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Review:
Church forests—the green spots of Ethiopian highlands

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Abstract. *Mekonen AB, Gebreegziabher BG, Wassie WA, Tsegay BA. 2019. Review: Church forests—the green spots of Ethiopian highlands. Asian J For 3: 45-53.* In the central and northern highlands of Ethiopia, native vegetation is almost restricted to church forests which are the only remnant natural forest in the region. The church forests are sacred because the church is believed to be the house of God and everything in its compound is sacred and respected. However, they are under severe threats by both anthropogenic and a few natural disturbances. This review paper summarizes the role of Ethiopian church forests under the authority of Ethiopian Orthodox Tewahido Churches (EOTC) in biodiversity conservation, source of seed and seedling of native vegetation, ecological importance, ecosystem values and services to the community and to the globe in general. It also emphasizes the main challenges of these forests in terms of human disturbance and natural disturbances. It states the conservation strategies of church forests. We conclude that the EOTCs besides their religious activities played a great role in conserving the forests. However, most church forests have no clear and documented demarcations which expose them to disturbances. The churches are also cultivating fast-growing exotic species to replace native trees for the income of local residents. Finally, we recommend that the head priests should evoke and customize the conservation of sacred groves using religious thought. The government should acknowledge the church for conservation and decide to have a clear boundary for the church forest to minimize further encroachment. Forest genetic resources conservation program (*in-situ*), Participatory Forest Management (PFM), and rehabilitation activities have to be implemented in addition to the church conservation effort using religious thoughts, religious sanctions, and legal protection for the integrity of these remnant sacred groves. Further studies are recommended to fill the gap of sacred groves in addressing the cause of disturbance and to provide possible solutions for better conservation.

Keywords: Conservation practice, disturbance, diversity, ecological values, ecosystem service

INTRODUCTION

Forest resources are one of the natural resources that contribute in many ways as products and services to the wealth of a country in increasing the national income and improving the well-being of the populations. Forestry, besides its direct contribution to the national economy through wood and non-wood products, contributes significantly to various sectors such as energy, agriculture, food, industry, health, environment, tourism and the like. Economically it helps to increase gross domestic product (GDP), employment generation, earning of foreign currency and savings through import substitutions of the country (Senbeta 2011; FAO 2016). Carbon sequestration stored in forest biomass helps to mitigate climate change (UNFCCC 2015). Forest ecosystem also helps to regulate hydrological cycle, conserve soil, and mitigate drought and flood as well as serve as the habitat of biodiversity (FAO 2016). In some areas, forest also has social and cultural significance for local communities.

Tropical forest contains over 75% of the world's biodiversity (Tilman 1999). However, studies show that over the last 200 years there has been a 50% reduction of tropical forests worldwide (Laurance et al. 2009). Agricultural corporations, governmental initiatives, and entrepreneurs together with small farmers led to this vast deforestation in tropics (Rudel 2007). Land-use change, due to economically driven anthropogenic activities, is the primary driving force for the loss of biodiversity and ecosystem services worldwide (Laurance et al. 2011).

Ethiopia is a country with a land area of 1.12 million square kilometers located in the northeastern highlands of tropical Africa. It has unique characteristics in terms of edaphic, climatic and biological resources. Ethiopian landmass covers a wide altitudinal variation ranging from 110m below sea level to 4620m above sea level. Furthermore, Ethiopia shares more than 50% of the Afromontane regions (above 1500masl) of Africa with 79.7% of the lands above 3000m (Yalden 1983). These geological and climatic diversities have resulted in rich flora and fauna with endemic organisms, making the country an important international center of biodiversity (Yirdaw 2001). For example, the number of species of higher plants in Ethiopia alone is estimated at about 6,500 - 7000, of which nearly 15% are endemic to the country (Teketay 2010).

Many forests in Ethiopia became deforested into remnant small fragment patches. The cause of deforestation is due to the expanding population because of the lack of economic opportunities leading to land conversion for agriculture and grazing, and timber exploitation for firewood and construction (Wassie et al. 2010). FAO

(2015) reported that nearly 141,000ha (0.93%) of the forest cover of Ethiopia was destroyed every year. Considering this problem, urgent actions are imperative not only for the sustainable management of the meager remnant natural forests but also for prompt ecological restoration management in order to preserve the rich biodiversity resources of the country from complete disappearance.

The problem of deforestation and biodiversity loss is more pronounced in the northern and central highlands of Ethiopia, where forests are reduced to patches. As a result, very little natural forest from the northern and central Ethiopian highlands remains today. The deterioration of natural forest resources not only destroys the environment but also undermines the bases of economic growth and long-term prosperity (Boerma 2006; Wassie 2002). The only areas where one can observe natural forests in northern highlands of Ethiopia are in the surroundings of churches (‘‘church forests’’). These patches of natural forest have survived as a result of the traditional conservation effort of the Ethiopian Orthodox Tewahido Churches (EOTC) (Wassie et al. 2010). It is one of the earliest churches in the world managing the surrounding forest using its own religious authorities based on holy bibles and religious thought that there are a spiritual bond between tree plantation and conservation.

These forests serve as sanctuaries of many endemic and endangered plant and animal species that have almost disappeared in most parts of northern Ethiopia (Wassie 2002; Bingelli et al. 2003). Thousands of small isolated church forests in Ethiopian highlands have considerable potentials for conservation (Bhagwat and Rutte 2006). The forests are also called sacred groves being kept for the last many hundred years ago through the strong biblical basis, theological thoughts, religious belief and commitment of the communities (Wassie 2002).

This review paper clearly states the importance of church forests to protect biodiversity, and to provide goods and ecological services to the community. It also reviewed the species composition, structure, and biomass production of some of these church forests remnants in the Ethiopian Highlands. It states the impact of humans, animals, altitude and climate change on these forest areas; and finally, this paper compiles the conservation strategies of traditional, religious (EOTC) doctrine and indigenous knowledge for sustainable forest management.

