeneration.

Cluster analysis classified JWF into five plant community types that revealed high species diversity and evenness. The community types were also rich in culturally important species such as medicinal and WEPs. The distribution of species across plant communities was significantly ($p < 0.001$) influenced by altitude and slope.

The ethnobotanical study further found diverse medicinal plants used for the treatment of human and livestock health problems. In addition to health importance, most of the medicinal plants provide many other additional uses (multiple cultural values) to local communities. The medicinal species were largely herbaceous in growth form, followed by shrubs. The majority of plant remedies were prepared from fresh leaves followed by roots, largely from single species and/or plant part, and then extracted in the form of sap or juice and infusion for oral application.

Of the documented medicinal plants, some medicinal plants (e.g. *Croton macrostachyus*, *Datura stramonium*, *Dracaena steudneri*, *Echinops longisetus*, *Justicia schimperiana* *Loxogramme abyssinica*, *Ocimum urticifolium*, and *Pentas schimperiana*) showed high informant consensus and could therefore be candidate for drug development. Analysis of social and geographic variables, found significant effect of age, gender, healing experience, and proximity to forest on possession/distribution of medicinal knowledge.

The study area flora was also rich in wild edible plants that a wide range of cultural importance. Some of the WEPs (e.g. *Acanthus pubescens* and *Bidens macroptera*) were not reported in previous literature as edible plants. It is believed that the newly reported species and related information will enrich the national WEP database.

Nutritional analysis carried on WEPs such as *Carissa spinarum*, *Syzygium guineense* subsp. *afromontanum*, *S. guineense* subsp. *macrocarpa*, *S. guineense* subsp. *guineense*, and *Ximenia americana* found rich nutrients that could potentially contribute to combat malnutrition.

The natural vegetation cover in the study area is deteriorating in many places. Some medicinal and wild edible plants were not available where they were previously available. Analysis of threat factors identified agricultural expansion, deforestation, and over-harvesting as the principal factor contributing to the deterioration of plant diversity.

Strengthening the protection of natural habitats such as JWF has paramount importance. Many rare species and those that showed low importance value index could be rescued from local extinction; many culturally important species which are lost due to deforestation and agricultural expansions could be protected. For example, JWF protection alone contributed to the conservation of at least 50% of the medicinal and WEPs used in Nole Kaba District. The ethnobotanical knowledge associated with these species can also be preserved.

5.3 Recommendations

- Despite the fact that the Jorgo Wato Forest is an important area of plant diversity, home to numerous culturally important plant species, the gene pool of economically important species such as *Coffea arabica*, there were an expansion of farm into the forest. Oromia Forest and Wild Life Enterprise therefore should strengthen the conservation of this forest. In addition, some tree species such as *Cordia africana*, *Polyscias fulva* and *Schefflera abyssinica* which showed lack of regeneration should receive priority for monitoring and enrichment planting. The enterprise should also respect the rights of people living around the forest and support activities that contribute to household income of the people such as providing improved beehive. These might reduce the pressure on the forest and increase the participation of the people on conservation.

- Medicinal plants such as *Croton macrostachyus*, *Datura stramonium*, *Dracaena steudneri*, *Echinops longisetus*, *Justicia schimperiana*, *Loxogramme abyssinica*, *Ocimum urticifolium*, *Pentas schimperiana*, *Phytolacca dodecandra* and *Securidaca longepedunculata* are recommended for pharmaceutical companies for further evaluation of the efficacy, safety and other quality requirements.

- WEPs such as *Carissa spinarum*, *Syzygium guineense* subsp. *afromontanum*, *S. guineense* subsp. *macrocarpa*, *S. guineense* subsp. *guineense*, and *Ximenia americana* were found nutritionally rich. These species are recommended as candidate species for domestication in their respective agroecological zones to contribute to nutritional and economic needs of households. Where priority is required, it should be given to *Ximenia americana* as this species contained high amounts of most analyzed nutrients compared to others. Agricultural offices, NGOs, entrepreneur offices and health extension services should cooperate with each other to implement the recommendation successfully. Accordingly, promoting the domestication and seedling supply should be given by agricultural development offices and NGOs; to contribute to household income from the species entrepreneur office should organize growers giving priority to low-income and food-deficit households and provide support on value addition such as processing methods of these fruits, to various products and market linkage; health extension workers should promote the domestication, nutritional importance, and the consumption of fruits of these species.

- Based on informants' conservation demand, medicinal plants that are declining or rare in abundance such as *Datura metel*, *Dracaena steudneri*, *Echinops longisetus*, *Euphorbia schimperiana*, *Gomphocarpus semilunatus*, *Ocimum urticifolium*, *Olea europaea* subsp. *cuspidata*, *Passiflora caerulea*, *Pentas schimperiana*, *Phytolacca dodecandra*, *Pittosporum viridiflorum*, *Podocarpus falcatus*, *Salvia nilotica*, *Securidaca longepedunculata*, and *Warburgia ugandensis* are recommended for conservation in field gene banks.

- Local authorities should establish area closures in each agroecological zone to rescue many other rare and threatened medicinal and WEPs from loss. Besides, institutions working on conservation medicinal plants should give priority germplasm collection to rare species for *ex-situ* conservation.

- In addition, awareness among people towards conservation and sustainable use of biodiversity in general and medicinal and WEPs in particular should be given by natural resource management offices at regional and local levels.

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Appendices

Appendix 1 List of plant species in JWF

N0	Scientific Name	Family	Habit	Local name	Coll. N0
1	<i>Abutilon figarianum</i> Webb	Malvaceae	H	ifte	K-254
2	<i>Abutilon longicuspe</i> Hochst. ex A. Rich.	Malvaceae	Sh	adaanniisa adii	KP68-147
3	<i>Acacia abyssinica</i> Hochst. ex Benth.	Fabaceae	T	sondii/laaftoo	K-160
4	<i>Acanthus eminens</i> C. B. Clarke	Acanthaceae	Sh	qoraatii boyyee	KP33-110
5	<i>Acanthus pubescens</i> (Oliv.) Engl.	Acanthaceae	Sh	kosoru	KP1013
6	<i>Achyranthes aspera</i> L.	Amaranthaceae	H	gosa qamaxee 3	KP26-097
7	<i>Adenostemma mauritanium</i> DC.	Asteraceae	H	gosa ababoo	K-208
8	<i>Adiantum poiretii</i> Wikstr.	Adiantaceae	H	shararii	KP1-007
9	<i>Aeschynomene abyssinica</i> (A. Rich.) Vatke	Fabaceae	Sh	hina	K-167
10	<i>Aeschynomene indica</i> L.	Fabaceae	H	gosa hinnaa	K-191
11	<i>Aframomum corrorima</i> (Braun) Jansen	Zingiberaceae	H	ogiyoo	K-139
12	<i>Ageratum conyzoides</i> L.	Asteraceae	H	gosa aramaa	K-187
13	<i>Ajuga alba</i> (Gürke) Robyns	Lamiaceae	H	dalacho	K-117
14	<i>Albizia gummifera</i> (J. F. Gmel.) C. A. Sm.	Fabaceae	T	ambaabeessa	KP 9-052
15	<i>Albizia schimperiana</i> Oliv.	Fabaceae	T	muka arbaa	KP 9-053
16	<i>Alchemilla abyssinica</i> Fresen.	Rosaceae	H	gosa margaa	K-199
17	<i>Allophylus abyssinicus</i> (Hochst.) Radlk.	Sapindaceae	T	marqaqoo	KP2-027
18	<i>Alysicarpus quartianianus</i> A. Rich.	Fabaceae	H	gosa arcuma	K-242
19	<i>Andropogon abyssinicus</i> Fresen.	Poaceae	H	gosa bal lama	K-230
20	<i>Antopetitia abyssinica</i> A. Rich.	Fabaceae	H	gosa aramaa	K-225
21	<i>Apodytes dimidiata</i> E. Mey. ex Arn.	Icacinaceae	T	wandabiyoo	KP1-011
22	<i>Ardisiandra sibthorpioides</i> Hook. f.	Primulaceae	H	gosa gura hantuuta	K-245
23	<i>Arthropteris monocarpa</i> (Cordem.) C. Chr.	Olendraceae	H	gixoo	KP16-078
24	<i>Arundo donax</i> L.	Poaceae	Sh	leeman	K-176
25	<i>Asparagus racemosus</i> Willd.	Asparagaceae	Liana	shararii	KP12-061
26	<i>Asplenium buettneri</i> Hieron. ex Brause	Aspleniaceae	H	dheertuu sarxee	K-184
27	<i>Asplenium protensum</i> Schrad.	Aspleniaceae	H	gosa gixoo	KP53-127
28	<i>Asplenium sandersonii</i> Hook.	Aspleniaceae	H	gosa gixoo	K-239
29	<i>Asplenium smedsii</i> Pic. Serm.	Aspleniaceae	H	gixoo kattaa	K-178
30	<i>Australina flaccida</i> (A. Rich.) Wedd.	Urticaceae	H	gosa qamaxee (2)	KP20-090
31	<i>Bersama abyssinica</i> Fresen.	Melanthiaceae	T	lolchiisa	KP2025
32	<i>Bidens macroptera</i> (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	H	gosa ababaa	KP3035
33	<i>Bothriocline schimperi</i> Oliv. & Hiern ex Benth.	Asteraceae	H	irbu	K-255
34	<i>Bridelia micrantha</i> (Hochst.) Baill.	Euphorbiaceae	T	rigarba	K-134
35	<i>Brillantaisia lamium</i> (Nees) Benth.	Acanthaceae	H	qamaxee 4	KP8-043
36	<i>Brucea antidysentrica</i> J. F. Mill.	Simaroubaceae	Sh	qomagnoo	KP20-28

37	<i>Buddleja polystachya</i> Fresen.	Loganiaceae	Sh	anfaree	KP 9052
38	<i>Calpurnia aurea</i> (Ait.) Benth.	Fabaceae	Sh	ceeqaa	K-100
39	<i>Canthium oligocarpum</i> Hiern	Rubiaceae	Sh	meexoo adii	KP 8-050
40	<i>Cardamine africana</i> L.	Brassicaceae	H	gosa sunqo	K-232
41	<i>Cassipourea malosana</i> (Baker) Alston	Rhizophoraceae	T	lokoo	KP10-10
42	<i>Caylusea abyssinica</i> (Fresen.) Fisch. & Mey.	Resedaceae	H	ilaanccoo	K-172
43	<i>Celosia schweinfurthiana</i> Schinz	Amaranthaceae	H	gosa homacho	K-251
44	<i>Celtis africana</i> Burm. f.	Ulmaceae	T	qe'ii	KP28-098
45	<i>Centella asiatica</i> (L.) Urban	Apiaceae	H	gurra hantuuta	K-169
46	<i>Chamaecrista mimosoides</i> (L.) Greene	Fabaceae	H	gosa qomoxora	K-261
47	<i>Cheilanthes farinosa</i> (Forssk.) Kaulf.	Sinopteridaceae	H	gixool	K-184
48	<i>Chionanthus mildbraedii</i> (Gilg & Schellenb) Stearn	Oleaceae	Sh	gagamaa	KP13-065
49	<i>Cirsium vulgare</i> (Savi.) Ten.	Asteraceae	H	luudata	KP14-070
50	<i>Clausena anisata</i> (Wild.) Benth.	Rutaceae	Sh	ulumayaa	KP8-050
51	<i>Clematis hirsuta</i> Perr. & Guill	Ranunculaceae	Liana	hidda fitii	KP10-055
52	<i>Clutia abyssinica</i> Jaub. & Spach.	Euphorbiaceae	Sh	qaqaroo	KP3-033
53	<i>Coffea arabica</i> L.	Rubiaceae	Sh	buna	KP20-090
54	<i>Coleochloa abyssinica</i> (Hochst. ex A. Rich.) Gilly	Cyperaceae	H	citaa	Kp13-066
55	<i>Combretum paniculatum</i> Vent.	Combretaceae	Liana	baggee	KP1-011
56	<i>Commelina latifolia</i> Hochst. ex A. Rich.	Commelinaceae	H	leelenxoo	KP2-030
57	<i>Conyza pyrrhopappa</i> Sch. Bip. ex A. Rich.	Asteraceae	H	haxayii	K-211
58	<i>Cordia africana</i> Lam.	Boraginaceae	T	waddeessa	KP2-018
59	<i>Crassocephalum rubens</i> (Juss. ex Jacq.) S. Moore	Asteraceae	H	gosa cinciri	K-229
60	<i>Crassula alsinoides</i> (Hook. f.) Engl.	Crassulaceae	H	kase	K-177
61	<i>Crotalaria gillettii</i> Polhill	Fabaceae	Liana	gosa kashkashe	K-265
62	<i>Crotalaria keniensis</i> Bak. f.	Fabaceae	Liana	gosa kashkashe	K-202
63	<i>Crotalaria pallida</i> Ait.	Fabaceae	H	gosa ceeqaa	K-100
64	<i>Croton macrostachyus</i> Del.	Euphorbiaceae	T	bakkanniisa	KP12-061
65	<i>Cyathea manniana</i> Hook.	Cyatheaceae	T	gixoo muka	KP14-071
66	<i>Cyathula uncinulata</i> (Schrader) Schinz	Amaranthaceae	Sh	darguu	KP10-10
67	<i>Cynoglossum amplifolium</i> Hochst. ex A. DC. in DC.	Boraginaceae	H	maxxannee	KP53-123
68	<i>Cyperus distans</i> L. f.	Cyperaceae	H	gosa qunnii 1	K-224
69	<i>Cyperus fischerianus</i> A. Rich.	Cyperaceae	H	qunnii	KP16-079
70	<i>Cyperus rotundus</i> L.	Cyperaceae	H	gosa qunnii 2	K-257
71	<i>Cyphostemma cyphopetalum</i> (FreserL) Desc. ex Wild & Drummond	Vitaceae	Liana	hidda reefaa	KP13-063
72	<i>Dalbergia lactea</i> Vatke	Fabaceae	T	ijigno	KP9-052
73	<i>Desmodium repandum</i> (Vahl) D C.	Fabaceae	H	qamaxee	KP12-059
74	<i>Dichrocephala integrifolia</i> (L. f.) O. Kuntze	Asteraceae	H	marga guracha	K-122

75	<i>Dicliptera laxata</i> C.B. Clarke	Acanthaceae	H	cinciri/ajooftu/	K-220
76	<i>Dombeya torrida</i> (J. F. Gmel.) P. Bamps	Sterculiaceae	Sh	adaanniisa	KP2-023
77	<i>Dracaena afromontana</i> Mildbr.	Dracaenaceae	Sh	sarxee	KP21-094
78	<i>Dracaena steudneri</i> Engl.	Dracaenaceae	Sh	afarfatu	K-118
79	<i>Drymaria cordata</i> (L.) Schultes	Caryophyllaceae	H	qoricha mada/shararitii	KP-63
80	<i>Drynaria volkensii</i> Hieron.	Polypodiaceae	H	sinkir balleessa lolchiisa	K-182
81	<i>Dryopteris inaequalis</i> (Schltdl.) Kuntze	Dryopteridaceae	H	gixoo2	K-245
82	<i>Dumasia villosa</i> DC.	Fabaceae	H	gosa kalala	K-188
83	<i>Ehretia cymosa</i> Thonn.	Boraginaceae	T	ulaagaa	KP34-111
84	<i>Ekebergia capensis</i> Sparrm.	Meliaceae	T	somboo	KP8-88
85	<i>Elatostema monticolum</i> Hook. f.	Urticaceae	H	gosa qamaxee	K-181
86	<i>Eleusine africana</i> Kenn.-O'Byrne	Poaceae	H	coqorsa	K-195
87	<i>Embelia schimperi</i> Vatke	Myrsinaceae	Liana	kossoo/hanqu	KP71-166
88	<i>Englerina woodfordioides</i> (Schweinf.) M. Gilbert	Loranthaceae	Sh	dheertu meexoo	KP32-105
89	<i>Ensete ventricosum</i> (Welw.) Cheesman	Musaceae	H	warqee	KP10-12
90	<i>Entada africana</i> Guill. & Perr.	Fabaceae	T	ambalaa	K-161
91	<i>Eriosema nutans</i> Schinz	Fabaceae	H	gosa qamaxee	K-186
92	<i>Erythrococca trichogyne</i> (Muell Arg.) Prain	Euphorbiaceae	Sh	caakoo	KP26-096
93	<i>Ficus sur</i> Forssk.	Moraceae	T	harbuu	KP33-108
94	<i>Ficus vasta</i> Forssk.	Moraceae	T	qilxuu	K-154
95	<i>Flacourtia indica</i> (Burm. f.) Merr.	Flacourtiaceae	Sh	akuukkuu	KP10-07
96	<i>Galiniera saxifraga</i> (Hochst.) Bridson	Rubiaceae	Sh	muka guraacha	KP60-135
97	<i>Geranium aculeolatum</i> Oliv.	Geraniaceae	H	gosa sharariitii	K-250
98	<i>Girardinia diversifolia</i> (Link) Friis	Urticaceae	H	doobbii	K- 76
99	<i>Glycine wightii</i> (Wight & Arn.) Verdc.	Fabaceae	H	kalala gamoojjii	K-157
100	<i>Gnaphalium rubriflorum</i> Hilliard	Asteraceae	H	gosa qodo	K-228
101	<i>Gouania longispicata</i> Engl.	Rhamnaceae	Liana	homachoo	KP69-149
102	<i>Grewia ferruginea</i> Hochst. ex A. Rich.	Tiliaceae	Sh	dhoqonuu	KP20-16
103	<i>Guizotia scabra</i> (Vis.) Chiov.	Asteraceae	H	tufo	K-248
104	<i>Hagenia abyssinica</i> (Bruce) J. F. Gmel.	Rosaceae	T	hexo	K-135
105	<i>Helichrysum schimperi</i> (Sch. Bip. ex A. Rich.) Moeser	Asteraceae	H	qodoo	K-131
106	<i>Helinus mystacinus</i> (Ait.) E. Mey. ex Steud.	Rhamnaceae	Liana	gosa boriino diima	K-236
107	<i>Hibiscus berberidifolius</i> A. Rich.	Malvaceae	Sh	quncee togo	K-273
108	<i>Hibiscus macranthus</i> Hochst. ex A. Rich.	Malvaceae	Sh	hinccinnii	KP8-047
109	<i>Hibiscus ovalifolius</i> (Frossk.) Vahl	Malvaceae	Sh	gosa hincinnii	K-221
110	<i>Hippocratea pallens</i> Planch. ex Oliv.	Celastraceae	Liana	qa'oo	KP19-086
111	<i>Huperzia dacrydioides</i> (Baker) Pic. Serm.	Lycopodiaceae	H	dheertu wandabiyo	K-222
112	<i>Hyparrhenia cymbaria</i> (L.) Stapf	Poaceae	H	gagawwee	KP-90

113	<i>Hyparrhenia hirta</i> (L.) Stapf	Poaceae	H	cita mana	K-210
114	<i>Hypericum peplidifolium</i> A. Rich.	Hypericaceae	H	gosa bala atari	K-268
115	<i>Hypericum quartinianum</i> A. Rich.	Hypericaceae	Sh	ullee fonii	KP10-04
116	<i>Hypoestes forskalii</i> (Vahl) R. Br.	Acanthaceae	H	gosa qamaxee	KP9-052
117	<i>Hypoestes triflora</i> (Forssk.) Roem. & Schult.	Acanthaceae	H	gosa qamaxee	K-198
118	<i>Ilex mitis</i> (L.) Radlk.	Aquifoliaceae	T	mi'eessa	KP14-121
119	<i>Impatiens hochstetteri</i> Warb.	Balsaminaceae	H	gosa qamaxe/riverine	K-202
120	<i>Indigofera arrecta</i> Hochst. ex A. Rich.	Fabaceae	Sh	hina guracha	K-209
121	<i>Ipomoea eriocarpa</i> R. Br.	Convolvulaceae	H	kalala jabbii	KP20-087
122	<i>Ipomoea tenuirostris</i> Choisy	Convolvulaceae	H	kalala jabbii	K-246
123	<i>Isodon ramosissimus</i> (Hook. f.) Codd	Lamiaceae	H	gosa qamaxee addaa	K-137
124	<i>Isoglossa somalensis</i> Lindau	Acanthaceae	Sh	gosa qamaxe horii	K-266
125	<i>Jasminum abyssinicum</i> Hochst. ex DC.	Oleaceae	Liana	ichible	KP60-40
126	<i>Justicia ladanoides</i> Lam.	Acanthaceae	H	gosa qamaxee	K-204
127	<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	Acanthaceae	Sh	dhumugaa	KP14-070
128	<i>Kalanchoe densiflora</i> Rolfe	Crassulaceae	H	gosa dhangagoo	K-70
129	<i>Keetia gueinzii</i> (Sond.) Bridson	Rubiaceae	Liana	meexoo qamalee	KP14-074
130	<i>Kosteletzkya adoensis</i> (Hochst. ex A. Rich.) Mast.	Malvaceae	H	gosa ciciniina	K-270
131	<i>Kyllinga odorata</i> Vahl	Cyperaceae	H	gosa qunni	K-224
132	<i>Lagenaria abyssinica</i> (Hook. f.) C. Jeffrey	Cucurbitaceae	H	gosa uma'oo	KP11-058
133	<i>Landolphia buchananii</i> (Hall. f.) Stapf	Apocynaceae	Liana	geboo	KP9-051
134	<i>Lepidotrichilia volkensii</i> (Gürke) Leroy	Meliaceae	T	gosa marqaqoo	KP10-02
135	<i>Leucas deflexa</i> Hook. f.	Lamiaceae	H	gosa mata boke	K-237
136	<i>Lippia adoensis</i> Hochst. ex Walp.	Verbenaceae	Sh	kusaye horii	K-192
137	<i>Loxogramme abyssinica</i> (Baker) M. G. Price	Polypodiaceae	Sh	sinkir balleessa	K-180
138	<i>Macaranga capensis</i> (Baill.) Sim	Euphorbiaceae	T	dogomaa	K-244
139	<i>Maesa lanceolata</i> Forssk.	Myrsinaceae	Sh	abbayyii	KP68-147
140	<i>Marisculus assimilis</i> (Steud.) Podlech	Cyperaceae	H	gosa coqorsa	K-204
141	<i>Maytenus addat</i> (Loes.) Sebsebe	Celastraceae	T	kombol fiixee	KP4-039
142	<i>Maytenus gracilipes</i> (Welw. ex Oliv.) Exell subsp. <i>argota</i> (Loes.) Sebsebe	Celastraceae	Sh	kombolcha	KP56-133
143	<i>Melinis repens</i> (Willd.) Zizka	Poaceae	H	gosa marga gogorii	K-212
144	<i>Milletia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	Fabaceae	T	sootaloo	Kp8-042
145	<i>Mucuna melanocarpa</i> Hochst.	Fabaceae	Liana	machaaraa	KP10-06
146	<i>Mucuna pruriens</i> (L.) DC.	Fabaceae	H	gosa kalal aguracha	K-202
147	<i>Myrsine africana</i> L.	Myrsinaceae	Sh	qawisa	K-130
148	<i>Nicardia physaloides</i> (L.) Gaertn.	Solanaceae	H	gosa nobbee	K-207
149	<i>Nuxia congesta</i> R. Br. ex Fresen.	Loganiaceae	Sh	gosa qawwisa	KP13-062
150	<i>Ochna holstii</i> Engl.	Ochnaceae	Sh	ilmayyoo	KP52-132

151	<i>Ocimum lamiifolium</i> Hochst. ex Benth.	Lamiaceae	Sh	gosa hancabbii	K-162
152	<i>Ocimum urticifolium</i> Roth	Lamiaceae	Sh	hancabbii	KP37-118
153	<i>Olea capensis</i> L. subsp. <i>hochstetteri</i> (Bak.) Friis & P. S. Green	Oleaceae	T	digajja	KP12-060
154	<i>Olea europaea</i> L. subsp. <i>cuspidata</i> (Wall. ex G. Don) Cif.	Oleaceae	T	ejersa	K-230
155	<i>Olea welwitschii</i> (Knobl.) Gilg & Schellenb.	Oleaceae	T	ba'aa	KP18-081
156	<i>Osyris quadripartita</i> Decn.	Santalaceae	Sh	gosa alaltu	K-259
157	<i>Panicum hochstetteri</i> Steud.	Poaceae	H	marga gogorii	KP1-04
158	<i>Pavetta oliveriana</i> Hiern	Rubiaceae	Sh	gosa meexo gamojjii	K-252
159	<i>Pavonia patens</i> (Andr.) Chiov.	Malvaceae	H	gosa hincinnii	K-203
160	<i>Pennisetum thunbergii</i> Kunth	Poaceae	H	bashude/migira adure	K-214
161	<i>Pennisetum trachyphyllum</i> Pilg.	Poaceae	H	jajjaba	K-53
162	<i>Pennisetum unisetum</i> (Nees) Benth.	Poaceae	H	gosa gagawwee	K-15
163	<i>Pentarrhinum insipidum</i> E. Mey.	Asclepiadaceae	H	gosa kalala 5	Kp8-042
164	<i>Pentas lanceolata</i> (Forssk.) Deflers	Rubiaceae	H	qoricha dhiitoo	KP-10
165	<i>Pentas schimperiana</i> (A. Rich.) Vatke	Rubiaceae	Sh	qoricha hadhaa	KP10-057
166	<i>Peperomia abyssinica</i> Miq.	Piperaceae	H	dheertuu kombolcha	K-219
167	<i>Peponium vogelii</i> (Hook.f.) Engl.	Cucurbitaceae	H	umbawo	K-114
168	<i>Periploca linearifolia</i> Quart-Dill. & A. Rich.	Asclepiadaceae	Liana	booriino	K-164
169	<i>Phaulopsis imbricata</i> (Forssk.) Sweet	Acanthaceae	H	gosa qamaxa horii	K-235
170	<i>Phoenix reclinata</i> Jacq.	Arecaceae	T	meexii	KP4-036
171	<i>Phyllanthus fischeri</i> Pax	Euphorbiaceae	H	caamoo	KP2-028
172	<i>Phyllanthus limmuensis</i> Cufod.	Euphorbiaceae	Sh	gosa ceeqa	KP41-120
173	<i>Phytolacca dodecandra</i> L'Hérit.	Phytolaccaceae	T	andodee	K-170
174	<i>Pilea rivularis</i> Wedd.	Urticaceae	H	gosa dobbii	K-234
175	<i>Piper capense</i> L. f.	Piperaceae	H	tunjoo	K-136
176	<i>Pittosporum viridiflorum</i> Sims	Pittosporaceae	Sh	soolee	KP31-103
177	<i>Plantago palmata</i> Hook. f.	Plantaginaceae	H	qoricha butii	K-176
178	<i>Platostoma rotundifolium</i> (Briq.) A. J. Paton	Lamiaceae	H	gosa yeero	K-227
179	<i>Podocarpus falcatus</i> (Thunb.) R. B. ex. Mirb.	Podocarpaceae	T	birbirsaa	K-273
180	<i>Polyscias fulva</i> (Hiern) Harms	Araliaceae	T	darakuu	KP8-048
181	<i>Pouteria adolfi-friederici</i> (Engl.) Baehni	Sapotaceae	T	qararoo	KP2-026
182	<i>Premna schimperi</i> Engl.	Lamiaceae	Sh	urgessa	K-240
183	<i>Prunus africana</i> (Hook. f.) Kalkm.	Rosaceae	T	homii	KP61-144
184	<i>Psychotria orophila</i> Petit	Rubiaceae	Sh	bururi diima	KP1-008
185	<i>Pteridium aquilinum</i> (L.) Khun	Pteridaceae	H	gosa gixoo/boola	KP33-109
186	<i>Pteris dentata</i> Forssk.	Pteridaceae	H	gixoo8	K-178
187	<i>Pteris pteridioides</i> (Hook.) Ballard	Pteridaceae	H	gixoo3	K-138
188	<i>Pycnostachys abyssinica</i> Fresen.	Lamiaceae	Liana	yeeroo	KP50-125

189	<i>Pycnostachys meyeri</i> Gürke	Lamiaceae	Liana	yeeroo	K-196
190	<i>Ranunculus multifidus</i> Forssk.	Ranunculaceae	H	gosa gondi	K-231
191	<i>Rhamnus prinoides</i> L'Herit.	Rhamnaceae	Sh	geshoo	KP7-041
192	<i>Rhus glutinosa</i> A. Rich.	Anacardaceae	Sh	xaxessaa	KP68-148
193	<i>Rhynchosia minima</i> (L.) DC.	Fabaceae	H	kalalaa gursade	K-272
194	<i>Ricinus communis</i> L.	Euphorbiaceae	H	qoboo	K-171
195	<i>Ritchiea albersii</i> Gilg.	Capparidaceae	Sh	danqarichoo	K-104
196	<i>Rubus apetalus</i> Poir.	Rosaceae	Liana	gora guraacha	KP17-080
197	<i>Rubus niveus</i> Thunb.	Rosaceae	Liana	gora gafarssaa	KP35-112
198	<i>Rumex abyssinicus</i> Jacq.	Polygonaceae	H	dhangagoo	K-101
199	<i>Rumex nepalensis</i> Spreng.	Polygonaceae	H	timijjii	K-152
200	<i>Sanicula elata</i> Buch.-Ham. ex D. Don	Apiaceae	H	balsadii	K-141
201	<i>Scadoxus multiflorus</i> (Martyn) Raf.	Amaryllidaceae	H	afrase	K027
202	<i>Schefflera abyssinica</i> (Hochst. ex A. Rich.) Harms	Araliaceae	T	gatamaa	KP14-068
203	<i>Schrebera alata</i> (Hochst.) Welw.	Oleaceae	T	dhama'ee	K-260
204	<i>Senna petersiana</i> (Bolle) Lock	Fabaceae	Sh	raamsoo	KP1-014
205	<i>Setaria poiretiana</i> (Schult.) Kunth	Poaceae	H	sokokee	KP30-34
206	<i>Sida rhombifolia</i> L.	Malvaceae	H	karabaa	KP-01
207	<i>Sida tenuicarpa</i> Vollesen	Malvaceae	H	insilale	K-199
208	<i>Sida ternata</i> L. f.	Malvaceae	H	gosa hincinnii	K-221
209	<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Asteraceae	Sh	tambatimboo	KP2-029
210	<i>Solanecio mannii</i> (Hook. f.) C. Jeffrey	Asteraceae	Sh	gosa timbatimboo	KP8-044
211	<i>Solanum anguivi</i> Lam.	Solanaceae	Sh	hiddii	KP10-056
212	<i>Solanum giganteum</i> Jacq.	Solanaceae	Sh	gosa hiddi warabessa	K-129
213	<i>Solanum incanum</i> L.	Solanaceae	Sh	hiddii	K-116
214	<i>Stereospermum kunthianum</i> Cham.	Bignoniaceae	T	botoroo	K-159
215	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>afromontanum</i> F. White	Myrtaceae	T	baddeessa	KP2-027
216	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>guineense</i>	Myrtaceae	T	gomare	K-175
217	<i>Tagetes minuta</i> L.	Asteraceae	H	gosa wallage	KP2-029
218	<i>Tectaria gemmifera</i> (Fée) Alston	Dryopteridaceae	H	gixoo4	K-219
219	<i>Teramnus labialis</i> (L. f.) Spreng.	Fabaceae	H	gosa hidda addaa	K-241
220	<i>Thalictrum rhynchocarpum</i> Dill. & A. Rich.	Ranunculaceae	H	shararitii	K-226
221	<i>Thumbergia alata</i> Boj. ex Sims	Acanthaceae	H	maracaa	KP41-121
222	<i>Tridactyle bicaudata</i> (Lindl.) Schltr.	Orchidaceae	H	dheertu kombolcha	K-219
223	<i>Trifolium mattirolanum</i> Chiov.	Fabaceae	H	siddisa/qqmaxee	KP 8-045
224	<i>Triumfetta rhomboidea</i> Jacq.	Tiliaceae	H	gosa jirbii gamojjii	K-246
225	<i>Tylophora sylvatica</i> Decne.	Asclepiadaceae	H	gosa gororsa	K-205
226	<i>Urera hypselodendron</i> (A. Rich) Wed.	Urticaceae	Liana	lanqessa	K-099