Church forests and their presence in Ethiopia

Sacred groves have been recognized for their major effect on the conservation of natural resources, ecology and climate mitigation in many parts of the world (Bhagwat and Rutte 2006). They have been found in every corner of Africa like, Ethiopia, Ghana, Tanzania, Nigeria, Egypt, and Zimbabwe. Sacred groves have been common in Europe, Northeast and Southeast Asia, Siberia, Korea, Japan, China, and India. These forests have been common in Indonesia, Sri Lanka, and Malaysia (Sibanda 1997). Although their doctrine of religions may vary, eventually their experience of conserving trees in the name of religion is obvious worldwide. Trees have not only met the economic and ecological needs of the people but also for their culture and spiritual tradition. In Tanzania there are over 600 sacred groves, in Ghana over 2,000 sacred forests, in India over 100,000; and in Japan Shinto and Buddhist shrines, forests cover over 110,000 hectares (Verschuuren 2010). Similarly, in Ethiopia, there are more than 35,000 Orthodox Churches in which most of them own forests (Wassie et al. 2009).

In the northern and central highlands of Ethiopia, patchy remnants of old-aged natural Afromontane forests called sacred groves can be found surrounding Ethiopian Orthodox Tewahido Churches (EOTC). Forests in most other areas have been almost completely destroyed and converted into farms and grazing lands. The local people perceive these forests as holy places in a religious, social and institutional sense. These church forests are the remnant natural forests from the northern highlands of Ethiopia. Hence, if there is a patch of indigenous old-aged trees in the northern highlands of Ethiopia, it can be sure that there is an Orthodox Church in the middle. They are visible from a great distance, with attractive appearance, usually built on small hills "overlooking" the surrounding villages (Figure 1).

The local people call the churches with the surrounding trees as “debr” or “geddam”. These places are religiously considered holy places as well as a socially respected and powerful institutions by the followers (Wassie 2007). The people with strong beliefs in the religion that attend the church ensure their sacred groves protection and vigilance rather than formal policing or other community in the region (Tilahun et al. 2015). The forests located around the churches comprise local as well as global hotspots as they are critical conservation areas that provide ecosystem services (Bhagwat 2009). Some of these churches that are established recently have developed a forest around them by rehabilitation processes that are not the natural Afromontane forests. These church forests possess woody indigenous tree species.

The role of Ethiopian church forests

Ethiopia has a total of around 35,000 churches and monasteries, some of which are 1660 years old. The oldest Ethiopian Orthodox Churches date from 4th century. Most of these churches are located in the Northern and Central Highlands of Ethiopia (Wassie 2002; Tilahun et al. 2015). The churches have natural forest vegetation rich in biodiversity of plants and animals. Their vegetation consists not only of trees but also shrubs and herbs, and they constitute important habitats for a variety of animal species (Bingelli et al. 2003). Different plant species provide services to the communities as the spiritual and medicinal values are attached to it (Yeshambel 2013). The local people near to church forest use the plant species as timber and non-timber forest products (NTFPs) includes source of income, agricultural implements, tools, household furniture, folk medicines, washing powder, insecticide, fumigants, aromatic ingredients, gum, ropes, tannery, food, fodder, bee forage and beehives, light, fuel and charcoal, construction, lumber, shade and shelter (Getachew et al. 2010). Generally, the Ethiopian church forests have the following major roles.

Church forests as in-situ *biodiversity conservation hot spot*

The churches and monasteries of the EOTC are often surrounded by small natural forests characterized by a high floral and faunal diversity with many indigenous and rare species (Wassie 2007; Cardelús et al. 2013). There are two kinds of church forests in Ethiopia of which the churches older than five hundred years are surrounded by primary forests while recently established churches of the last decades are observed with secondary forests and in this case the older church forests are characterized by a high floral and faunal diversity with many indigenous and rare species. These closely located forests have high ecological importance to form corridors and are important for species exchange and the distribution of genetic resources in conservation (Wassie et al. 2010).

Sacred groves are the ideal sites to be chosen for species afforestation programs in their specific localities (*in-situ*) and that could serve as models of sustainable forest management and biodiversity conservation. Many endangered species of flora in Northern Ethiopia are found surrounding churches and monasteries (Tilahun et al. 2015). The EOTC is making a sustained effort to teach and advise the clergy and the people living in the community; highlight the need to protect existing trees; induce the desire to plant and look after newly planted trees, and in particular care of indigenous trees and plants (Wassie 2002).

The church forests are the sanctuary of many indigenous species protected in different agro-ecological/climatic zones, could be used as germplasm for regeneration and then conserve biodiversity (Tilahun et al. 2015). The two tree species, *Juniperus procera*, and *Prunus africana*, which are listed in the IUCN red list, are mostly found in church forests of Ethiopia (WCMC 1996). Sacred groves are often safe places for trees and other biodiversity resources. In other words, church compounds are serving as in situ conservation and hot spot sites for biodiversity resources, including many endemic and endangered species, mainly indigenous trees and shrubs of Ethiopia (Wassie 2002; Dudley et al. 2012).

Church forest for ecosystem services

Church forests provide ecosystem services for pioneer organisms in different landscapes and serve as stepping stones for restoration in long-term forest sustainability, biodiversity conservation, and social benefits. They also provide valuable, often unique, and secured habitats for plants and animals as well as green spaces for people to relieve the stressed mind. Densely forested and well-protected sacred groves give prestige for the religious sites to mean respected and believed to have many blessings from the presence of angels in the compound of such churches (Wassie 2002). Forest restoration and genetic conservation in the degraded high lands of Ethiopia depend on the remnant church forests and a few trees around on farms (Teketay et al. 2010). In addition, these forests provide other essential ecosystem services including non-timber forest products especially, climate change mitigation through carbon sequestration, induce spring water and moisture, spiritual and cultural value (Dudley et al. 2012).

Figure 1. Kulala Meskel; one of the church forests in South Gondar zone, Northern Ethiopia (Picture by Authors)

Table 1. Above and below-ground biomass stock (equivalent carbon dioxide) in each study site (Tura 2011)

Name of the church	CO_2 in AGB (t/ha)	CO_2 in BGB (t/ha)
Birhanata Alem Petros Wa Pawulos	113.43	22.72
Geneta Tsige Kidus Giorgis	685.81	137.29
Debre Keraniyo Medihanalem	187.91	37.62
Risa Adibarate Entoto Kidist Mariam	73.43	14.72
Kachane Debre Selam Medihanalem	566.37	113.33
Menbera Tsebaot Kidist Silase cathedral	1628.54	326.01
Yeka Debre Sehil Kidus Micheal	77.49	15.52

Ecological values of church forests

Church forests are among the last remnants of Ethiopia's historic Afromontane forests, which date back to the 4th century. They are ecologically important as: (i) the only natural seed source for native Ethiopian trees, (ii) a place hosting birds, insects, reptiles, and vertebrates (a reservoir for biodiversity), (iii) source of freshwater springs including holy water and hydrological services for nearby farmland, and d) a place for soil and water conservation (Wassie 2007; Bhagwat and Palmer 2009; Tilahun et al. 2015). Church forests also harbor pollinator species, including native bees and other insects that add value to outlying crops (Bhagwat and Palmer 2009). These forests also provide food, medicine, construction materials and architectural works as well as other essential human needs for the local community (Wassie 2002; Bhagwat and Palmer 2009). According to Wassie (2002), their disappearance would be a disaster for plants, animals, soil nutrients and moisture resulting in degraded area in northern Ethiopia.

Church forest for carbon sequestration in mitigating climate change

Climate change mitigation can be achieved by reducing greenhouse gas emissions and by sequestering these gases from the atmosphere. Limiting global warming below or close to 1.5 °C from pre-industrial levels would require to decrease net emissions of greenhouse gas by around 45% by 2030 (IPCC 2018). It is required to remove from 100-1000 $GtCO_2$ over the 21st century to achieve the limit of global warming to 1.5°C (IPCC 2018).

One option for reducing greenhouse gas concentrations in the atmosphere, and thus mitigating climate change, is by increasing the amount of carbon removed and stored in forests (CFI 2012). When trees grow, they sequester carbon in their tissues, and as the amount of tree biomass increases (within a forest or in forest products) the increase in atmospheric CO_2 is mitigated (CFI 2012). The ability of these plantations to sequester carbon has received renewed interest since carbon sequestration projects in developing nations could receive investments from companies and governments wishing to offset their emissions of greenhouse gases through the Kyoto Protocol's Clean Development Mechanism (Fearnside 1999). Church forests can sink carbon so as to mitigate the greenhouse gas emissions that drive climate change (UNFCCC 2015).

Forests play a significant role in climate change mitigation by sequestering and storing more carbon from the atmosphere than any other terrestrial ecosystem. Church forests, including other sacred places, are relatively more protected than forests in any other place (Tura 2011). According to Tura (2011), the contribution of church forests to the reduction of atmospheric carbon concentration can be estimated by conducting case studies in a few selected churches around Addis Ababa. He found significant amounts of CO_2 stored inside both above and below-ground biomass in seven church forests in Addis Ababa (Table 1).

Church forest for researchers

As a lesson for forest conservation practice

The church has immense religious knowledge of forest conservation in which the church and its believers have developed over generations through experiences. This knowledge enables the church compound to be home to diverse flora and fauna where one can see endemic and indigenous species diversity. However, the remaining forests are currently under threat, due to diminishing areas and extensive grazing by cattle. In such areas, conserving and maintaining plant diversity has been a very challenging task (Wassie and Teketay 2006). According to Wassie and Teketay (2006), the EOTC is believed to play its role in three ways to conserve forest biodiversity: First based upon and rooted in their own understanding of the relationship between humanity and the rest of nature; Second they can teach about the environment and natural systems upon which life depends; Third they can provide active leadership in initiating practical environmental projects.

As field laboratories for practicing scientific ecological studies

Protecting church forest is not only for conservation of natural resource but also for serving researchers and academicians as field laboratories/centres/sites for practical training, research on biology, ecology, forestry, pharmacology, sociology/anthropology, socio-economics, forest history/history, etc. Church forests and monasteries are excellent learning and research centers in general and in particular they are ideal sites for studies on vegetation history, ecology, taxonomy and other fields of biology and forestry (Tilahun et al. 2015). Generally, although the main purpose of churches is as places for worship, burials and meditating religious festivals, they also provide valuable, often unique, and secured habitats for plants and animals, ecological values and green spaces for people. Besides being rich in biodiversity, these spiritually designated forests sequester carbon, help to regulate climate changes, conserve water, reduce soil erosion, and provide shade and natural medicine. They are native seed banks for the future of the given landscape. They also harbor pollinator species, including native bees and other insects that add value to outlying crops (Lori 2015).

Floristic composition and vegetation structure of some church forests

Species and structural composition of church forests in South Gondar Zone

Wassie et al (2010) studied 28 church forests in South Gondar Zone Northern Ethiopia, covering a total of over 500 hectares of remnant forests (range 1.6 to 100 ha). The study confirms 168 woody species of 69 families, of which 160 were indigenous (23 are threatened indigenous tree species) and 8 exotic woody species (100 trees, 51 shrubs, and 17 lianas). The total number of species per church ranged from 15 to 78. The species composition of these church forests is old-growth type where *Juniperus procera*, *Olea europaea*, and *Celtis africana* predominate (Wassie 2007). These groves are not only hosting vegetation but also provide diverse forest products and services. They can also act as sources of genetic materials for the restoration of degraded dry Afromontane forests (Wassie et al. 2009).

Species and structural composition of church forests in North Shewa Zone

Tilahun et al. (2015) studied 6 church forests in 6 districts of North Shewa zone, Amhara regional state Ethiopia with an area ranging from 1.6 ha to 100 ha. The total number of species and families in each of the churches ranged from 17 to 60 and 15 to 39 respectively (Tilahun et al. 2015). There was variation in regeneration status across the height and DBH class distribution. The difference in height and DBH class distributions of individual trees in each studied church forest showed that the forests are at different secondary stages of development. The variation of altitude across each church forest showed the differentiation in tree species type. Results also indicated that the church forests persist because of the commitment of the community, with strong theological thoughts, and biblical basis. The community respects and protects church forests; from these, church forests can be assigned as a central institution and platform for biodiversity conservation (Tilahun et al. 2015).

Species and structural composition of church forests in Addis Ababa

Tura (2011) found the number of tree species in seven studied sites of church forest in Addis Ababa is 22 different tree species with the total tree stems were 1519 and DBH ranging from 10 to 162cm while height ranging from 4 to 44m. The total mean density of trees per hectare from all seven church forests of Addis Ababa is 217 trees ha^{-1}. The DBH ranged from 10 to 162 cm produced a higher mean above-ground biomass 276.29 t ha^{-1}. This suggests that EOTC forests might strongly contribute to conserve woody species diversity in Ethiopia even in highly populated city Addis Ababa.