227	<i>Vepris dainellii</i> (Pic. Serm.) Kokwaro	Rutaceae	T	hadheessa	KP53-127
228	<i>Vernonia auriculifera</i> Hiern	Asteraceae	Sh	reejjii badda	KP18-082
229	<i>Vernonia hochsteteri</i> Sch. Bip. ex Walp.	Asteraceae	Sh	gosa tijjimoo	KP2-019
230	<i>Vernonia hymenolepis</i> A. Rich.	Asteraceae	Sh	tijjimoo	K-153
231	<i>Vernonia rueppellii</i> Sch. Bip. ex Walp.	Asteraceae	Sh	reejjii	KP4-038
232	<i>Vernonia thomsoniana</i> Oliv. & Hiern ex Oliv.	Asteraceae	Sh	soyama guracha	K-156
233	<i>Vernonia wollastonii</i> S. Moore	Asteraceae	H	gosa ababoo	KP1-003
234	<i>Veronica abyssinica</i> Fres.	Scrophulariaceae	H	gosa kalala	K-188
235	<i>Vigna parkeri</i> Bak.	Fabaceae	H	gosa kalalaa3	K-190
236	<i>Viola abyssinica</i> Oliv.	Violaceae	H	gosa kalalaa 6	K-197
237	<i>Zehneria scabra</i> (Linn. f.) Sond.	Cucurbitaceae	H	gosa maracaa	K-269

Appendix 2 List of plant species not reported for Wollega floristic region on Flora of Ethiopia and Eritrea

N0	Name	Family	Growth forms
1	<i>Acanthus pubescens</i> (Oliv.) Engl.	Acanthaceae	Sh
2	<i>Adenostemma mauritianum</i> DC.	Asteraceae	H
3	<i>Aeschynomene indica</i> L.	Fabaceae	H
4	<i>Agrocharis incognita</i> (Norman) Heyw. & Jury	Apiaceae	H
6	<i>Alchemilla abyssinica</i> Fresen.	Rosaceae	H
7	<i>Amorphophallus gallaensis</i> (Engl.) N. E. Sr.	Araceae	H
8	<i>Andropogon abyssinicus</i> Fresen.	Poaceae	H
9	<i>Ardisiandra sibthorpioides</i> Hook. f.	Primulaceae	H
10	<i>Argemone mexicana</i> L.	Papaveraceae	H
11	<i>Arundo donax</i> L.	Poaceae	Sh
12	<i>Asplenium buettneri</i> Hieron. ex Brause	Aspleniaceae	H
13	<i>Asplenium protensum</i> Schrad.	Aspleniaceae	H
14	<i>Asplenium sandersonii</i> Hook.	Aspleniaceae	H
15	<i>Asplenium smedsii</i> Pic. Serm.	Aspleniaceae	H
16	<i>Australina flaccida</i> (A. Rich.) Wedd.	Urticaceae	H
17	<i>Bidens macroptera</i> (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	H
18	<i>Cardamine africana</i> L.	Brassicaceae	H
19	<i>Carissa spinarum</i> L.	Apocynaceae	Sh
20	<i>Caylusea abyssinica</i> (Fresen.) Fisch. & Mey.	Resedaceae	H
21	<i>Cheilanthes farinose</i> (Forssk.) Kaulf.	Sinopteridaceae	H
22	<i>Cirsium vulgare</i> (Savi.) Ten.	Asteraceae	H
23	<i>Clutia abyssinica</i> Jaub. & Spach.	Euphorbiaceae	Sh
24	<i>Commelina latifolia</i> Hochst. ex A. Rich.	Commelinaceae	H
25	<i>Crassula alsinoides</i> (Hook. f.) Engl.	Crassulaceae	H
26	<i>Crotalaria pychnostachya</i> Benth.	Fabaceae	H
27	<i>Cryptotaenia africana</i> (Hook. f.) Drude	Apiaceae	H
28	<i>Cynoglossum amplifolium</i> Hochst. ex A. DC. in DC.	Boraginaceae	H
29	<i>Cyperus distans</i> L. f.	Cyperaceae	H
30	<i>Cyperus rotundus</i> L.	Cyperaceae	H
31	<i>Datura metel</i> L.	Solanaceae	H
32	<i>Dicrocephala integrifolia</i> (L. f.) Kuntze	Asteraceae	H
33	<i>Discopodium penninervium</i> Hochst.	Solanaceae	T
34	<i>Dumasia villosa</i> DC.	Fabaceae	H
35	<i>Eleusine africana</i> Kenn.-O'Byrne	Poaceae	H
36	<i>Entada africana</i> Guill. & Perr.	Fabaceae	T

38	<i>Euphorbia ampliphylla</i> Pax	Euphorbiaceae	T
39	<i>Euphorbia schimperiana</i> Scheele	Euphorbiaceae	H
40	<i>Ficus exasperata</i> Vahl	Moraceae	T
41	<i>Geranium arabicum</i> Forssk.	Geraniaceae	H
42	<i>Geranium ocellatum</i> Cambess.	Geraniaceae	H
43	<i>Helichrysum schimper</i> (Sch. Bip. ex A. Rich.) Moeser	Asteraceae	H
44	<i>Hibiscus macranthus</i> Hochst. ex A. Rich.	Malvaceae	Sh
45	<i>Hibiscus ovalifolius</i> (Frossk.) Vahl	Malvaceae	Sh
46	<i>Hippocratea pallens</i> Planch. ex Oliver	Celastraceae	Liana
47	<i>Hyparrhenia cymbaria</i> (L.) Stapf	Poaceae	H
48	<i>Isoglossa somalensis</i> Lindau	Acanthaceae	Sh
49	<i>Kalanchoe densiflora</i> Rolfe	Crassulaceae	H
50	<i>Kyllinga odorata</i> Vahl	Cyperaceae	H
51	<i>Lagenaria abyssinica</i> (Hook.f.) C. Jeffrey	Cucurbitaceae	H
52	<i>Lobelia giberroa</i> Hemsl.	Lobeliaceae	Sh
53	<i>Loxogramme abyssinica</i> (Baker) M.G. Price	Polypodiaceae	Sh
54	<i>Maytenus addat</i> (Loes.) Sebsebe	Celastraceae	T
55	<i>Momordica foetida</i> Schumach.	Cucurbitaceae	H
56	<i>Morus alba</i> L.	Moraceae	T
57	<i>Myrsine africana</i> L.	Myrsinaceae	Sh
58	<i>Ochna holstii</i> Engl.	Ochnaceae	Sh
59	<i>Olea capensis</i> L. subsp. <i>hochstetteri</i> (Bak.) Friis & P. S. Green	Oleaceae	T
60	<i>Olea europaea</i> L. subsp. <i>cuspidata</i> (Wall. ex G. Don) Cif.	Oleaceae	T
61	<i>Panicum hochstetteri</i> Steud.	Poaceae	H
62	<i>Passiflora caerulea</i> L.	Passifloraceae	H
63	<i>Pavonia patens</i> (Andr.) Chiov.	Malvaceae	H
64	<i>Pennisetum trachyphyllum</i> Pilg.	Poaceae	H
65	<i>Pentarrhinum insipidum</i> E. Mey.	Asclepiadaceae	H
66	<i>Pentas lanceolata</i> (Forssk.) Deflers	Rubiaceae	H
67	<i>Pentas schimperiana</i> (A. Rich.) Vatke	Rubiaceae	Sh
68	<i>Peponium vogelii</i> (Hook.f.) Engl.	Cucurbitaceae	H
69	<i>Phyllanthus fischeri</i> Pax	Euphorbiaceae	H
70	<i>Pilea rivularis</i> Wedd.	Urticaceae	H
71	<i>Plantago palmata</i> Hook. f.	Plantaginaceae	H
72	<i>Plectranthus longipes</i> Baker	Lamiaceae	H
73	<i>Polyscias fulva</i> (Hiern) Harms	Araliaceae	T
74	<i>Pteris dentata</i> Forssk.	Pteridaceae	H

75	<i>Pycnostachys abyssinica</i> Fresen.	Lamiaceae	Liana
76	<i>Rhus glutinosa</i> A. Rich.	Anacardiaceae	Sh
77	<i>Rhynchosia minima</i> (L.) DC.	Fabaceae	H
78	<i>Rubus niveus</i> Thunb.	Rosaceae	Liana
79	<i>Rumex nervosus</i> Vahl	Polygonaceae	H
80	<i>Salvia nilotica</i> Jacq.	Lamiaceae	H
81	<i>Schrebera alata</i> (Hochst.) Welw.	Oleaceae	T
82	<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Asteraceae	Sh
83	<i>Solanum aculeatissimum</i> Jacq.	Solanaceae	H
84	<i>Solanum incanum</i> L.	Solanaceae	Sh
85	<i>Solanum nigrum</i> L.	Solanaceae	H
86	<i>Sphaeranthus suaveolens</i> (Forssk.) DC.	Asteraceae	H
87	<i>Tagetes minuta</i> L.	Asteraceae	H
88	<i>Teramnus labialis</i> (L. f.) Spreng.	Fabaceae	H
89	<i>Tridactyle bicaudata</i> (Lindl.) Schltr.	Orchidaceae	H
90	<i>Tylophora sylvatica</i> Decne.	Asclepiadaceae	H
91	<i>Vernonia rueppellii</i> Sch. Bip. ex Walp.	Asteraceae	Sh
92	<i>Vernonia thomsoniana</i> Oliv. & Hiern ex Oliv.	Asteraceae	Sh
93	<i>Veronica abyssinica</i> Fres.	Scrophulariaceae	H
94	<i>Warburgia ugandensis</i> Sprague	Canellaceae	T
95	<i>Ximenia americana</i> L.	Oleaceae	Sh

Appendix 3 Ecological importance of woody species with dbh ≥ 2.5 cm

Scientific names	Growth forms	Frequency	Density (ha-1)	Dominance (ha-1)	RF	Relative density	Relative dominance	IVI
<i>Pouteria adolfi-friederici</i> (Engl.) Baehni	T	67.12	101.71	30.15	0.63	6.89	30.15	37.67
<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>afromontanum</i> F. White	T	67.12	131.85	8.08	6.63	8.93	8.08	23.64
<i>Dracaena afromontana</i> Mildbr.	Sh	67.12	283.56	0.69	0.63	19.2	0.69	20.52
<i>Chionanthus mildbraedii</i> (Gilg & Schellenb) Stearn	Sh	60.27	132.88	0.99	5.95	9	0.99	15.94
<i>Croton macrostachyus</i> Del.	T	49.32	46.23	4.28	4.87	3.13	4.28	12.28
<i>Ficus sur</i> Forssk.	T	38.36	38.01	5.04	3.79	2.57	5.04	11.4
<i>Maytenus gracilipes</i> (Welw. ex Oliv.) Exell subsp. <i>argota</i> (Loes.) Sebsebe	Sh	45.21	87.33	0.12	4.47	5.91	0.35	10.73
<i>Olea welwitschii</i> (Knobl.) Gilg & Schellenb.	T	45.21	43.49	1.8	4.47	2.94	1.8	9.21
<i>Apodytes dimidiata</i> E. Mey. ex Arn.	T	42.47	32.88	2.19	4.19	2.23	2.19	8.61
<i>Macaranga capensis</i> (Baill.) Sim	T	34.25	43.49	2.14	3.38	2.94	2.14	8.46
<i>Landolphia buchananii</i> (Hall. f.) Stapf	Liana	42.47	60.27	0.16	4.19	4.08	0.16	8.43
<i>Vepris dainellii</i> (Pic. Serm.) Kokwaro	T	38.36	37.33	0.84	3.79	2.53	0.84	7.16
<i>Bersama abyssinica</i> Fresen.	T	41.1	33.22	0.1	4.06	2.25	0.1	6.41
<i>Galiniera saxifraga</i> (Hochst.) Bridson	Sh	32.88	40.75	0.08	3.25	2.76	0.08	6.09
<i>Allophylus abyssinicus</i> (Hochst.) Radlk.	T	26.03	25	0.34	2.57	1.69	0.34	4.6
<i>Embelia schimperii</i> Vatke	Liana	17.81	10.96	0.01	1.76	0.74	1.18	3.68
<i>Cassipourea malosana</i> (Baker) Alston	T	21.92	18.84	0.1	2.17	1.28	0.1	3.55
<i>Maesa lanceolata</i> Forssk.	Sh	17.81	20.89	0.24	1.76	1.41	0.24	3.41
<i>Millettia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	T	12.33	29.11	0.22	1.22	1.97	0.22	3.41
<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Sh	9.59	31.16	0.03	0.95	2.11	0.03	3.09
<i>Hippocratea pallens</i> Planch. ex Oliv.	Liana	17.81	15.41	0.04	1.76	1.04	0.04	2.84
<i>Prunus africana</i> (Hook. f.) Kalkm.	T	16.44	9.59	0.43	1.62	0.65	0.43	2.7
<i>Brucea antidysentrica</i> J. F. Mill.	Sh	19.18	10.27	0.02	1.89	0.7	0.02	2.61
<i>Maytenus addat</i> (Loes.) Sebsebe	T	12.33	10.62	0.62	1.22	0.72	0.62	2.56
<i>Canthium oligocarpum</i> Hiern	Sh	13.7	15.07	0.05	1.35	1.02	0.05	2.42
<i>Ekebergia capensis</i> Sparrm.	T	9.59	4.11	0.69	0.95	0.28	0.69	1.92
<i>Schefflera abyssinica</i> (Hochst. ex A. Rich.) Harms	T	2.74	0.68	1.54	0.27	0.05	1.54	1.86
<i>Olea capensis</i> L. subsp. <i>hochstetteri</i> (Bak.) Friis & P. S. Green	T	8.22	13.7	0.07	0.81	0.93	0.07	1.81
<i>Erythrococca trichogyne</i> (Muell Arg.)	Sh	8.22	4.79	0.01	0.81	0.32	0.51	1.64

Prain								
<i>Ilex mitis</i> (L.) Radlk.	T	5.48	10.27	0.35	0.54	0.7	0.35	1.59
<i>Gouania longispicata</i> Engl.	Liana	10.96	7.19	0.01	1.08	0.49	0.01	1.58
<i>Combretum paniculatum</i> Vent.	Liana	4.11	6.51	0.01	0.41	0.44	0.7	1.55
<i>Buddleja polystachya</i> Fresen.	Sh	5.48	11.64	0.03	0.54	0.79	0.03	1.36
<i>Ehretia cymosa</i> Thonn.	T	4.11	12.33	0.08	0.41	0.83	0.08	1.32
<i>Dombeya torrida</i> (J. F. Gmel.) P. Bamps	Sh	6.85	7.53	0.05	0.68	0.51	0.05	1.24
<i>Hypericum peplidifolium</i> A. Rich.	Sh	5.48	9.93	0.01	0.54	0.67	0.01	1.22
<i>Rhus glutinosa</i> A. Rich.	Sh	4.11	7.88	0.08	0.41	0.53	0.08	1.02
<i>Albizia gummifera</i> (J. F. Gmel.) C. A. Sm.	T	2.74	6.51	0.24	0.27	0.44	0.24	0.95
<i>Cordia africana</i> Lam.	T	5.48	3.08	0.2	0.54	0.21	0.2	0.95
<i>Phoenix reclinata</i> Jacq.	Sh	5.48	5.14	0.06	0.54	0.35	0.06	0.95
<i>Albizia schimperiana</i> Oliv.	T	4.11	5.14	0.17	0.41	0.35	0.17	0.93
<i>Jasminum abyssinicum</i> Hochst. ex DC.	Liana	4.11	2.74	0.01	0.41	0.19	0.3	0.9
<i>Keetia gueinzii</i> (Sond.) Bridson	Liana	4.11	6.16	0.01	0.41	0.42	0.01	0.84
<i>Polyscias fulva</i> (Hiern) Harms	T	5.48	1.37	0.2	0.54	0.09	0.2	0.83
<i>Clematis hirsuta</i> Perr. & Guill	Liana	2.74	2.74	0	0.27	0.19	0.3	0.76
<i>Myrsine africana</i> L.	Sh	2.74	2.4	0	0.27	0.16	0.26	0.69
<i>Nuxia congesta</i> R. Br. ex Fresen.	Sh	2.74	4.45	0.08	0.27	0.3	0.08	0.65
<i>Abutilon longicuspe</i> Hochst. ex A. Rich.	Sh	1.37	2.4	0	0.14	0.16	0.26	0.56
<i>Urera hypselodendron</i> (A. Rich) Wed.	Liana	1.37	2.4	0	0.14	0.16	0.26	0.56
<i>Flacourtia indica</i> (Burm. f.) Merr.	Sh	4.11	2.05	0	0.41	0.14	0	0.55
<i>Clausena anisata</i> (Willd.) Benth.	Sh	1.37	2.05	0	0.14	0.14	0.22	0.5
<i>Coffea arabica</i> L.	Sh	1.37	2.05	0	0.14	0.14	0.22	0.5
<i>Ocimum urticifolium</i> Roth	Sh	1.37	2.05	0	0.14	0.14	0.22	0.5
<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	Sh	4.11	1.03	0.01	0.41	0.07	0	0.48
<i>Celtis africana</i> Burm. f.	T	1.37	1.71	0	0.14	0.12	0.19	0.45
<i>Dalbergia lactea</i> Vatke	Sh	1.37	1.71	0	0.14	0.12	0.19	0.45
<i>Ochna holstii</i> Engl.	Sh	1.37	1.71	0	0.14	0.12	0.19	0.45
<i>Psychotria orophila</i> Petit	Sh	1.37	1.71	0	0.14	0.12	0.19	0.45
<i>Rubus apetalus</i> Poir.	Liana	2.74	1.03	0	0.27	0.07	0.11	0.45
<i>Acanthus eminens</i> C. B. Clarke	Sh	2.74	0.68	0	0.27	0.05	0.08	0.4
<i>Rubus niveus</i> Thunb.	Cl	2.74	0.68	0	0.27	0.05	0.08	0.4
<i>Lepidotrichilia volkensii</i> (Gürke) Leroy	Sh	1.37	1.37	0	0.14	0.09	0.14	0.37
<i>Cyathea manniana</i> Hook.	T	2.74	1.03	0.01	0.27	0.07	0.01	0.35
<i>Pittosporum viridiflorum</i> Sims	Sh	1.37	1.03	0	0.14	0.07	0.11	0.32

<i>Vernonia auriculifera</i> Hiern	Sh	1.37	2.4	0	0.14	0.16	0	0.3
<i>Phyllanthus limmuensis</i> Cufod.	Sh	1.37	0.68	0	0.14	0.05	0.08	0.27
<i>Grewia ferruginea</i> Hochst. ex A. Rich.	Sh	1.37	0.34	0	0.14	0.02	0.03	0.19
<i>Solanecio mannii</i> (Hook. f.) C. Jeffrey	Sh	1.37	0.34	0	0.14	0.02	0.03	0.19
<i>Senna petersiana</i> (Bolle) Lock	Sh	1.37	0.34	0.01	0.14	0.02	0.01	0.17

Appendix 4 List of medicinal and wild edible plants found in JWF

N0	Scientific name	Family	Habit	Local name	Use
1	<i>Acanthus pubescens</i> (Oliv.) Engl.	Acanthaceae	Sh	kosoruu	F
2	<i>Achyranthes aspera</i> L.	Amaranthaceae	H	qamaxee	M
3	<i>Adiantum poiretii</i> Wikstr.	Adiantaceae	H	Facatuu	M
4	<i>Aframomum corrorima</i> (Braun) Jansen	Zingiberaceae	H	ogiyoo/kororiimaa	F
5	<i>Ageratum conyzoides</i> L.	Asteraceae	H	Cinciri	M
6	<i>Ajuga alba</i> (Gürke) Robyns	Lamiaceae	H	Qoricha gara ciniinaa	M
7	<i>Albizia schimperiana</i> Oliv.	Fabaceae	T	Muka arbaa	M
8	<i>Asparagus racemosus</i> Willd.	Asparagaceae	Liana	Sarariitii	M
9	<i>Australina flaccida</i> (A. Rich.) Webb.	Urticaceae	H	Gurati/mada miila cifatu	M
10	<i>Bersama abyssinica</i> Fresen.	Melanthiaceae	T	Lolchiisaa	M
11	<i>Bidens macroptera</i> (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	H	Kello	F
12	<i>Bridelia micrantha</i> (Hochst.) Baill.	Euphorbiaceae	T	Rigarba	FM
13	<i>Brucea antidycentrica</i> J.F. Mill.	Simaroubaceae	Sh	Qomonyoo	M
14	<i>Buddleja polystachya</i> Fresen.	Loganiaceae	Sh	Hanfaarree	M
15	<i>Calpurnia aurea</i> (Ait.) Benth.	Fabaceae	Sh	Ceekaa	M
16	<i>Cassipourea malosana</i> (Baker) Alston	Rhizophoraceae	T	Lokoo	M
17	<i>Caylusea abyssinica</i> (Fresen.) Fisch. & Mey.	Resedaceae	H	Ilaancoo	FM
18	<i>Centella asiatica</i> (L.) Urban	Apiaceae	H	Gurra hantuuta	M
19	<i>Chionanthus mildbraedii</i> (Gilg & Schellenb) Stearn	Oleaceae	Sh	Gagamaa	M
20	<i>Cirsium vulgare</i> (Savi.) Ten.	Asteraceae	H	Luudata/Qoricha sabata waqayyoo	M
21	<i>Clausena anisata</i> (Wild.) Benth.	Rutaceae	Sh	Ulmaayii	FM
22	<i>Coffea arabica</i> L.	Rubiaceae	Sh	Buna	FM
23	<i>Combretum paniculatum</i> Vent.	Combretaceae	Liana	Baggee	M
24	<i>Conyza pyrrhopappa</i> Sch. Bip. ex A. Rich.	Asteraceae	H	Qoricha dhiito	M
25	<i>Cordia africana</i> Lam.	Boraginaceae	T	Waddeessa	FM
26	<i>Croton macrostachyus</i> Del.	Euphorbiaceae	T	Bakkanniisa	M
27	<i>Cyathula uncinulata</i> (Schrad.) Schinz	Amaranthaceae	Sh	darguu	M
28	<i>Cynoglossum amplifolium</i> Hochst. ex A. DC. in DC.	Boraginaceae	H	Maxxannee	M
29	<i>Cyperus fischerianus</i> A. Rich.	Cyperaceae	H	Qunnii	M
30	<i>Cyphostemma cyphopetalum</i> (FreserL) Desc. ex Wild & Drummond	Vitaceae	Liana	Hidda reeffaa	M
31	<i>Dicrocephala integrifolia</i> (L. f.) Kuntze	Asteraceae	H	Burii	M
32	<i>Dracaena steudneri</i> Engl.	Dracaenaceae	Sh	Afarfatuu	M
33	<i>Drymaria cordata</i> (L.) Schultes	Caryophyllaceae	H	Qoricha mada	M
34	<i>Ehretia cymosa</i> Thonn.	Boraginaceae	T	Ulaagaa	M
35	<i>Eleusine africana</i> Kenn.-O'Byrne	Poaceae	H	coqorsa	M
36	<i>Embelia schimperii</i> Vatke	Myrsinaceae	Liana	Hanquuu	FM
37	<i>Englerina woodfordioides</i> (Schweinf.) M. Gilbert	Loranthaceae	Sh	Dheertu geesho	M
38	<i>Ensete ventricosum</i> (Welw.) Cheesman	Musaceae	H	Warqee	F

39	<i>Entada africana</i> Guill. & Perr.	Fabaceae	T	Ambalta	M
40	<i>Ficus sur</i> Forssk.	Moraceae	T	Harbu	F
41	<i>Ficus vasta</i> Forssk.	Moraceae	T	Qilxuu	M
42	<i>Galiniera saxifraga</i> (Hochst.) Bridson	Rubiaceae	Sh	Muka guraacha	M
43	<i>Girardinia diversifolia</i> (Link) Friis	Urticaceae	Liana	Doobbii	M
44	<i>Guizotia scabra</i> (Vis.) Chiov.	Asteraceae	H	Tuufuu	M
45	<i>Helichrysum schimperi</i> (Sch.Bip. ex A. Rich.) Moeser	Asteraceae	H	Qoricha ilkanii	M
46	<i>Helinus mystacinus</i> (Ait.) E. Mey. ex Steud.	Rhamnaceae	Liana	Hidda hoomoo	M
47	<i>Indigofera arrecta</i> Hochst. ex A. Rich.	Fabaceae	Sh	Heennaa	M
48	<i>Justicia ladanoides</i> Lam.	Acanthaceae	H	Qoricha marataa	M
49	<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	Acanthaceae	Sh	Dhumugaa	M
50	<i>Kalanchoe densiflora</i> Rolfe	Crassulaceae	H	Dhoqdhoqee	M
51	<i>Leucas deflexa</i> Hook. f.	Lamiaceae	H	Qoricha michii/yeroo	M
52	<i>Lippia adoensis</i> Hochst. ex Walp.	Verbenaceae	Sh	Kusaayee	F
53	<i>Loxogramme abyssinica</i> (Baker) M. G. Price	Polypodiaceae	Sh	Sinkir balleessa	M
54	<i>Maesa lanceolata</i> Forssk.	Myrsinaceae	Sh	Abbayyii	M
55	<i>Maytenus gracilipes</i> (Welw. ex Oliv.) Exell	Celastraceae	Sh	Kombolcha	M
56	<i>Milletia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	Fabaceae	T	Sootalloo	M
57	<i>Mucuna melanocarpa</i> Hochst.	Fabaceae	Liana	machara	M
58	<i>Nicardia physaloides</i> (L.) Gaertn.	Solanaceae	H	Qoricha kormammuu	M
59	<i>Ocimum lamiifolium</i> Hochst. ex Benth.	Lamiaceae	Sh	Damakase	M
60	<i>Ocimum urticifolium</i> Roth	Lamiaceae	Sh	Ancabii/hancabii	M
61	<i>Olea europaea</i> L. subsp. <i>cuspidata</i> (Wall. ex G. Don) Cif.	Oleaceae	T	Ejersa	M
62	<i>Pavetta oliveriana</i> Hiern	Rubiaceae	Sh	Mixoo	M
63	<i>Pentas lanceolata</i> (Forssk.) Deflers	Rubiaceae	H	Qoricha dhiito	M
64	<i>Pentas schimperiana</i> (A. Rich.) Vatke	Rubiaceae	Sh	Suuma leencaa	M
65	<i>Peponium vogelii</i> (Hook. f.) Engl.	Cucurbitaceae	H	Hadhoftu sexana	M
66	<i>Phoenix reclinata</i> Jacq.	Arecaceae	Sh	meexii	F
67	<i>Phytolacca dodecandra</i> L'Hérit.	Phytolaccaceae	T	andodee	M
68	<i>Piper capense</i> L. f.	Piperaceae	H	Tunjo	FM
69	<i>Pittosporum viridiflorum</i> Sims	Pittosporaceae	T	Soolee	M
70	<i>Plantago palmata</i> Hook. f.	Plantaginaceae	H	Qoricha marataa	M
71	<i>Podocarpus falcatus</i> (Thunb.) R. B. ex. Mirb.	Podocarpaceae	T	Birbirsaa	M
72	<i>Premna schimperi</i> Engl.	Lamiaceae	Sh	Urgeessaa	M
73	<i>Prunus africana</i> (Hook. f.) Kalkm.	Rosaceae	T	Hoomii	M
74	<i>Pteridium aquilinum</i> (L.) Khun	Pteridaceae	H	Giixoo boollaa	F
75	<i>Pycnostachys abyssinica</i> Fresen.	Lamiaceae	Liana	yeruo (bada)/mata boke	M
76	<i>Ranunculus multifidus</i> Forssk.	Ranunculaceae	Liana	Qoricha simbiraa	M
77	<i>Rhamnus prinoides</i> L'Herit.	Rhamnaceae	Sh	Gesho	FM
78	<i>Ricinus communis</i> L.	Euphorbiaceae	H	Qobo simbira	M

79	<i>Ritchiea albersii</i> Gilg.	Capparidaceae	Sh	Deqoo/denqericho?	M
80	<i>Rubus apetalus</i> Poir.	Rosaceae	Liana	gora guraacha	F
81	<i>Rubus niveus</i> Thunb.	Rosaceae	Liana	Gora gafarssaa	F
82	<i>Rumex abyssinicus</i> Jacq.	Polygonaceae	H	Dhangaggoo	FM
83	<i>Rumex nepalensis</i> Spreng.	Polygonaceae	H	Timijjii	M
84	<i>Schefflera abyssinica</i> (Hochst. ex A. Rich.) Harms	Araliaceae	T	Gatamaa	M
85	<i>Schrebera alata</i> (Hochst.) Welw.	Oleaceae	T	Dhama'ee	M
86	<i>Senna petersiana</i> (Bolle) Lock	Fabaceae	Sh	Raamsoo	F
87	<i>Setaria poiretiana</i> (Schult.) Kunth	Poaceae	H	Sokokee	M
88	<i>Sida rhombifolia</i> L.	Malvaceae	H	Karabii	M
89	<i>Sida tenuicarpa</i> Vollesen	Malvaceae	H	Insilale	M
90	<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Asteraceae	Sh	Timbatimbo	M
91	<i>Solanum anguivi</i> Lam.	Solanaceae	Sh	Hiddii qalamee	M
92	<i>Solanum giganteum</i> Jacq.	Solanaceae	Sh	Dalachoo/solanum spp	M
93	<i>Solanum incanum</i> L.	Solanaceae	Sh	Hiddii	M
94	<i>Stereospermum kunthianum</i> Cham.	Bignoniaceae	T	Botoroo	M
95	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>afromontanum</i> F. White	Myrtaceae	T	Badessa	FM
96	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>guineense</i>	Myrtaceae	T	Gomare	F
97	<i>Thalictrum rhynchocarpum</i> Dill. & A. Rich.	Ranunculaceae	H	wallage/Sirabizuu2	M
98	<i>Urera hypselodendron</i> (A. Rich) Wed.	Urticaceae	Liana	lanqessa	M
99	<i>Vepris dainellii</i> (Pic. Serm.) Kokwaro	Rutaceae	T	Hadheessa	FM
100	<i>Vernonia auriculifera</i> Hiern	Asteraceae	Sh	Reejjii baddaa	M
101	<i>Vernonia hymenolepis</i> A. Rich.	Asteraceae	Sh	Tijimo	M
102	<i>Vernonia rueppellii</i> Sch. Bip. ex Walp.	Asteraceae	Sh	Balaantaa	M

NB: F = food; M = medicinal; FH = food and medicinal

Appendix 5 Ecological importance of medicinal and WEPs in JWF

N0	Names	Growth forms	Frequency	Density (ha-1)	Dominance (ha-1)	Relative frequency	Relative density	Relative dominance	IVI
1	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>afromontanum</i> F. White	T	67.12	131.85	8.08	6.63	8.93	8.08	23.64
2	<i>Chionanthus mildbraedii</i> (Gilg & Schellenb) Stearn	Sh	60.27	132.88	0.99	5.95	9.00	0.99	15.94
3	<i>Croton macrostachyus</i> Del.	T	49.32	46.23	4.28	4.87	3.13	4.28	12.28
4	<i>Ficus sur</i> Forssk.	T	38.36	38.01	5.04	3.79	2.57	5.04	11.40
5	<i>Maytenus gracilipes</i> (Welw. ex Oliv.) Exell subsp. <i>argota</i> (Loes.) Sebsebe	Sh	45.21	87.33	0.12	4.47	5.91	0.35	10.73
6	<i>Vepris dainellii</i> (Pic. Serm.) Kokwaro	T	38.36	37.33	0.84	3.79	2.53	0.84	7.16
7	<i>Bersama abyssinica</i> Fresen.	T	41.10	33.22	0.10	4.06	2.25	0.10	6.41
8	<i>Galiniera saxifraga</i> (Hochst.) Bridson	Sh	32.88	40.75	0.08	3.25	2.76	0.08	6.09
9	<i>Embelia schimperii</i> Vatke	Liana	17.81	10.96	0.01	1.76	0.74	1.18	3.68
10	<i>Cassipourea malosana</i> (Baker) Alston	T	21.92	18.84	0.10	2.17	1.28	0.10	3.55
11	<i>Maesa lanceolata</i> Forssk.	Sh	17.81	20.89	0.24	1.76	1.41	0.24	3.41
12	<i>Millettia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	T	12.33	29.11	0.22	1.22	1.97	0.22	3.41
13	<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Sh	9.59	31.16	0.03	0.95	2.11	0.03	3.09
14	<i>Prunus africana</i> (Hook. f.) Kalkm.	T	16.44	9.59	0.43	1.62	0.65	0.43	2.70
15	<i>Brucea antidysentrica</i> J. F. Mill.	Sh	19.18	10.27	0.02	1.89	0.70	0.02	2.61
16	<i>Schefflera abyssinica</i> (Hochst. ex A. Rich.) Harms	T	2.74	0.68	1.54	0.27	0.05	1.54	1.86
17	<i>Combretum paniculatum</i> Vent.	Liana	4.11	6.51	0.01	0.41	0.44	0.70	1.55
18	<i>Buddleja polystachya</i> Fresen.	Sh	5.48	11.64	0.03	0.54	0.79	0.03	1.36
19	<i>Ehretia cymosa</i> Thonn.	T	4.11	12.33	0.08	0.41	0.83	0.08	1.32
20	<i>Cordia africana</i> Lam.	T	5.48	3.08	0.20	0.54	0.21	0.20	0.95
21	<i>Phoenix reclinata</i> Jacq.	Sh	5.48	5.14	0.06	0.54	0.35	0.06	0.95
22	<i>Albizia schimperiana</i> Oliv.	T	4.11	5.14	0.17	0.41	0.35	0.17	0.93
23	<i>Urera hypselodendron</i> (A. Rich) Wed.	Liana	1.37	2.4	0	0.14	0.16	0.26	0.56
24	<i>Clausena anisata</i> (Wild.) Benth.	Sh	1.37	2.05	0.00	0.14	0.14	0.22	0.50
25	<i>Coffea arabica</i> L.	Sh	1.37	2.05	0.00	0.14	0.14	0.22	0.50
26	<i>Ocimum urticifolium</i> Roth	Sh	1.37	2.05	0.00	0.14	0.14	0.22	0.50
27	<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	Sh	4.11	1.03	0.01	0.41	0.07	0.00	0.48
28	<i>Rubus apetalus</i> Poir.	Liana	2.74	1.03	0.00	0.27	0.07	0.11	0.45
29	<i>Acanthus eminens</i> C. B. Clarke	Sh	2.74	0.68	0.00	0.27	0.05	0.08	0.40
30	<i>Rubus niveus</i> Thunb.	Liana	2.74	0.68	0.00	0.27	0.05	0.08	0.40
31	<i>Pittosporum viridiflorum</i> Sims	T	1.37	1.03	0.00	0.14	0.07	0.11	0.32
32	<i>Vernonia auriculifera</i> Hiern	Sh	1.37	2.40	0.00	0.14	0.16	0.00	0.30
33	<i>Senna petersiana</i> (Bolle) Lock	Sh	1.37	0.34	0.01	0.14	0.02	0.01	0.17