Benefits of churches from the forests

Forests besides providing grace and prestige to the church, the wood and non-wood products of church forests have several benefits for churches. The main benefits of churches from the forests can be broadly categorized under products and services.

Products

Church forests provide various products for the churches include woods (for the maintenance and construction of the church building, roofs, and walls) firewood, charcoal and other wood products either to use it or sell and earn income for churches collected from church forests (Tilahun et al. 2015). The vegetations of church forests are used to produce sacramental and sacred utensils such as oil, incense, drums, crosses, plates, beads and prayer sticks for church services. The fruits and leaves of some vegetation in churches are used as food for monks, hermits and church students. They used vegetations of church forests for folk medicine. They also used these plants to make ink and dyes for many holy paintings and to decorate churches (Wassie 2007).

Services

Church forests provide a variety of services to churches such as protecting the church building from strong wind, storms and soil erosion. Forests also serve as classrooms for the traditional church school. It creates privacy and calms for hermits and monks to pray. Forests give grace and esteem to churches. Trees give shade to celebrate religious festivals and as platforms for followers meetings outside the church buildings. Forests provide a green and pleasant area for prayers. Forests serve as a place for social gatherings like '*Mahabber and Senbetie'*. The church scholars and followers equate a church without trees to a naked person (Wassie 2007).

The church forests are primarily reserved for the church services as stated above. However, there are some possible forest benefits allowed for the followers under the permission and recognition of the church administrators whereas some benefits have been entirely forbidden. These include the collection of fuelwood, construction wood, fodder, seedlings, honey, recreation, and enjoyment (Wassie (2007). Some other benefits are permitted to be used including seeds, medicine (tree parts), fruits and spiritual contemplation and praying (Wassie 2007).

EOTC and its philosophy in the conservation of forests

The Ethiopian Orthodox Tewahido Church (EOTC) is an ancient native and integral Christian Church of Ethiopia which is one of the oldest Churches in the world and founding member of the World Council of Churches (Wassie 2002). EOTC has a long history of planting and conserving tree species in its yard. The spiritual bond between tree plantation, conservation and protection is based on the holy bibles and the EOTC scholars' thought (Tura et al. 2017). Church compounds are monasteries of trees and other biodiversity resources. Many indigenous trees and shrubs destroyed almost completely over the last century are still found standing in the compounds of rural churches (Tilahun et al. 2015). The area of forest cover preserved by the Ethiopian Orthodox churches in some parts of the country has been declined and found in patches. These patches of forests are used as sources of seeds for raising seedlings in nurseries (Wassie and Teketay 2006).

According to Wassie (2007), church and monastery forests persist since long time ago by the commitment and effort of the holy fathers and mothers and the religious followers. It is obvious that religion, in this case, acts as an effective “social fence” (Bhagwat and Rutte 2006) and also the combination of religious and utilitarian worth that makes them valuable to the community and has thus ensured church forests preservation. According to the prominent church scholars, including the Archbishop and the Holy Scriptures of the church (The Holy Bible, King James Version), the main theological bases and religious perspective in conserving forest resources include the following.

The Church on the earth signifies and symbolizes the new heaven, the holy city, New Jerusalem coming down from God out of heaven, prepared as a bride, adorned for her husband. Thus, it should have the same semblance and appearance as Eden heaven was (Wassie 2002). Therefore, the church like Eden was beautified with many plants, animals and other organisms and the holy water/streams infinitely has been surpassing from these forests that were believed to proceed out of the throne of God.

The trees in the compound are symbolic of the presence of angels guarding the church. On top of this, they are precious heritages passed from many generations with the sacrifice of holy fathers and mothers. They have got blessings of many saints beneath their roots where their holy flesh rested in peace. Therefore, trees in the compound are not to be cut unless for the purpose of the church itself and the land is not to be plowed (Wassie 2002). Clearly, in the holy bible, the Lord God commanded to preserve and conserve forests/trees as described in the following statements: “*You shall not destroy the trees thereof by forcing an ax against them, for you may eat them, and you shall not cut them down. Are trees in the field men that they should be besieged by you…?*” (Deut. 20: 19) (Cited in Wassie 2002).

Churches protect and conserve their forest resources by using two different methods, namely religious sanctions and/or legal protection.

Religious sanctions

The main mode of protection is achieved by creating religious commitment and respect among the followers. As the church is believed to be the house of God, everything in the compound is sacred and respected. Every follower is expected to respect and protect the house of God together with the forest enveloping the church. Cutting a tree in the church compound is considered as denying the presence of God unless it is for the special purpose of the church. It is believed that cutting in and smuggling of trees from the church compound would bring a curse and the one who did it is considered as a person who has violated the Kingdom of God and would be alienated from the church communities. A person that cuts a tree or even a dead branch for personal use would be presented to the church community/church scholars and asked to repent and be committed not to repeat the mistake again. If the person fails to admit his/her mistake voluntarily or makes the same mistake again, he/she would be alienated from the church community and would not be entitled to services from the church. This sanction is known as *‘Gizet’*. Hence, since Orthodox Christians fear ‘G*izet’*, they do not dare cut trees in church forests (Tilahun et al. 2015).

Legal protections

Since churches and their forest resources are found in a world where there are different attitudes and perspectives of people, they also use guards and civil law to protect their forest resources. At present, the demand for wood is increasing, and religious perspectives are diversified. Therefore, since most of the churches have assigned guards, encroachers and outlaws are caught and brought to the civil courts for the appropriate measures. It was reported that though churches are primarily houses of God, they are also houses looked after by the State, which provides the necessary legal protection to their forest resources (Tilahun et al. 2015).

Forest conservation and religious view

Long-time before the existence of systematically protected areas, people were protecting the sacred area. Faiths have been involved in some of the earliest forms of habitat protection in existence, both through the preservation of particular places as sacred natural sites and through religious-based control systems. This habitat protection method using religious thought resulted in sacred groves with a large sanctuary of biodiversity (Bhagwat 2009). Sacred areas are probably the oldest form of habitat protection conserving natural ecology and biodiversity. From a conservation perspective, sacred natural sites and other places of importance to faith groups exist both inside and outside official “protected areas” as recognized by IUCN. The conservation of sacred natural sites can be integrated into any of the systematic management models that brings a sacred area into a national protected area (UNESCO 2003).

People may value forests for spiritual, economic, aesthetic, cultural and scientific reasons. Ethiopian Orthodox Church perceives the forest and other living things in forest ecosystem as beauty work of God and therefore they give to learn the miracle of the creature, worship, meditate, pray and practice with the trees (Bingeli et al. 2003). The church has owned its forest for centuries based on the fact in the bible that the church forest and its compound are sacred. According to the Holy Bible, God called to Moses out of the burning bush. "*Moses, Moses*!" And he said, from "*Here I am*." Then He said, "*Come no closer! Remove the sandals your feet, for the place on which you stand is holy ground*." Exodus (3: 4-5). This shows that everything around us and the earth which stands on it, is created by God and the grounds within the church compound specifically are holy (Cited in Wassie 2002).

Challenges to the church forest

Deforestation due to demographic pressures with increasing demand for firewood, construction wood, grazing and agricultural land made conservation of these remnant church forests a very challenging task. These together with sedentary farming leads to persistent land exploitation in Ethiopia have made farmers degrade the environment and invade the church forest surrounding (CSA 2013). In some cases, the line that separates the church forest from community agricultural land became blurred (Yirdaw 2001). The church forests' resources have been degraded due to human settlements and utilization (Yitebitu et al. 2010).

Conservation of monastery and church forests is becoming beyond the capacity of churches to save them from the pressure of the local people for agricultural land expansion, grazing, and over-exploitation of timber. The issue of ownership aggravated the rate of deforestation by the surrounding people. The Ethiopian Orthodox Tewahido Church should be entitled to its forests. This increases the recognition of monastery and church forests and can be considered as one of the forest ownership categories by the government (Tilahun et al. 2015). The threats on church forests owned by EOTC include:

Grazing of seedlings and sapling by the domestic animals

Livestock grazing is the major factor limiting seedling establishment, seedling survival, and growth in church forests (Wassie et al. 2009). It also removes the sapling and shrubs of forests, reducing its regeneration. Studies in Ethiopian highlands showed that heavy grazing pressure significantly increased surface runoff and soil loss and reduced infiltration capacity of the soil which in turn undermines suitability of sites for germination (Tilahun et al. 2015).

Anthropogenic encroachment

Encroachment into the church forests by individuals for farmland expansion, settlement, tree cutting and fuelwood collection leads to a decline in the sizes and diversity (richness and evenness) of the forests. The encroachment by the local people is caused by the critical shortage of fuelwood and farmland (Tilahun et al. 2015). The decision to conserve and sustainable use of forest resources by humans is determined by culture. This aspect of conserving biodiversity is referred to as cultural diversity, recognizing the important role of sociological, ethical, religious, and ethnobotanical values in human activities (Wassie 2002).

Substitution of native trees by fast-growing exotic species in church forests

Most of the churches do not have enough income to operate their services and other expenses. Hence, there is a growing tendency of cultivating *Eucalyptus* species replacing indigenous trees inside sacred groves due to its fast growth habit and the high demand of the community is a great threat that may entirely substitute those indigenous tree species by these exotic species for economic use (Tilahun et al. 2015). In the church forests of Northern Ethiopia, *Eucalyptus* is replacing the native species for its fast-growing and cash crop habit to get finance for their administration (Klepeis et al. 2016; Cardelús et al. 2017).

Construction of monuments and improper grave houses in the forests

Many stone and marble made monuments, with an average surface area of $4m^2$, and constructing from small to big grave houses are observed covering considerable segments of the forest areas of churches. Unlike other traditional grave spots, these affect the regeneration potential of the forest. Construction of monuments and houses on graves has never been a tradition of EOTC and still is not accepted by the church scholars (Wassie 2002).

The dominance of some invasive species

According to Tilahunet et al. (2015), the destructive impacts of invasive alien species were identified in Kewet, Yifratana Gidim districts towards Afar and Dessie. Among the invasive species, *Lantana camara* was replacing most of the shrub plant species at a very rapid rate. This is intensified to the right of Tarmaber to Menz Guassa plains and terrains from Shewarobit to Ataye, in these areas it quickly takeover indigenous herbs and shrub species (Tilahun et al. 2015; Liang et al. 2016).

Death of many old trees without being substituted

Most of the churches in Northern Ethiopia have been serving for more than a century with their forest resources. Thus, many of the trees are aged and dying without any replacement. This may result in complete losses of valuable indigenous tree species and lead to the decline of species composition of the church forests (Wassie 2002). The other threat is the denying and overlooking of EOTC values, which may increase in the coming generation due to the influence of other religious sects and 'modernity' leading to the overlooking of the EOTC values (Wassie 2002). In spite of the sacred groves' ecological and spiritual benefits, the status of church forests has continued to decline due to a combined effect of economic, environmental, and cultural factors (Aerts et al. 2016).

The major threat of Ethiopian church forests at different time

Historically, most of the church forests were destroyed and burned with the churches and other precious heritages by the anti-Christian expedition led by Ahmed Ibn Ibrahim also called 'Gragn' meaning 'left-handed' at the beginning of the 16th century. After 'Gragn' was eradicated in 1543, most of the churches and monasteries were reconstructed together with their forests (Wassie 2002). In the process of nationalization of private properties during the socialist regime in Ethiopia in 1974, with the central aspect of land reform, adopted the land reform proclamation in 1975 and nationalized all rural land. The EOTC was left without its land holdings, including the forests, which have been preserved for centuries. The fate of those forests was ruthless exploitation and destruction, resulting in the degradation of the area (Tilahun et al 2015).

Although, the EOTC and its doctrine have a strong initiative to conserve their sacred groves the growth of human population caused to increase in the demand for trees for firewood, construction, income source and gathering. This high population growth accompanied by sedentary agriculture and extensive cattle husbandry compete with the preservation of church forests. Thus the religious followers have threatened the forests inadvertently for agricultural land expansion, grazing, footpaths to churches, firewood, charcoal, and timber production (Yirdaw 2001; Tilahun et al. 2015). In addition, societal requirements of buildings like gathering houses, monuments and cemented graves caused the clearance of trees and resulted in a permanent disturbance. Cultivation of fast-growing exotic species (*Eucalyptus*) and native trees (*Coffea*, *Rhamnus*, etc) for financing the church as a cash crop also disturb the forest critically (Cardelus et al. 2019).