Appendix 6 List of ethnomedicinal plants used in Nole Kaba District and their applications

NO	Scientific name	Family	Local name	Habits	Local name of treated diseases	Mode of formulation and application	Coll. NO
1	<i>Acacia abyssinica</i> Hochst. ex Benth.	Fabaceae	sondi	T	dugda kuta , swelling	Root extract concocted with coffee is drunk to cure back pain; bark infusion is drunk to treat swelling	K-160
2	<i>Achyranthes aspera</i> L.	Amaranthaceae	qamaxe	H	mada ibida	Crushed leaf is applied on fire burn	K-046
3	<i>Acmella caulirhiza</i> Del.	Asteraceae	gororsiisa	H	huba qonqoo, dhukuba ilkanii fi sare	Flower infusion is drunk with salt or coffee to treat tonsillitis; flower and leaves are crushed and held between teeth to treat toothache; root infusion is drunk with salt or coffee to treat rabies	K-027
4	<i>Adiantum poiretii</i> Wikstr.	Adiantaceae	facatuu/sirabizu	H	sarariti/fincooftu, cophxo	Fresh leaves are crushed and applied on the affected part; leaf concoction containing garlic and hot pepper is drunk to treat gonorrhea	K-123
5	<i>Ageratum conyzoides</i> L.	Asteraceae	cinciri/udan awanniisa/cincirii	H	dhiiga lagu dhabu, mata bowo, dhiiga dhabu	Leaf is crushed and tied on a bleeding wound; crushed leaves are inhaled to treat migraine; crushed leaves is applied on the bleeding wound	K-187
6	<i>Agrocharis incognita</i> (Norman) Heyw. & Jury	Apiaceae	qoricha garaa kaasaa	H	gara kasa	The leaf infusion is drunk	K-003
7	<i>Ajuga alba</i> (Gürke) Robyns	Lamiaceae	qoricha gara ciniinaa	H	gara ciniina	the leaf infusion is drunk	K-131
8	<i>Amorphophallus gallaensis</i> (Engl.) N. E. Br.	Araceae	qicuu	H	miila dhiita	Root is crushed and concocted with butter and tied on the affected part	K-122
9	<i>Argemone mexicana</i> L.	Papaveraceae	qoricha marataa	H	hadha marata/bofa	Leaf infusion concocted with butter is drunk to treat snakebite	K-058
10	<i>Asparagus racemosus</i> Willd.	Asparagaceae	sarariti	Liana	sariti/fincooftu	Leaves are crushed, mixed with butter and the poultice is applied on the affected part	K-075
11	<i>Aspilota mossambicensis</i> (Oliv.) Wild	Asteraceae	hadaa	H	dhiiga dhabu	Leaf is crushed and applied on the bleeding wound	K-142
12	<i>Bersama abyssinica</i> Fresen.	Melanthiaceae	lolchiisaa	T	dhukuba ilkanii, maga, mata bowo	The bark is chewed and held between affected teeth; bark extract is salted and drunk to treat amoeba; bark infusion is dropped into nostrils and rubbed on the face to treat migraine	K-008
13	<i>Brucea antidysentrica</i> J. F. Mill.	Simaroubaceae	qomonyoo	Sh	mata bowo, michi, busa, qole gogsa dhukuba sare marate	Leaf is gently heated and kept on the forehead and inhaled to treat migraine, febrile; leaf infusion is drunk to treat meningitis, malaria and rabies	K-028
14	<i>Calpurnia aurea</i> (Ait.) Benth.	Fabaceae	ceekaa	Sh	dhukuba sare marate, gara kasaa		K-100
15	<i>Capparis tomentosa</i> Lam.	Capparidaceae	harangama gurraacha	Liana	mata bowo, jonji, michi, gara cinina, dhukuba ilkan, buda	The smoke of dried or fresh root is inhaled to treat migraine, circling sickness and febrile; root is chewed and held between teeth to treat toothache; infusion of bark and root is drunk to treat stomachache; the infusion is dropped into nostrils to treat evil eye	K-007

16	<i>Carissa spinarum</i> L.	Apocynaceae	agamsa	Sh	gara ciniina, maga, raamoo, jonji, dhukuba kalee	Fruits are eaten to treat stomachache; root infusion is drunk to treat amoeba, intestinal worms and circling sickness; The seed infusion is drunk to treat kidney problems	K-067
17	<i>Cassipourea malosana</i> (Baker) Alston	Rhizophoraceae	lokoo	T	dhukuba sare marate	Leaf is crushed, mixed with water and the salted extract is drunk to treat rabies	K-091
18	<i>Caylusea abyssinica</i> (Fresen.) Fisch. & Mey.	Resedaceae	ilaancoo	H	ballile, busa, qufa, guba laphe	Leaf is crushed and applied on a fungal affected part; boiled leaves are eaten as a vegetable with pancake (as nutraceutical) to treat malarial; leaf infusion is drunk to treat cough; cooked leaves are eaten as vegetable to cure chest burn	K-002
19	<i>Centella asiatica</i> (L.) Urban	Apiaceae	gurra hantuuta	H	michi	The dried leaf is pounded and mixed with water the infusion is drunk to treat febrile	K-111
20	<i>Cirsium vulgare</i> (Savi.) Ten.	Asteraceae	ludata	H	dhukuba sare marate, gara cinina, dhitto	Root is crushed, mixed with water, and the extract concocted with salt, milk or honey is drunk to treat rabies and stomachache; root infusion is drunk to treat glandular swelling	K-053
21	<i>Cissus populnea</i> Guill. & Perr.	Vitaceae	harkisa	Liana	summii, qufa	Fresh leaf is crushed and the liquid is dropped on snakebite, and dropped into nostrils to treat cough	K-134
22	<i>Clausena anisata</i> (Wild.) Benth.	Rutaceae	ulmaayii	Sh	mada ibida	Leaf sap is dropped onto burned part	K-060
23	<i>Clematis hirsuta</i> Perr. & Guill	Ranunculaceae	hidda fiitii	Liana	dhukuba simbira, dhukuuba ilkanii, dhukuba sare marate	A leaf infusion is drunk to treat jaundice; the crushed leaf is held on the affected tooth; root infusion is drunk to treat rabies	K-128
24	<i>Clerodendrum myricoides</i> (Hochst.) Vatke	Lamiaceae	bordoqee/marachiisa	Sh	garagara ciniina, ramoo gara, jinni	Root is chewed and the liquid is swallowed to treat stomachache; the liquid is dropped into nostrils to treat evil spirit; root infusion is drunk to treat intestinal worms	K-062
25	<i>Coffea arabica</i> L.	Rubiaceae	buna	Sh	dhiiga dhabu	Roasted coffee seed powder is applied on the bleeding wound	K-011
26	<i>Combretum molle</i> R. Br. ex Don	Combretaceae	dhandhansa	T	gara ciniina	The bark is chewed and the liquid is swallowed to treat stomachache	K-035
27	<i>Combretum paniculatum</i> Vent.	Combretaceae	baggee	Liana	dhukuba ija	A leaf sap is dropped into an eye to treat the eye problem	
28	<i>Conyza pyrrhopappa</i> Sch. Bip. ex A. Rich.	Asteraceae	qoricha dhiito	H	dhiito	Root infusion concocted with coffee or salt is drunk to treat swelling	K-136
29	<i>Cordia africana</i> Lam.	Boraginaceae	wadessa	T	saririi/finciooftu, gara ciniina	A leaf is crushed and applied on the affected part; root and bark are crushed together, mixed with water and the infusion is drunk to treat stomachache	K-72
30	<i>Crassocephalum crepidioides</i> (Benth.) S. Moore		ajo	H	dhukuba simbira	The leaf infusion is drunk to treat jaundice	K-72
31	<i>Crassocephalum macropappum</i> (Sch. Bip. ex A. Rich.) S. Moore	Asteraceae	qoricha dhiitoo	H	dhiito	A root infusion is drunk with salt or coffee to treat swelling	K-020

32	<i>Crepis rueppellii</i> Sch. Bip.	Asteraceae	anannoo	H	gara ciniina, hadhaa bofaa	Root is crushed, mixed with water and the salted infusions is drunk to treat stomachache and snake bite; at the same time crushed root is tied on the snakebite	K-020
33	<i>Crotalaria incana</i> L.	Fabaceae	atari qalame	H	fincooftu, miciree	Leaves are crushed and tied onto affected part of a skin	K-005
34	<i>Crotalaria pycnostachya</i> Benth.	Fabaceae	alangee	H	gara ciniina, hadhaa marata, jinni	Fresh root is crushed, mixed with water, and the infusion is drunk to treat stomachache, snake bite and evil spirit	K-139
35	<i>Croton macrostachyus</i> Del.	Euphorbiaceae	bakkanniisa	T	dhiga dhabu, mata bowo, jonji, michi, qole gogsa, dhukuba sare marate, dhiito	The leaf infusion is dropped onto bleeding wound; leaf is gently heated and held on the forefront to treat migraine; a leaf infusion is dropped into the nostril to treat febrile and circling sickness; leaf infusion is drunk to treat rabies; root and bark are crushed together and applied to cure swelling	K-079
36	<i>Cryptotaenia africana</i> (Hook. f.) Drude	Apiaceae	gondi	H	dhukuba ija, michi	Fresh leaf is crushed and liquid is dropped into the eye; leaf and flower are crushed, mixed with water and concocted with barely soup and drunk to treat febrile	K-079
37	<i>Cynoglossum amplifolium</i> Hochst. ex A. DC. in DC.	Boraginaceae	maxxannee	H	gara ciniina	Root is chewed and the liquid is swallowed to treat stomachache	K-109
38	<i>Cyperus fischerianus</i> A. Rich.	Cyperaceae	qunnii	H	hadha marata/bofa	A root infusion is concocted with lemon juice is drunk, the crushed residue is applied on the snakebite	K-070
39	<i>Cyphostemma cyphopetalum</i> (Fresen.) Desc. ex Wild & Drummond	Vitaceae	hida reefa	H	dhukuba sare marate	Root is crushed and drunk to treat rabies	K-045
40	<i>Datura metel</i> L.	Solanaceae	qoricha marataa	H	hadha marata/bofa	Root and leaf infusion is drunk to treat snake bite	K-045
41	<i>Datura stramonium</i> L.	Solanaceae	asangira	H	dhukuba sare marate, dhukuba ilkanii, cinii	Leaves and roots are crushed, mixed with water; infusion often concocted with salt, milk or honey or butter is drunk to treat rabies. Gently heated seed is held between affected teeth to treat toothache; Crushed leaves are applied on the head to remove lice infestation	K-101
42	<i>Dicrocephala integrifolia</i> (L. f.) Kuntze	Asteraceae	burii	H	gara ciniina	A root infusion is drunk or root is chewed and the liquid is swallowed to treat stomachache	K-139
43	<i>Discopodium penninervium</i> Hochst.	Solanaceae	goficho	T	mata bowo	Fresh leaf is heated and held on the forefront to treat migraine	K-128
44	<i>Dissotis senegambiensis</i> (Guill. & Perr.) Triana	Melastomataceae	darar diimessa	H	mada, huba qoonqo	The whole part is crushed and applied on sore; juice is swallowed to treat tonsillitis	K-44
45	<i>Dracaena steudneri</i> Engler	Dracaenaceae	afarfatu	Sh	dhukuba sare marate	Bark infusion salted or concocted with milk is drunk to treat rabies	K-118
46	<i>Dregea schimperi</i> (Decne.) Bullock	Asclepiadaceae	qoricha marata	Liana	hadha marata/bofa	Root and leaf are crushed together and applied on snakebite	K-61
47	<i>Drymaria cordata</i> (L.) Schultes	Caryophyllaceae	qoricha mada	H	dhukuba ilkanii, hadha marata/ bofa, dhukuba simbira	Leaf is chewed and held between teeth; leaf infusion is drunk to treat snakebite and jaundice	K-056

48	<i>Echinops amplexicaulis</i> Oliv.	Asteraceae	dichoo diimmaa	Sh	utallo/qufa, jini	A root extract is concocted with salt or coffee and drunk to treat flu and evil spirit	K-034
49	<i>Echinops longisetus</i> A. Rich.	Asteraceae	qabarichoo	Sh	mata bowo, jonji, michi, gara cinina, buda, qufa, hadha marata/bofa, dhukuba ilkanii	Dried root is burned on fire and its smoke is inhaled to treat migraines, circling sickness, febrile, evil eye and flu. Fresh root is chewed and held between teeth to treat toothache; root infusion is drunk to treat stomachache and snakebite	K-021
50	<i>Ehretia cymosa</i> Thonn.	Boraginaceae	ulaagaa	T	dhukuba ilkanii	Leaf is heated and held on between teeth or chewed and held between teeth	K-138
51	<i>Eleusine africana</i> Kenn.-O'Byrne	Poaceae	coqorsa	H	saritii/fincooftu	The whole part is crushed and applied on the affected skin	K-127
52	<i>Embelia schimperi</i> Vatke	Myrsinaceae	hanquu	Liana	kosoo, dhukuba sare marate	Seeds are crushed and mixed with water, the extract is drunk to treat tapeworm; leaf infusion is drunk to treat rabies	K-037
53	<i>Englerina woodfordioides</i> (Schweinf.) M. Gilbert	Loranthaceae	dheertu gesho	Sh	bokoka	Leaves are crushed, mixed with water and salted infusion is drunk to treat bloating	K-144
54	<i>Eriosema scioanum</i> Avetta	Fabaceae	qoricha ilkanii	H	dhukuba ilkanii	Leaf is chewed and held between teeth to treat toothache	K-109
55	<i>Euphorbia ampliphylla</i> Pax	Euphorbiaceae	adaamii	T	maga, tafki	Milky latex is concocted with tef or barley soup is drunk to treat amoeba; the latex is sprayed to remove the infestation of flea	K-054
56	<i>Euphorbia schimperiana</i> Scheele	Euphorbiaceae	anaano qalame	H	ballile, mada ibida	Latex is applied to treat dandruff and fire burn	K-096
57	<i>Ficus vasta</i> Forssk.	Moraceae	qilxu	T	dhiiga dhabu	Milky sap is dropped onto the bleeding wound	K-154
58	<i>Galinsoga quadriradiata</i> Ruiz & Pavon	Asteraceae	qoricha michi	H	michi	Leaves are crushed and inhaled; leaves are boiled steam bath inhaled to treat febrile	K-107
59	<i>Gardenia ternifolia</i> Schumach. & Thonn.	Rubiaceae	gambelloo	T	dhukuba ilkanii	The bark is chewed and held on the affected tooth	K-036
60	<i>Geranium arabicum</i> Forssk.	Geraniaceae	qoricha michii	H	michi	Leaves are crushed and inhaled, rubbed on the face to treat febrile	K-105
61	<i>Geranium ocellatum</i> Cambess.	Geraniaceae	qoricha shararitii	H	sarritii/fincooftu	Leaves are crushed and applied on skin affected by spider poisonous	K-042
62	<i>Guizotia scabra</i> (Vis.) Chiov.	Asteraceae	tufoo	H	gara ciniina, buda	Root is crushed together with ginger and garlic, mixed with water, salted extract of the mixture is drunk to treat stomachache; root infusion is drunk to treat evil eye	K-248
63	<i>Helichrysum schimperi</i> (Sch.Bip. ex A. Rich.) Moeser	Asteraceae	qoricha ilkanii	H	dhukuba ilkanii	Root is chewed and held between teeth to treat toothache	K-085
64	<i>Helinus mystacinus</i> (Ait.) E. Mey. ex Steud.	Rhamnaceae	hidda hoomo	Liana	agi ijoolee	Leaf, flower, and seed are crushed, mixed with water and the infusion is drunk to treat child tonsillitis	K-143
65	<i>Hygrophila schulli</i> (Hamilt.) M. R. & S. M. Almeida	Acanthaceae	balan warante	H	dhukuba tasaa, gara ciniina, dhukuba simbira	Crushed root is mixed with water, often salted and the drunk to treat sudden illness; leaf infusion is drunk to treat jaundice	K-085
66	<i>Indigofera arrecta</i> Hochst. ex A. Rich.	Fabaceae	hina guracha	Sh	sararitii/fincooftu	Dried or fresh leaves are crushed and rubbed/tied on skin part affected by spider poisonous	K-122
67	<i>Justicia ladanoides</i> Lam.	Acanthaceae	qoricha marata	H	hadha marata/bofa	Leaf is crushed and applied on snakebite or leaf infusion is drunk	K-015