Uniting church philosophy and science for forest conservation

According to UNESCO (2003), sacred natural areas are model sites for management because these sites integrate cultural, social and natural values in a single management system and can act as models for participatory conservation. In legally protected areas with a resident population, the integration of sacred natural sites can improve people's attitude to protected area regulations. The church forest is important for preserving traditional knowledge for applying adapted forest conservation practices often found in sacred natural sites and serve as healing sanctuaries (Bhagwat and Palmer 2009). Traditional ecological knowledge is often applied with regard to their management, thus providing good opportunities for integrating western science and traditional knowledge systems.

According to Dudley et al. (2012) the spiritual faiths, which are followed by most people, have impacts on the natural environment: the interaction can be through the form/s of the sacredness of places and/or influence of faiths. Since the existence of sacred areas within a protected area can create a challenge for managers, decisions whether or not to make a sacred area important to faiths into an officially protected area need to be made on a case-by-case basis.

The Convention on Biological Diversity realized that many areas of the world that contain high levels of biodiversity are anthropogenic landscapes inhabited by indigenous and local communities, requiring that approaches need to be refined to link conservation initiatives with local culture and religious views (Agrawal 2001). A comprehensive understanding of the cultural context (indigenous knowledge in this case) of a given community is necessary for biodiversity conservation activities. Understanding the role that church forests play in the provision of ecosystem services is critical, particularly for soil conservation, freshwater protection, and carbon sequestration. To preserve these forests, and perhaps even expand them multidisciplinary approach that includes all stakeholders from biologists, social scientists, ethnographers, religious leaders, and local people must collaborate. Understanding the relationship between local peoples and the forest is the way to empower the community to protect and conserve the forest (Cardelus 2012).

According to Terefe (2003), community participation is very crucial to overcome the rate of deforestation. For this purpose Participatory Forest Management (PFM) is adopted and implemented by involving the local community who intimately related to forest resources in order to fulfill the interest, respecting of traditional users, their culture (indigenous knowledge in this case) and religious contribution in saving the forest of the country from small scale to large scale and bottom-up approach which encourage a sense of belongingness to the rural people in general and landless rural youth in particular (Winberg 2010).

Conclusion

The EOTC has strong institutional ability to resist deforestation of the church forests and has customary plans to establish forests in the yards of new churches well ahead of time. Church forests have a crucial role in preserving biodiversity by allowing the forests to be used as a source of indigenous tree seeds for local communities and state nurseries. Most of the church forests have no clear and documented border demarcations, which encourage encroachment by farmers owning land adjacent to the forests. There is a lack of scientific forest management practices like inventories of the forests resources and forest management plans in the church. The two modes of protection 'Gizet' as a house of God and 'Legal protection' as a house of the state is a two-sided blade to protect the resources. When people inevitably overlook religious values and start to violate those protections or 'Gizet', then he/she will be outcasted by the community from social life and the church from God as he did sin. But, secularism and the view of other religious sects may degrade the value of the church thus for all of these risks legal protection is of paramount importance in addition to the religious sanction.

Recommendation

The participatory forest conservation program will be more successful if the knowledge of the local community, indigenous cultures and religious institutions (particularly of EOTC) with a cooperative effort has been taken into consideration. Researchers have to fill the gap of churches and monasteries in doing scientific forest management practices like inventories of the forests resources and forest management plans to protect them from decline. The government should acknowledge the church for conservation; assure to have a clear boundary for the church forest to minimize further encroachment and should work together in enforcing the legal protection of the forest. Studies should be conducted on the status of conservation, regeneration, and structure of sacred groves ecosystem, and determinant factors affecting them for the better wellbeing of indigenous species to be preserved for the future generation.

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Tree species preference and land rehabilitation perspective by local community: Case study in Bondowoso, East Java, Indonesia

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Abstract. *Danarto SA, Budiharta S, Fauziah. 2019. Tree species preference and land rehabilitation perspective by local community: Case study in Bondowoso, East Java, Indonesia. Asian J For 3: 54-63.* Forest and land rehabilitation efforts require socio-economic assessment to enhance the likelihood of success when such efforts are implemented on the ground. This study aimed to find out local community's preference on tree species used for rehabilitation programs and their perspective that influence such selections in regard to social, economic and ecological objectives of land management. The study was conducted Gubrih sub-watershed, Sampean watershed in Bondowoso District, East Java, Indonesia which provided an ideal case study of land rehabilitation. Questionnaires were distributed to respondents chosen randomly to select tree species that have ecological and/or economic values. Result of the study showed that among 62 species of trees listed in the questionnaire, there were 45 species chosen by the respondents. There were 13 species of trees selected by more than 20% of total respondents (high preferred), suggesting the potential list of species for rehabilitation programs in the region. Local community in Gubrih Sub-watershed had understood the importance of trees as a source of income as well as a measure to conserve environmental functions. This was strengthened with land-use systems they selected which preferred tree-based land-use systems, such as in the form of plantation of timber species and agroforestry over dry land agriculture. The findings of this study suggested that there is opportunity in rehabilitating degraded lands in Sampean watershed using tree species preferred by local communities under the land use system of timber plantation or agroforestry. Our study demonstrates that similar strategy of incorporating ecological and socio-economic perspectives could be applied to another regional context to enhance the chance of success of rehabilitation programs.

Keywords: Land degradation, land rehabilitation, trees preferences, social-ecological systems, watershed

INTRODUCTION

Deforestation and land degradation in Indonesia, especially in Java, have been occurring since long time ago which is caused by forest clearing for agricultural activities to feed the expanding population and for developing settlements, resulting in the decreasing extent of forested areas (Nawir et al. 2007). Land conversion and exploitation from forested or tree-based vegetation into different land uses (such as agriculture, urban settlement, and industries) sometimes lack to consider soil conservation practices, causing soil degradation (Faisol and Indarto 2010). Soil degradation in the form of erosion can lead to further environmental deterioration through sedimentation, pollution and increased flooding (Morgan 2009). These conditions have been the driving force behind rehabilitation programs since the colonial eras with the main objective are to conserve soil and water.