						to treat snakebite	
68	<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	Acanthaceae	dhumugaa	Sh	dhukuba sare marate, mata bowo	Root and leaves are crushed, mixed with water, and the extract is drunk to treat rabies; liquid of crushed root is dropped into nostrils, rubbed on the face and steam bath is inhaled to treat migraine	K-092
69	<i>Kalanchoe densiflora</i> Rolfe	Crassulaceae	dhoqdhoqee	H	dhiito, agi ijooole	Leaf is gently heated and held on the swollen body part; salted leaf infusion is drunk to treat child tonsillitis	K-050
70	<i>Leucas deflexa</i> Hook. f.	Lamiaceae	qoricha michii	H	michi	Leaves are smashed and inhaled to treat migraine	K-057
71	<i>Lippia adoensis</i> Hochst. ex Walp.	Verbenaceae	kusaayee	Sh	gara ciniina	A leaf infusion is drunk to treat stomachache	K-057
72	<i>Loxogramme abyssinica</i> (Baker) M. G. Price	Polypodiaceae	sinkir balleessa	Sh	dhukuba ilkanii	The stem is crushed and held between affected teeth	K-180
73	<i>Maytenus gracilipes</i> (Welw. ex Oliv.) Exell	Celastraceae	kombolcha	Sh	gara kasaa	Fruit is chewed and the liquid is swallowed to treat diarrhea	K-123
74	<i>Mikania capensis</i>	Asteraceae	maracaa	H	gagabduu	Leaves are heated or smashed and inhaled to treat epilepsy	K-119
75	<i>Milletia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	Fabaceae	sootalloo	T	hadha marata/bofa, gara ciniina, ramoo gara	The bark is crushed and tied on snakebite; bark is chewed and the liquid is swallowed to treat stomachache; fruit is eaten to remove intestinal worms	K-106
76	<i>Momordica foetida</i> Schumach.	Cucurbitaceae	qoricha agi iljoolee	H	agi ijooolee	Leaves are crushed, mixed with water, salted and then drunk to treat child tonsillitis	K-059
77	<i>Nicardia physaloides</i> (L.) Gaertn.	Solanaceae	qoricha kormammuu	H	kormomuu	Leaf is crushed and rubbed on affected part to treat a wart	K-099
78	<i>Ocimum lamiifolium</i> Hochst. ex Benth.	Lamiaceae	damakase	Sh	mata bowo, michi, dhukuba ija, waransa gura, utallo ,ciniina gara	Leaves are crushed, mixed with water and infusion is drunk to treat migraine, febrile; the liquid is dropped into eye treat eye problem; leaves are also crushed and inhaled or its smoke is inhaled to treat the above health problems; drop of leaf extract is dropped into ears and nostrils to treat earache and flu, respectively. Infusion is drunk to treat stomachache	K-012
79	<i>Ocimum urticifolium</i> Roth	Lamiaceae	ancabii	Sh	mata bowo, michii, dhukuba ija, saritii/fincooftu	Leaves are smashed and inhaled, sap is dropped into nostrils to treat migraine and febrile. Crushed leaves are rubbed on affected eye and also tied on skin part affected by spider poisonous	K-099
80	<i>Olea europaea</i> L. subsp. <i>cuspidata</i> (Wall. ex G. Don) Clf.	Oleaceae	ejersa	T	buda, dhukuba ilkanii	Leaves are crushed, mixed with water, the infusion is concocted with honey or butter and drunk to treat evil eye; bark is chewed and held between teeth to treat toothache	K-152
81	<i>Oxalis radicata</i> A. Rich.	Oxalidaceae	qoricha shararitii/	H	sarritii/fincooftu	Leaves are crushed and applied on skin affected by spider poisonous	K-057
82	<i>Passiflora caerulea</i> L.	Passifloraceae	gura shane	H	hadha marata/bofa	Leaves are crushed, mixed with water, and the extract is drunk to treat snakebite	K-049
83	<i>Pentas lanceolata</i> (Forssk.) Deflers	Rubiaceae	qoricha dhiito	H	dhiito	A root infusion is drunk to treat swellings	K-108

84	<i>Pentas schimperiana</i> (A. Rich.) Vatke	Rubiaceae	suuma leencaa	Sh	cabaa	Leaves are crushed, concocted with barley soup and then drunk to treat bone fracture	K-67
85	<i>Periploca linearifolia</i> Quart-Dill. & A. Rich.	Asclepiadaceae	boriino	Liana	qufa	A root infusion is drunk or root is chewed and the liquid is swallowed to treat flu	K-164
86	<i>Phytolacca dodecandra</i> L'Hérit.	Phytolaccaceae	andodee	T	dhukuba sare marate, cophxoo, dhulandula	Leaves and roots are crushed, mixed with water, salted or concocted with coffee or milk is drunk to treat rabies and gonorrhea; leaf juice is dropped into nostrils to treat leech	K-091
87	<i>Piper capense</i> L. f.	Piperaceae	tunjo	H	gara ciniina	Seed is pounded, mixed with water, salted and the extract is drunk to treat stomachache	K-070
88	<i>Pittosporum viridiflorum</i> Sims	Pittosporaceae	soolee	T	dhukuba ilkanii	Leaf is chewed and held between teeth to treat toothache	K-023
89	<i>Plantago lanceolata</i> L.	Plantaginaceae	qorxobbii	H	mada	Leaf is crushed and applied on the bleeding wound	K-019
90	<i>Plantago palmata</i> Hook. f.	Plantaginaceae	qoricha marataa	H	hadha marata/bofa	Leaf infusion is drunk; the crushed leaf is applied on the snakebite	K-048
91	<i>Plectocephalus varians</i> (A. Rich.) C. Jeffrey ex Cufod.	Asteraceae	qoricha hadha bofaa	H	hadhaa/summii	A leaf infusion is drunk to treat poisonous	K-102
92	<i>Plectranthus longipes</i> Baker	Lamiaceae	yeroo	H	mata bowo, michi dugda kuta, dhukuba ija, dhaqna guba	The leaf is heated and held on the forehead and inhaled to treat migraine and febrile; leaf is heated or smashed and rubbed on affected eye to cure eye disease; leaf infusion is drunk to treat back pain; root and leaf are boiled and steam bath is inhaled to treat fever	K-102
93	<i>Podocarpus falcatus</i> (Thunb.) R. B. ex. Mirb.	Podocarpaceae	birbisa	T	qufa yeroo dheera	Leaves and bark are crushed, mixed with water, concocted with milk or honey is drunk to treat cough	K-149
94	<i>Premna schimper</i> Engl.	Lamiaceae	urgeessaa	Sh	dhukuba ilkanii	Leaf is crushed and held between teeth	K-146
95	<i>Prunus africana</i> (Hook. f.) Kalkm.	Rosaceae	homii	T	qufa yero dheera	Gum is eaten to cure a persistent cough	K-146
96	<i>Pycnostachys abyssinica</i> Fresen.	Lamiaceae	yeroo (bada)	H	mata bowo, michi, dhukuba ija, dhukuba gura, qole gogsa	Leaf is heated and held on the forehead and inhaled to treat migraine, febrile and meningitis; the leaf is heated and held on affected eye to treat eye disease; leaf infusion is dropped into the ear to treat earache	K-93
97	<i>Ranunculus multifidus</i> Forssk.	Ranunculaceae	qoricha simbiraa	H	dhukuba simbira	Leaves are concocted with butter and drunk to treat jaundice	K-064
98	<i>Rhamnus prinoides</i> L'Hérit.	Rhamnaceae	geshoo	Sh	ballile	Seed is crushed, mixed with a drop of water, smashed and painted on skin affected by dandruff	K-064
99	<i>Ricinus communis</i> L.	Euphorbiaceae	qobo simbira	H	dhukuba sare marate, hadha marata/bofa	Root and leaves are crushed, the infusion is concocted with milk or coffee and then drunk to treat rabies; leaf infusion is drunk to treat snakebite or crushed leaf is tied on snakebite	K-171
100	<i>Ritchiea albersii</i> Gilg.	Capparidaceae	danqaricho/deqo/	Sh	qolee gogsaa, mata bowo, dhaqna guba	Fresh leaf is crushed or gently heated and applied on the neck to treat meningitis; the crushed leaf is inhaled and sap is dropped into nostrils to treat migraine and fever	K-124

101	<i>Rumex abyssinicus</i> Jacq.	Polygonaceae	dhangaggoo	H	ballile	Root is crushed and rubbed/painted on affected skin to treat dandruff	K-101
102	<i>Rumex nepalensis</i> Spreng.	Polygonaceae	timijjii	H	gara ciniina, michi	Root is chewed and the liquid is swallowed to treat stomachache; the leaf is heated and inhaled and liquid from the crushed leaf is dropped into nostrils to treat febrile	K-062
103	<i>Rumex nervosus</i> Vahl	Polygonaceae	dalote/gosa dhangago	H	dhukuba ilkanii	Leaf is gently heated and held on affected tooth to treat toothache	K-130
104	<i>Salvia nilotica</i> Jacq.	Lamiaceae	abbaa giddii	H	michi, mata bowo jonji, waransa gurra	A leaf infusion is drunk to treat febrile, migraines and circling sickness; Leaf is also smashed and inhaled or leaves are burned and smoke is inhaled to treat febrile and migraines; the infusion is also dropped into the ear to treat earache.	K-024
105	<i>Securidaca longepedunculata</i> Fresen.	Polygalaceae	xamanaayii	Sh	gara ciniina jonji, mata bowo	Root is crushed, mixed with water, and infusion concocted with honey or coffee and then drunk to treat stomachache; the root is crushed and the liquid is dropped through nostrils or steam bath of the root is inhaled to treat circling sickness and migraine	K-087
106	<i>Senna didymobotrya</i> (Fresen.) Irwin & Barneby	Fabaceae	kash kashe	Sh	hadha marataa/bofa, saritii/fincioftu, miciree	Leaves are crushed tied on snakebite; crushed fruit and leaf is applied on the area affected by spider poisonous; the crushed leaf is applied on skin affected tinea	K-039
107	<i>Senna occidentalis</i> (L.) Link	Fabaceae	qoricha boffaa	Sh	hadha marata/bofa	Leaf is crushed and kept on bite and leaf infusion is drunk	K-030
108	<i>Setaria poiretiana</i> (Schult.) Kunth	Poaceae	sokokee	H	dhukuba sare marate	Root extract is concocted with milk and is drunk to treat rabies	K-045
109	<i>Sicyos polyacanthus</i> Cogn.	Cucurbitaceae	gurgube	Liana	dhukuba sare marate, dhukuba ilkanii	A root infusion is drunk to treat rabies; the root is chewed and held between teeth to treat toothache	K-129
110	<i>Sida rhombifolia</i> L.	Malvaceae	karabii	H	mada, kintaroti	Leaves are crushed and applied on sore and hemorrhoids	K-129
111	<i>Smithia elliotii</i> Bak. f.	Fabaceae	qoricha gara ciniinaa	H	gara ciniina	A root is chewed and the liquid is swallowed to treat stomachache	K-135
112	<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Asteraceae	timbatimbo	Sh	dhukuba sare marate	Root infusion is drunk to treat rabies	K-135
113	<i>Solanum aculeatissimum</i> Jacq.	Solanaceae	hiddii	H	dhukuba ilkanii	A piece of fresh fruit is held between affected teeth to treat toothache	K-077
114	<i>Solanum anguivi</i> Lam.	Solanaceae	hiddii qalamee	Sh	ballile	Leaves are crushed and rubbed on the affected area to treat dandruff	K-011
115	<i>Solanum giganteum</i> Jacq.	Solanaceae	dalachoo/solanum spp	Sh	gara ciniina, mata bowo, dhukuba ilkanii, dhukuba sare marate	Root is chewed and liquid is swallowed to treat stomachache; the liquid is dropped into nostrils to treat migraine; dried fruit is placed on fire and the smoke is fumigated to treat toothache; Leaves are crushed, mixed with water, and the salted extract or concocted with coffee or milk is drunk to treat rabies	K-094
116	<i>Solanum incanum</i> L.	Solanaceae	hiddii	Sh	gara ciniina	Root is chewed and the liquid is swallowed to treat stomachache	K-060
117	<i>Solanum nigrum</i> L.	Solanaceae	ansho	H	busa	Leaves are chewed and the liquid is swallowed to treat malaria	K-127
118	<i>Sphaeranthus suaveolens</i> (Forssk.) DC.	Asteraceae	qorich gara ciniina	H	gara ciniina	Root and leaf are chewed and the liquid is swallowed to treat stomachache	K-115

119	<i>Stephania abyssinica</i> (Dillon & A. Rich.) Walp.	Menispermaceae	kalala	H	dhukuba sare	Root or leaf are crushed mixed with water and infusion is drunk to treat rabies	K-026
120	<i>Stereospermum kunthianum</i> Cham.	Bignoniaceae	botoroo	T	gara ciniina	A bark infusion is drunk to treat cough or swallow the liquid of chewed bark to treat stomachache	K-026
121	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>afromontanum</i> F. White	Myrtaceae	myrtaceae	T	gara ciniina	A bark is chewed and the liquid is swallowed to treat stomachache	K-020
122	<i>Thalictrum rhynchocarpum</i> Dill. & A. Rich.	Ranunculaceae	sirabizuu2	H	saritii/fincooftu	Leaf is crushed and rubbed on skin affected by spider poisonous	K-097
123	<i>Urera hypselodendron</i> (A. Rich) Wed.	Urticaceae	lanqessa	Liana	gara ciniina	The stem is crushed, mixed with water, and the salted extract is drunk to treat stomachache	K-027
124	<i>Vernonia amygdalina</i> Del.	Asteraceae	eebicha	Sh	qufa yero dheera, dhiiga dhabu	Leaves are crushed and infusion is drunk to treat TB; the leaf is crushed and applied on the wound	K-155
125	<i>Vernonia auriculifera</i> Hiern	Asteraceae	reejjii baddaa	Sh	dhiiga dhabu	Crushed leaves are applied on the wound	K-025
126	<i>Vernonia hymenolepis</i> A. Rich.	Asteraceae	tijimo	Sh	gara ciniina	Root infusion is salted or concocted with honey to treat stomachache	K-104
127	<i>Vernonia rueppellii</i> Sch. Bip. ex Walp.	Asteraceae	balantaa	Sh	mada ibida	Leaf is crushed and applied on fire burn	K-83
128	<i>Warburgia ugandensis</i> Sprague	Canellaceae	biftii	T	garagara ciniina, dhukuba ilkanii	Bark is crushed, mixed with water, salted or concocted with coffee and the drunk to treat stomachache; bark is crushed and held on teeth to treat toothache	K-038
129	<i>Ximenia americana</i> L.	Olacaceae	hudha	Sh	gara ciniina, qufa	Fruit is eaten to treat stomachache; leaves and bark are crushed, mixed with water, infusion concocted with honey is drunk to treat cough	K-009

NB: H = Herb; Sh = Shrub; T = Tree

Appendix 7 List of ethoveterinary medicinal plants used in Nole Kaba District and their application

N0	Scientific name	Family	Local name	Growth forms	Treated health problems or conditions	Disease and application of plant remedies	Coll. N0
1	<i>Adiantum poiretii</i> Wikstr.	Adiantaceae	Facatuu/Sirabizu	H	Blackleg, paraphimosis	Root is crushed, mixed with water and the extract is drenched using a plastic bottle to treat blackleg. Infusion of leaves is drenched to treat paraphimosis	K-123
2	<i>Acmella caulirhiza</i> Del.	Asteraceae	gororsiisa	H	Rabies	Root is crushed, mixed with water and the infusion is given to drunk	K-027
3	<i>Albizia schimperiana</i> Oliv.	Fabaceae	Muka arbaa	T	Babesiosis, problem of respiratory tract, eye problem, reduced milk yield	The bark is crushed, mixed with water and given to drunk to treat babesiosis; leaves are crushed and the liquid is dropped into the nostrils to treat respiratory problem; bark is crushed and the liquid is dropped into the affected eye; bark is crushed, mixed with water, salted and given to drink to increase milk yield	K-081
4	<i>Amorphophallus gallaensis</i> (Engl.) N. E. Br.	Araceae	Qicuu	H	Blackleg, pasteurellosis	Root is crushed together with garlic and ginger. The mixture is given to drunk to treat blackleg; root infusion is given to drunk to treat pasteurellosis	K-122
5	<i>Argemone mexicana</i> L.	Papaveraceae	Qoricha marataa/argemum mexicana	H	Snakebite	The leaf infusion is given to drunk to treat snakebite	K-058
6	<i>Australina flaccida</i> (A. Rich.) Webb.	Urticaceae	Gurati/qoricha mada miila cifatu	H	Sore	The root is crushed and applied on sore	K-121
7	<i>Bersama abyssinica</i> Fresen.	Melanthiaceae	Lolchiisaa	T	Fattening	The bark is crushed, salted and fed to fatten cattle	K-08
8	<i>Bridelia micrantha</i> (Hochst.) Baill.	Euphorbiaceae	Rigarba	T	Babesiosis	The bark is crushed together with garlic, and ginger, mixed with water and then given to drunk	K-028
9	<i>Brucea antidysentrica</i> J. F. Mill.	Simaroubaceae	Qomonyoo	Sh	Rabies	Leaves are crushed, mixed with water and the infusion is given to drunk	K-28
10	<i>Buddleja polystachya</i> Fresen.	Loganiaceae	anfaarree	Sh	Eye problem	Leaves are crushed and the liquid is dropped into the affected eye	K-066
11	<i>Calpurnia aurea</i> (Ait.) Benth.	Fabaceae	Ceekaa	Sh	Rabies, helminths	Flowers are crushed, mixed with water and the	K100

						infusion is given to drunk to treat rabies; leaf infusion is given to drunk to treat helminths	
12	<i>Capparis tomentosa</i> Lam.	Capparidaceae	Harangama gurraacha	Liana	Babesiosis	Roots are crushed together, mixed with water and infusion is given to drunk to cure babesiosis	K-007
13	<i>Carduus schimperi</i> Sch. Bip.	Asteraceae	Araba dubartii	H	Disease characterized by red spots at the base of the tongue	Roots are crushed together, mixed with water. Infusion is given to drunk with a plastic bottle	K-014
14	<i>Cassipourea malosana</i> (Baker) Alston	Rhizophoraceae	Lokoo	T	Rabies	Leaves are crushed together, mixed with water and infusion is given to drunk	K-091
15	<i>Chionanthus mildbraedii</i> (Gilg & Schellenb) Stearn	Oleaceae	Gagamaa	Sh	Emaciation	The bark is crushed together, mixed with water and infusion is given to drunk to treat emaciation	K-016
16	<i>Cirsium vulgare</i> (Savi.) Ten.	Asteraceae	Iudata/Qoricha sabata waqayyoo	H	Rabies, cough, liver problem	Roots are crushed together, mixed with water and salted infusion is given to drunk/drenched to treat rabies and cough; leaf infusion is drunk to treat a liver problem	K-053
17	<i>Cissampelos mucronata</i> A. Rich.	Menispermaceae	Qoricha waan arabaa	H	Rabies, disease characterized by red spots at the base of the tongue	Roots are crushed together, mixed with water, and the salted infusion is given to drunk rabies; disease showing red spot at the back of the tongue	K-134
18	<i>Cissus populnea</i> Guill. & Perr.	Vitaceae	Ulmaayii	Liana	snakebite	Leaves are crushed together, mixed with water and then given to drunk	K-134
19	<i>Clematis hirsuta</i> Perr. & Guill	Ranunculaceae	Hidda fiitii	Liana	Rabies	Roots are crushed together, mixed with water and then given to drunk	K-128
20	<i>Clutia abyssinica</i> Jaub. & Spach.	Euphorbiaceae	qaqaroo	Sh	Blackleg	The bark is crushed together, mixed with water, and then given to drunk	K-068
21	<i>Combretum molle</i> R. Br. ex Don	Combretaceae	Dhandhansa	T	Emaciation	Roots are crushed together, mixed with water and then given to drunk	K-035
22	<i>Cordia africana</i> Lam.	Boraginaceae	Wadessa	T	Eye problem	The bark is crushed and the liquid is dropped into the affected eye	K-72
23	<i>Crassocephalum macropappum</i> (Sch. Bip. ex A. Rich.) S. Moore	Asteraceae	Qoricha dhiitoo	H	Swelling	Roots are crushed, mixed with water and then given to drunk	K-020

24	<i>Crinum abyssanicum</i> Hochst. ex A. Rich.	Amaryllidaceae	Qulubii jaldessa	H	Cough	Roots are crushed, mixed with water and then given to drunk to treat cough in sheep	K-005
25	<i>Crotalaria phychnostachya</i> Benth.	Fabaceae	Alangee	H	Snakebite, Disease characterized by red spots at the base of the tongue	Roots are crushed, mixed with water and then given to drunk to treat the health problems	K-139
26	<i>Croton macrostachyus</i> Del.	Euphorbiaceae	Bakkanniisa	T	Rabies, swelling, Blackleg, Disease characterized by red spots at the base of the tongue	Leaves are crushed, mixed with water and the salted mixture is given to drunk to treat rabies; root and bark infusion is given to drunk to treat swelling and blackleg; root and stem infusion is given to drunk to treat a disease characterized by red spots at the base of the tongue	K-079
27	<i>Cucumis ficifolius</i> A. Rich.	Cucurbitaceae	Sirabizuu	H	Babesiosis, Paraphimosis	Root is crushed, mixed with water and then given to drunk	K-010
28	<i>Cyathula uncinulata</i> (Schr.) Schinz	Amaranthaceae	darguu	H	Blackleg	Roots are crushed, mixed with water and then given to drunk	K-120
29	<i>Cyperus fischerianus</i> A. Rich.	Cyperaceae	Qunnii	H	Snakebite	Root is crushed, mixed with water and then given to drunk Snakebite	K-070
30	<i>Cyphostemma cyphopetalum</i> (Fresen.) Desc. ex Wild & Drummond	Vitaceae	Hidda reefaa	Liana	Babesiosis	Roots are crushed, mixed with water and then given to drunk	K-045
31	<i>Datura metel</i> L.	Solanaceae	Qoricha marataa	H	Snakebite	Roots and leaves are, crushed, mixed with water and then given to drunk	K-045
32	<i>Datura stramonium</i> L.	Solanaceae	asangira	H	Rabies, exto-parasite	Leaves are crushed, mixed with water and then given to drunk/drenched to treat rabies; the crushed leaves are applied/ brushed/ rubbed onto skin hair of cattle to clear ecto-parasite	K-101
33	<i>Dioscorea schimperiana</i> Kunth	Dioscoreaceae	barodii	Liana	Bloat	Root is crushed, mixed with water and then given to drunk	K-128
34	<i>Dracaena steudneri</i> Engler	Dracaenaceae	Afarfatuu	Sh	Rabies, Blackleg, Babesiosis, trypanosomiasis; Disease	The bark is crushed, mixed with water and then given to drunk/drenched to treat rabies, blackleg, babesiosis, trypanosomiasis, and a disease characterized by red spots at the base of the tongue;	K-118

					characterized by red spots at the base of the tongue, Fattening	crushed and salted bark is fed to fatten cattle	
35	<i>Dregea schimperi</i> (Decne.) Bullock	Asclepiadaceae	Qoricha marata	Liana	Snakebite	Roots and leaves are crushed, mixed with water and then given to drunk	K-61
36	<i>Drymaria cordata</i> (L.) Schultes	Caryophyllaceae	Qoricha mada/bala atari	H	Snakebite	Leaves are crushed, mixed with water and then given to drunk	K-056
37	<i>Echinops amplexicaulis</i> Oliv.	Asteraceae	Dichoo diimmaa	Sh	Babesiosis, Blackleg	Roots and leaves are crushed, mixed with water, then given to drunk to treat babesiosis and blackleg	K-034
38	<i>Echinops longisetus</i> A. Rich.	Asteraceae	Qabarichoo	Sh	Evil eye, Cough, snakebite	Root and leaves are crushed, mixed with water and then given to drunk to treat cough and snakebite; the infusion dropped into the eye	K-021
39	<i>Embelia schimperi</i> Vatke	Myrsinaceae	Hanquu	Liana	Rabies	Leaves are crushed, mixed with water, and then given to drunk	KP4037
40	<i>Entada africana</i> Guill. & Perr.	Fabaceae	Ambalta	T	Sore, Constipation	The bark is crushed and applied on sore; the salted bark infusion is given to drunk to treat constipation	K-109
41	<i>Euphorbia ampliphylla</i> Pax	Euphorbiaceae	Adaamii	T	Sore	Milky sap is dropped on sore	K-054
42	<i>Ficus exasperata</i> Vahl	Moraceae	Balaansofi	T	Sore	Latex is applied to treat sore	K-139
43	<i>Galiniera saxifraga</i> (Hochst.) Bridson	Rubiaceae	Muka guraacha	Sh	Blackleg	Leaves are crushed, mixed with water, concocted with local liquor (AREKE) and is drenched	KP2017
44	<i>Girardinia diversifolia</i> (Link) Friis	Urticaceae	Dobii	H	Helminths	Root is crushed, mixed with water, concocted with powder of hot pepper, and then drenched	K-183
45	<i>Gomphocarpus semilunatus</i> A. Rich.	Asclepiadaceae	ribuu qlame	H	Stomachache	Leaves are crushed, mixed with water and then infusion is drenched and also dropped into nostrils	K-125
46	<i>Guizotia scabra</i> (Vis.) Chiov.	Asteraceae	tufoo	H	Prevention of abortion	leaves, stem, and flower are crushed, mixed with water and drenched	K-248
47	<i>Hygrophila schulli</i> (Hamilt.) M. R. & S. M. Almeida	Acanthaceae	Balan warante	H	Blackleg, Babesiosis	Root is crushed, mixed with water and drenched to treat blackleg and babesiosis	K-085
48	<i>Justicia ladanoides</i> Lam.	Acanthaceae	qoricha marata	H	snakebite	Infusion of leaves is given to drunk	K-015
49	<i>Justicia schimperiana</i> (Hochst. ex Nees) T. Anders.	Acanthaceae	Dhumugaa	Sh	Rabies, Blackleg	Root and leaves are crushed, mixed with water, concocted with milk and then given to	K-092

						drunk/drenched; the root is crushed, mixed with water and then given to drunk rabies	
50	<i>Kalanchoe densiflora</i> Rolfe	Crassulaceae	Dhoqdhoqee	H	Swelling	Leaves are crushed, mixed with water and drenched to swelling	K-050
51	<i>Lagenaria abyssinica</i> (Hook. f.) C. Jeffrey	Cucurbitaceae	Hadhoftu sexana	H	Cough in equines, Babesiosis	Seeds are crushed, mixed with water and then given to drunk to treat cough in equines; seeds are crushed, mixed with water, the salted infusion is drenched to treat babesiosis	K-050
52	<i>Lobelia giberroa</i> Hemsl.	Lobeliaceae	Faga Jaldessa	Sh	Stomachache	Root is crushed together with garlic and ginger, mixed with water and then given to drunk	K-141
53	<i>Maesa lanceolata</i> Forssk.	Myrsinaceae	Abbayyii	Sh	Cough	Root is crushed together with garlic and ginger, mixed with water and then given to drunk to treat cough	K-141
54	<i>Millettia ferruginea</i> (Hochst.) Bak. subsp. <i>ferruginea</i>	Fabaceae	Sootalloo	T	Snakebite, Helminths	The bark is crushed, mixed with water and then drenching; fruit is prepared similarly and given to drunk to treat helminths	K-106
55	<i>Momordica foetida</i> Schumach.	Cucurbitaceae	umbao	H	Blackleg	Root is crushed, mixed with water, salted and then drenching	K-059
56	<i>Mucuna melanocarpa</i> Hochst.	Fabaceae	machara	Liana	Babesiosis, Fattening	Root is crushed, mixed with water, concocted with milk and then drenching; the crushed root is salted and then fed to fatten cattle	K-059
57	<i>Olea europaea</i> L. subsp. <i>cuspidata</i> (Wall. ex G. Don) Cif.	Oleaceae	Ejersa	T	Cough	Leaves are crushed, mixed with water and then drenching	K-152
58	<i>Passiflora caerulea</i> L.	Passifloraceae	Gura shane	H	Snakebite, Anthrax	Leaves are crushed, mixed with water and is given to drunk to treat snake poison; the mixture is also drunk to treat anthrax	K-049
59	<i>Pavetta oliveriana</i> Hiern	Rubiaceae	Meexo adi	Sh	Swelling	Leaves are crushed, mixed with local liquor (AREKE) and the preparation is given to drunk	K-100
60	<i>Pavonia urens</i> Cav.	Malvaceae	Hincinnii	Sh	Blackleg	Root is crushed, mixed with garlic and hot pepper and then given to drunk	K-014
61	<i>Pentas lanceolata</i> (Forssk.) Deflers	Rubiaceae	Qoricha dhiito	H	Swelling	Root is crushed, mixed with water and then given to drunk	K-108

62	<i>Pentas schimperiana</i> (A. Rich.) Vatke	Rubiaceae	Suuma leencaa	Sh	Bone fracture, Swelling	Leaves are crushed, concocted with barley or tef soup is given to drunk or fed to treat bone fracture; root and leaves infusion is given to drunk to treat swelling	K-67
63	<i>Phytolacca dodecandra</i> L'Hérit.	Phytolaccaceae	andodee	T	Rabies, Leech, Paraphimosis	Root and leaves are crushed, mixed with water and salted infusion is given to drunk/drenched to treat rabies; little drops into nostrils to treat leech; root infusion is drenched to treat paraphimosis	K-091
64	<i>Piper capense</i> L. f.	Piperaceae	Tunjo	H	Fattening, Reduced milk yield, trypanosomiasis	Seeds are crushed, mixed with water, salted and given to drunk or fed to fatten cattle; leaf infusion is salted and given to drunk to increase milk yield, trypanosomiasis	K-070
65	<i>Pittosporum viridiflorum</i> Sims	Pittosporaceae	Soolee	T	Pasteurellosis, Blackleg, Reduced milk yield	The bark is crushed, mixed with water, and infusion is given to drunk to treat pasteurellosis and blackleg; leaf infusion is given to drunk to treat low milk yield	K-023
66	<i>Plantago africana</i> Verde.	plantaginaceae	Waacaa	H	Stomachache	Root is crushed, mixed with water and infusion is given to drunk	K-070
67	<i>Plectocephalus varians</i> (A. Rich.) C. Jeffrey ex Cufod.	Asteraceae	Qoricha hadha bofaa	H	Snakebite	Leaves are crushed, mixed with water and the infusion is given to drunk	K-102
68	<i>Prunus africana</i> (Hook. f.) Kalkm.	Rosaceae	Hoomii	T	Sore, Babesiosis, Blackleg	The bark is crushed and applied on sore; salted bark infusion is given to drunk to treat babesiosis and blackleg	K-146
69	<i>Pteridium aquilinum</i> (L.) Khun	Pteridaceae	Giixoo boollaa	H	Disease characterized by red spots at the base of the tongue; Fattening	Infusion of roots is given to drunk to treat a disease characterized by red spots at the base of the tongue; Crushed root is salted, wrapped with pancake and fed to fatten cattle	K-052
70	<i>Ricinus communis</i> L.	Euphorbiaceae	Qobo simbira	H	Rabies, snakebite	Root and bark are crushed together, mixed with water and the infusion is given to drunk/drenched to treat rabies; leaf infusion is given to drunk to treat snakebite	K-171
71	<i>Rumex nervosus</i> Vahl	Polygonaceae	Dalote	Sh	Diarrhea	Seeds are crushed, mixed with water, and salted infusion is given to drunk	K-130
72	<i>Salvia nilotica</i> Jacq.	Lamiaceae	Abagidi	H	Sore	Leaf is crushed on the affected part	K-024