Land rehabilitation is necessary to improve biological and habitat diversity at a landscape level, increase the productivity of land by planting trees to generate timber and non-timber products, enhance forest functions such as water storage, water balance, sequestration of carbon, climate mitigation, and restore soil fertility and physical properties for protection against erosion (Kobayashi et al. 2001). In other perspectives, land rehabilitation by tree planting can promote human well-being (i.e. economic benefits and quality of life) as described by Fisher et al. (1996). The economic benefits of rehabilitation can be in the form of additional incomes from selling timber and non-timber products, while the quality of life includes reduced heat effect, pollution reduction, fresh air and aesthetic view as the results of planting trees (Elmqvist et al. 2015; Roy et al. 2012).

Forest and land rehabilitation conducted either at a site level (i.e. small area consisting of single land management) or at a landscape scale (i.e., large area consisting of multiple land management) will affect different people in different ways. There were many cases of rehabilitation programs that failed because of the lack of involvement of local communities or ignorance of their interests when implementing the programs (Lamb and Gilmour 2003). Therefore, perception, acceptance, and participation by local communities in forest and land rehabilitation are important when designing forest rehabilitation programs to enhance feasibility and likelihood of success of the programs (Kobayashi 2004; Budiharta et al. 2016). Study by Soejono and Budiharta (2013) showed that there were some tree species preferred by the local community for rehabilitation of open area around water spring in Pasuruan East Java with the purposes of delivering ecological functions and providing socio-economic benefits. Study of trees preferences conducted by Salam et al. (2000) demonstrated that there are many factors influencing trees preference by farmers in agroforestry system in which the farmers preferred economic benefits rather than ecological concerns.

The selection of tree species for land rehabilitation needs several aspects to consider, including socio-economic aspects, socio-cultural values, environmental services, general performance of tree species and biodiversity aspect whether the species are native or exotic/alien species (Reubens et al. 2011). While there are several studies on ecological aspects of forest and land rehabilitation, there is little information on social aspects particularly regarding community's preference on species selection and land uses management at watershed level. Several previous studies discussed the role of communities in selecting trees for land rehabilitation including trees preferences for water spring rehabilitation (Soejono and Budiharta 2013), rehabilitation of degraded land in Kenya (Glover 2012), selection of tree species in the form of agroforestry for slope stability in North Korea (He et al. 2015), and selection of trees for forest reforestation in the Philippines (Chechina and Hamann 2015). This research aimed to investigate the preference of villagers in selecting tree species for land rehabilitation programs in Sampean watershed, Bondowoso District, East Java, Indonesia and factors that influence those selections in regard to social, economic and ecological objectives of land management. We expect this study can enrich the limited studies on forest and land rehabilitation viewed from social perspective.

MATERIALS AND METHODS

Study areas

This study was conducted in Gubrih sub-watershed, Bondowoso, East Java on April-May 2016. Gubrih sub-watershed is a part of Sampean watershed and encompasses three sub-districts, i.e. Wringin, Tegal Ampel and Pakem. Study location has temperature ranging from 20.4 – 25.9ºC with average temperature of 25.7ºC. Average rainfall is 6475 mm/year with long rain time is 9 days per month. Minimum rainfall is 1622 mm in June while maximum rainfall is 13102 mm in January. Dry season occurs from June to October while the rainy season occurs from November to May. Soil type that dominates the study location is regosol (Bapeda Jawa Timur, 2013).

Forest cover in Bondowoso is 59.867,95 ha, consisting of watershed protection forest (*hutan lindung*) with an area of 30.863,70 ha that covers 33,99% of Sampean watershed. Other land uses are timber plantation (*kebun pohon*), agroforestry (*kebun campur*), rice field (*sawah*), non-rice crop field (*tegalan*) and settlement area, covering of 7,59%, 19,76%, 27,70%, and 4,62% respectively (Asmaranto et al. 2012). Previous study suggested that the ideal composition of land use in Sampean watershed consists of plantation and agroforestry areas with a portion 28.71% of total extent, rice fields (3.12%), non-rice crop fields (20.27%), and settlement (3.22%) (Asmaranto et al. 2012). The gaps between the ideal and existing conditions especially on tree-based vegetation cover (i.e., plantation/agroforestry) requires study on how to increase such land cover through land rehabilitation.

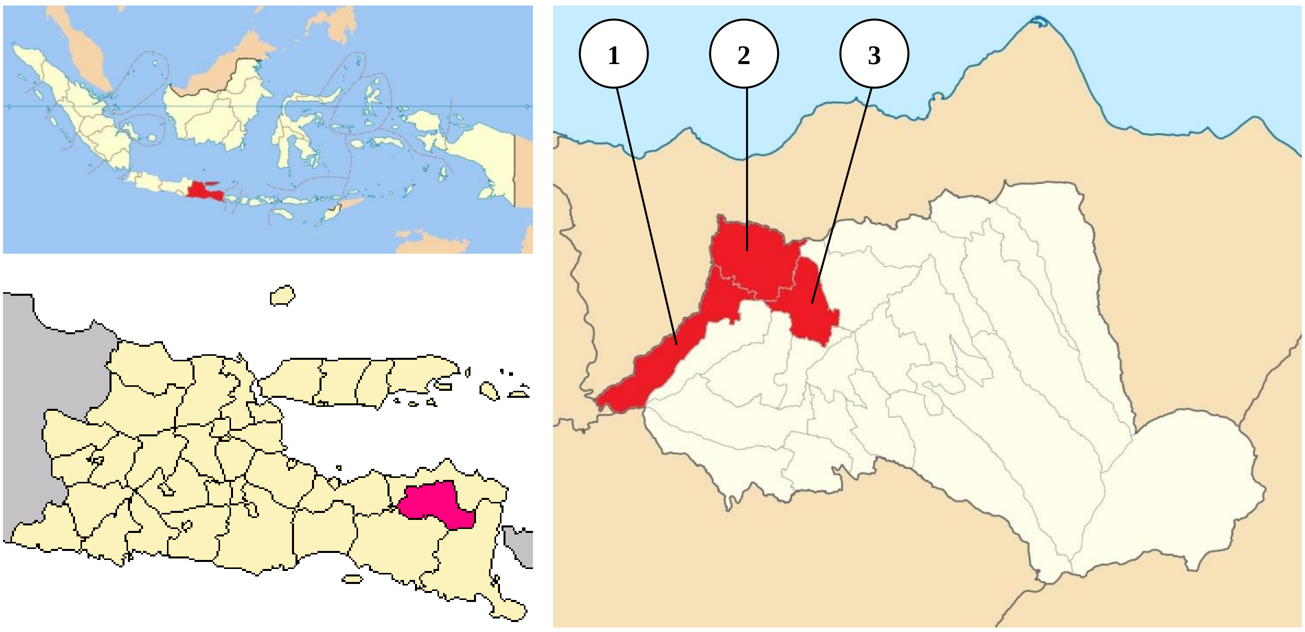

Figure 1. Study location in Gubrih sub-watershed, Sampean watershed, Bondowoso Distric, East Java Province, Indonesia which include Sub-districts of Pakem (1), Wringin (2), and Tegal Ampel (3)