73	<i>Schefflera abyssinica</i> (Hochst. ex A. Rich.) Harms	Araliaceae	Gatamaa	T	Blackleg, Constipation	The bark is crushed, mixed with water, and salted infusion is drenched to treat blackleg and constipation	K-093
74	<i>Schrebera alata</i> (Hochst.) Welw.	Oleaceae	Dhama'ee	Sh	Lameness	leaf infusion concocted with milk or barley soup and then drenching	K-039
75	<i>Senna occidentalis</i> (L.) Link	Fabaceae	Qoricha boffaa	H	Snakebite	The whole part is crushed, mixed with water and then given to drunk	K-030
76	<i>Setaria poiretiana</i> (Schult.) Kunth	Poaceae	Sokokee	H	Rabies	Root is crushed, mixed with water and then given to drunk	
77	<i>Sicyos polyacanthus</i> Cogn.	Cucurbitaceae	Gurgube	H	Rabies	Root is crushed, mixed with water and then given to drunk	K-129
78	<i>Sida rhombifolia</i> L.	Malvaceae	Karabii	H	Retained placenta	Stem and leaves are crushed together, mixed with water, and then given to drunk	K-129
79	<i>Sida tenuicarpa</i> Vollesen	Malvaceae	Insilale	H	Rabies	Root is crushed, mixed with water and infusion is given to drunk	K-063
80	<i>Solanecio gigas</i> (Vatke) C. Jeffrey	Asteraceae	Timbatimbo	Sh	Rabies	Root is crushed, mixed with water and infusion is given to drunk	K-135
81	<i>Solanum giganteum</i> Jacq.	Solanaceae	Dalachoo/solanum spp	H	Cough, Rabies	Root is crushed, mixed with water and salted infusion is given to drunk to treat cough; bark or leaves are crushed mixed with water, often salted and then given to drunk to treat rabies	K-094
82	<i>Stephania abyssinica</i> (Dillon & A. Rich.) Walp.	Menispermaceae	Kalala	Lia	Rabies	Root or leaves are crushed mixed with water and the infusion is given to drunk	K-026
83	<i>Taccazea apiculata</i> Oliv.	Asclepiadeaceae	Hidda konno	Lia	Rabies	Leaves are crushed, mixed with water and drenched to the affected animal	K-143
84	<i>Thalictrum rhynchocarpum</i> Dill. & A. Rich.	Ranunculaceae	Sirabizuu2	H	Babesiosis, liver problem, paraphimosis	Root is crushed, mixed with water, salted and given to drunk to treat babesiosis, liver problem, and paraphimosis	K-097
85	<i>Trichilia dregeana</i> Sond.	Meliaceae	Uuya	T	Babesiosis, liver problem, paraphimosis	The bark is crushed, mixed with water, the salted and given to drunk babesiosis, liver problem, and paraphimosis	K-088
86	<i>Vepris dainellii</i> (Pic. Serm.) Kokwaro	Rutaceae	Hadheessa	T	Fattening	Leaves and bark are crushed together, mixed with water, salted and then drenching	K-018

87	<i>Vernonia amygdalina</i> Del.	Asteraceae	Eebicha	Sh	Retained placenta	Leaves are crushed, mixed with water and then drenching	K-155
88	<i>Vernonia auriculifera</i> Hiern	Asteraceae	Reejjii baddaa	Sh	Sore, Paraphimosis	Leaf is crushed and applied on sore; the leaf is crushed, mixed with water, and infusion is given to drunk	K-025
89	<i>Vernonia hymenolepis</i> A. Rich.	Asteraceae	Tijimo	Sh	Blackleg	Root is crushed, mixed with water and the extract is given to drunk	K-104
90	<i>Vernonia leopoldi</i> (Sch. Bip. ex Walp.) Vatke	Asteraceae	Sooyyama	Sh	Urine retention	The flower is crushed, mixed with water and is given to drunk to treat urine retention	K-156
91	<i>Warburgia ugandensis</i> Sprague	Canellaceae	Biftii	T	Bloat, Skin disease	The bark is crushed, mixed with water, the salted infusion is given to drunk to treat bloat; the crushed bark is rubbed/painted to treat skin disease	K-038

Appendix 8 List of wild edible plants used in Nole Kaba District and mode of consumption

N0	Scientific name	Family	Habit	Local name	Parts used	Usage form	Mode of consumptions	Coll. N0
1	<i>Acanthus pubescens</i> (Oliv.) Engl.	Acanthaceae	Sh	kosoru	Nectar	fresh	Nectar is consumed by children	K-027
2	<i>Aframomum corrorima</i> (Braun) Jansen	Zingiberaceae	H	ogiyio	Seed	cooked	Powdered seeds are used as spices in processing butter, hot pepper	K-139
3	<i>Amorphophallus gallaensis</i> (Engl.) N. E. Br.	Araceae	H	qicu	fruit	fresh	Ripe fruits are eaten raw	K-122
4	<i>Bidens macroptera</i> (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	H	kello	leaves	cooked	Leaves are cooked and used as a vegetable	K-028
5	<i>Bridelia micrantha</i> (Hochst.) Baill.	Euphorbiaceae	T	rigaraba	fruit	fresh	Ripe fruits are eaten raw	K-028
6	<i>Carissa spinarum</i> L.	Apocynaceae	Sh	agamsa	fruit	fresh	Ripe fruits are eaten raw	K-091
7	<i>Caylusea abyssinica</i> (Fresen.) Fisch. & Mey.	Resedaceae	H	ilaancoo	leaves	cooked	Young leaves are used as a vegetable	K-002
8	<i>Clausena anisata</i> (Wild.) Benth.	Rutaceae	Sh	ulumayaa	leaves	cooked	Young leaves are used as a vegetable	K-062
9	<i>Coffea arabica</i> L.	Rubiaceae	Sh	buna	seed/fruit	Boiled/chewed	Seeds powder are boiled as a stimulant, fleshy part is chewed and consumed	K-035
10	<i>Cordia africana</i> Lam.	Boraginaceae	T	wadessa	fruit	fresh	Ripe fruits are eaten raw	K-131
11	<i>Dioscorea praeheensis</i> Benth.	Dioscoreaceae	Lia	buri	root	cooked	Root is cooked and consumed as a vegetable	K-128
12	<i>Dioscorea schimperiana</i> Kunth	Dioscoreaceae	Lia	barodii	root	cooked	Root is cooked and consumed as a vegetable	K-118
13	<i>Discopodium penninervium</i> Hochst.	Solanaceae	T	goficho	fruit	fresh	Ripe fruits are eaten raw	K-61
14	<i>Ehretia cymosa</i> Thonn.	Boraginaceae	T	ulagaa	fruit	fresh	Ripe fruits are eaten raw	K-138
15	<i>Embelia schimperi</i> Vatke	Myrsinaceae	Lia	hanquu	leaves, seed	fresh	Ripe fruits are eaten raw	K-012
16	<i>Ensete ventricosum</i> (Welw.) Cheesman	Musaceae	H	warqee	Fruit	fresh	Ripe fruits are eaten raw	K-109
17	<i>Erythrococca abyssinica</i> Pax	Euphorbiaceae	Sh	caakoo	leaves	cooked	Young leaves are used as a vegetable	K-108
18	<i>Ficus sur</i> Forssk.	Moraceae	T	harbu	fruit	fresh	Ripe fruits are eaten raw	K-033
19	<i>Ficus vasta</i> Forssk.	Moraceae	T	qilxu	fruit	fresh	Ripe fruits are eaten raw	K-154
20	<i>Momordica foetida</i> Schumach.	Cucurbitaceae	H	Sarambawo	fruit	fresh	Ripe fruits are eaten raw	K-059
21	<i>Morus alba</i> L.	Moraceae	T	gora	fruit	fresh	Ripe fruits are eaten raw	K-22
22	<i>Ocimum urticifolium</i> Roth	Lamiaceae	Sh	hancabii	leaf	cooked	Young leaves are used as a vegetable	K-139
23	<i>Phoenix reclinata</i> Jacq.	Arecaceae	Sh	meexii	fruit	fresh	Ripe fruits are eaten raw	K-066
24	<i>Physalis peruviana</i> L.	Solanaceae	H	buqulii	fruit	fresh	Ripe fruits are eaten raw	K-081
25	<i>Piper capense</i> L. f.	Piperaceae	H	Tunjo	fruit	cooked/fre	Ripe fruits are eaten raw	K-070

						sh		
26	<i>Pteridium aquilinum</i> (L.) Khun	Pteridaceae	H	Gixoo	shoot	cooked	Ripe fruits are eaten raw	K-052
27	<i>Rhamnus prinoides</i> L'Herit.	Rhamnaceae	Sh	gesho	seed, leaves and stem	beverages	Powdered seeds, leaves, and stems are used as an ingredient of the local beverage	K-064
28	<i>Ritchiea albersii</i> Gilg.	Capparidaceae	Sh	daqgo	fruit	fresh	Ripe fruits are eaten raw	K-124
29	<i>Rubus apetalus</i> Poir.	Rosaceae	Lia	goraa	fruit	fresh	Ripe fruits are eaten raw	K-124
30	<i>Rubus niveus</i> Thunb.	Rosaceae	Lia	gora gafarsa	fruit	fresh	Ripe fruits are eaten raw	K-112
31	<i>Rumex abyssinicus</i> Jacq.	Polygonaceae	H	dhangago o	leaves	cooked	Young leaves are used as a vegetable	K-101
32	<i>Rumex nepalensis</i> Spreng.	Polygonaceae	H	timijjii	leaves	cooked	Young leaves are used as a vegetable	K-062
33	<i>Senna petersiana</i> (Bolle) Lock	Fabaceae	Sh	raamso	fruit	fresh	Ripe fruits are eaten raw	K-030
34	<i>Solanum nigrum</i> L.	Solanaceae	H	anshu	fruit	Fresh	Ripe fruits are eaten raw	K-127
35	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>afromontanum</i> F. White	Myrtaceae	T	Baddessa	fruit	fresh	Ripe fruits are eaten raw	K-027
36	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>guineense</i>	Myrtaceae	T	gumare	fruit	fresh	Ripe fruits are eaten raw	K-178
37	<i>Syzygium guineense</i> (Willd.) DC. subsp. <i>macrocarpa</i> (Engl.) F. White	Myrtaceae	T	goosu	fruit	fresh	Ripe fruits are eaten raw	K-175
38	<i>Vepris dainellii</i> (Pic. Serm.) Kokwaro	Rutaceae	T	Hadhessa	fruit	fresh	Ripe fruits are eaten raw	K-155
39	<i>Ximenia americana</i> L.	Olacaceae	Sh	hudha	fruit	fresh	Ripe fruits are eaten raw	K-009

Date _____

1. Informants' information

1. Name _____
2. Sex _____ [M] [F]
3. Age _____
4. Education [No schooling] [Basic edu] [Elementary] [High school]
5. Occupation _____ KEBELE _____ Agroecological zone _____
6. Distance from health centers (hr) _____ Distance from forest JWF _____

2. Herbarium information

1. Scientific name: _____
2. Vernacular (local) name of the plant _____
3. Habit: _____
4. Collection N^o _____ Locality _____
5. Altitude _____ Longitude _____ latitude _____
6. Habitat: [1. [Forests/borders] 2. [Woodlands/borders] 3. [Farmlands/borders] 4. [Home-garden] 5 other []]

3. Ethnomedicinal uses: -

1. Do you currently use plant material for medicine? [Yes] [No], if No, have you used it in the past? [yes] [No]
2. Has the number of your patient changed compared to the past? [deceased], [increased], [the same], [do not know]
3. How long have you been healing people (in years) _____ (**for healers**)
4. What are the major human diseases in this area?
5. What are the major live stock diseases in this area?
6. What are the medicinal uses of the plants? _____
7. Plant parts used in medicine: 1. fruit 2. root 3. stem 4. leaves 5. flower 6. whole part 7. above ground 8. seed 9. Sap or latex 10. bark
8. Forms of plant part used: 1. Fresh 2. Dried 3. Both
9. Dosage form: 1. Powder 2. Decoction 3. Concoction 4. Infusion
10. Unit of measurement: 1. cup (small/medium/large) 2. Bottle (small/medium/large)
11. Any other ingredients and their importance _____

12. Organ applied to: _____
13. Mode of preparation and application: 1. Crush and paint or tie the crushed part or powder; 2. Crush, homogenize with cold water and drink; 3. Hold b/n teeth; 4. Chew & swallow the juice; 5. Crush, heat/ burn or boil the part and inhale its smoke or steam; 6. Boil and do steam bath; 7. Drink the concoction; 8. Boil the part and paint the decoction. 9. Other _____
14. Route of administration method of use: 1. Oral 2. Nasal 3. Skin 3. Auricular 4. Optical
15. Any noticeable side effect of the medicine _____
16. Any Antidotes in use? _____
17. Are the medicinal plants marketable? Yes/no; if yes, where? Parts sold?
18. Other uses of the MPs -----

3. Wild edible plants: -

1. Do you currently use edible wild plants? [Yes] [No], If No, have you used it in the past? [yes][No]
2. How is the current use of edible wild plants compared to 5-10 years before? [increasing], [the same], [decreasing]
3. If decreasing, what are factors affecting the use of edible wild plants?
4. What are the edible plants in your area? _____
5. Parts Used: 1. fruit 2. root 3. stem 4. leaves 5. flower 6. whole part 7. above ground 8. seed 9. Sap or latex 10. bark
6. Seasons of availability [rainy season], [dry season], [year round]
7. Method of preparation for use _____
8. Any other ingredients and their importance _____
9. Side effect if any _____.
10. Is there variation in collection and use of wild edible plants?
11. Who is responsible more for the above tasks? [Men] [Women] [Children]
12. What are the edible plants used during food shortage?
13. What are the marketable edible wild plants and parts sold?
14. Who are gathering and selling? [men] [women] children]
15. Other uses of the WEPs -----

4. Healers/local peoples' perception on medicinal and edible plants threats and conservation

1. Which of your medicinal and edible plants are getting rare/threatened? _____
2. What are the threats to the medicinal and edible plants
 - i. Over harvesting/overgrazing

- ii. Habitat conversion (deforestation, agricultural expansion, encroachment)
 - iii. Fire
 - iv. Climate change related such as drought
 - v. Any other
3. Do you grow/cultivate/manage medicinal and edible plants in your garden or farm?[Yes][No]
 4. If Yes, what are the species?
 5. Which species need immediate for conservation action? Why?

5. Other Uses of Reported Medicinal and Wild Edible Plants

1. Construction (timber, pole, roofing, fencing, rope) others
2. Fuel wood (firewood and charcoal) others
3. Utensils (farm implements, bench/chair) others
4. Forage (livestock, bee) others
5. Environmental (shade, wind break, soil and water protection), others
6. Rituals
7. Any Other_____

Thank you

Declaration

I, the undersigned declare that this Dissertation is my original work and it has not been presented in other universities, colleges or institutes for a degree or other purpose. All sources of the materials used have been duly acknowledged.

Name: _____ Signature: _____ Date: _____

This work has been done under our supervision.

Name: 1. Prof. Zemedet Asfaw _____ Signature: _____ Date: _____

2. Prof. Sebsebe Demissew _____ Signature: _____ Date: _____

3. Dr. Gemedo Dalle _____ Signature: _____ Date: _____