Table 1. Species of trees to select by respondents at the studied areas in Gubrih sub-watershed, Sampean watershed, Bondowoso District, East Java, Indonesia

Species	Family	Local name	Potential uses
Albizia procera (Roxb.) Benth.	Fabaceae	Wangkal	Ecology and economy
Aleurites moluccanus (L.) Willd.	Euphorbiaceae	Kemiri	Ecology and economy
Alstonia scholaris (L.) R. Br.	Apocynaceae	Pule	Ecology
Anthocephalus cadamba (Roxb.) Miq.	Rubiaceae	Jabon	Economy
Antidesma bunius (L.) Spreng.	Euphorbiaceae	Buni	Ecology
Artocarpus altilis (Parkinson ex F.A.Zorn) Fosberg	Moraceae	Sukun	Ecology and economy
Artocarpus heterophyllus Lam.	Moraceae	Nangka	Ecology and economy
Bischofia javanica Blume	Phyllanthaceae	Gintungan	Ecology
Buchanania arborescens (Blume) Blume	Anacardiaceae	Gerok ayam	Ecology
Calophyllum inophyllum L.	Clusiaceae	Nyamplung	Ecology
Cananga odorata (Lam.) Hook.f. & Thomson	Annonaceae	Kenanga	Ecology and economy
Canarium vulgare Leenh.	Burseraceae	Kenari	Ecology
Cassia javanica L.	Fabaceae	Trengguli	Ecology
Ceiba pentandra (L.) Gaertn.	Bombacaceae	Randu	Economy
Coffea arabica L.	Rubiaceae	Kopi	Economy
Diospyros blancoi A.DC.	Ebenaceae	Bisbul	Ecology
Dracontomelon dao (Blanco) Merr. & Rolfe	Anacardiaceae	Rau	Ecology
Durio zibethinus L.	Bombacaceae	Duren	Economy
Dysoxylum gaudichaudianum (A.Juss.) Miq.	Meliaceae	Kedoyo	Ecology
Erythrina orientalis Murray	Fabaceae	Dadap	Ecology
Ficus variegata Blume	Moraceae	Gondang	Ecology
Gmelina arborea Roxb.	Verbenaceae	Gmelina	Economy
Leucaena leucocephala (Lam.) de Wit	Fabaceae	Lamtoro	Economy
Litsea glutinosa (Lour.) C.B.Rob.	Lauraceae	Po ketek	Ecology
Madhuca longifolia (J.Koenig ex L.) J.F.Macbr.	Sapotaceae	Kecik-kecik	Ecology
Michelia alba DC.	Magnoliaceae	Cempaka	Ecology
Pangium edule Reinw.	Achariaceae	Kluwek	Economy
Paraserianthes falcataria (L.) I.C.Nielsen	Fabaceae	Sengon	Economy
Parkia timoriana (DC.) Merr.	Fabaceae	Kedawung	Ecology
Peltophorum pterocarpum (DC.) K.Heyne	Fabaceae	Saga	Ecology
Persea americana Mill.	Lauraceae	Alpukat	Economy
Pipturus sp.	Urticaceae	Senu	Ecology
Pometia pinnata J.R.Forst. & G.Forst.	Sapindaceae	Matoa	Ecology and economy
Syzygium aqueum (Burm.f.) Alston	Myrtaceae	Jambu air	Economy
Pterocarpus indicus Willd.	Fabaceae	Angsana	Ecology and economy
Pterocymbium tinctorium Merr.	Palongan	Sterculiaceae	Ecology
Sapindus rarak DC.	Sapindaceae	Klerek	Ecology
Saraca indica L.	Fabaceae	Asoka	Ecology
Schleichera oleosa (Lour.) Merr.	Sapindaceae	Kesambi	Ecology
Senna siamea (Lam.) H.S.Irwin & Barneby	Fabaceae	Johar	Ecology
Spondias dulcis Parkinson	Anacardiaceae	Kedondong	Economy
Sterculia cordata Blume	Sterculiaceae	Kelumpang	Ecology
Swietenia macrophylla King	Meliaceae	Mahoni	Economy
Syzygium cumini (L.) Skeels	Myrtaceae	Juwet	Ecology
Syzygium polyanthum (Wight) Walp.	Myrtaceae	Salam	Ecology and economy
Tectona grandis L.f.	Lamiaceae	Jati	Economy
Annona muricata L.	Annonaceae	Sirsat	Economy
Bambusa vulgaris Schrad.	Poaceae	Bambu	Ecology and economy
Chrysophyllum cainito L.	Sapotaceae	Buah Susu	Economy
Citrus maxima (Burm.) Merr.	Rutaceae	Jeruk bali	Economy
Cocos nucifera L.	Arecaceae	Kelapa	Economy
Dimocarpus longan Lour.	Sapindaceae	Kelengkeng	Economy
Garcinia mangostana L.	Clusiaceae	Manggis	Economy
Gliricidia sepium (Jacq.) Kunth ex Walp.	Fabaceae	Gamal	Economy
Gnetum gnemon L.	Gnetaceae	Melinjo	Economy
Lansium domesticum Corrêa	Meliaceae	Duku	Economy
Mangifera indica L.	Anacardiaceae	Mangga	Economy
Manilkara kauki (L.) Dubard	Sapotaceae	Sawo	Ecology
Melia azedarach L.	Meliaceae	Mindi	Ecology
Nephelium lappaceum L.	Sapindaceae	Rambutan	Economy
Parkia speciosa Hassk.	Fabaceae	Petai	Economy
Sesbania grandiflora (L.) Pers.	Fabaceae	Turi	Economy

Data collection

This study used questionnaires to collect data which were distributed randomly to respondents. Sampling method used in this survey was simple random sampling. This method allows each member of the population (villager) to have an equal chance of being selected to minimize bias (Groves et al. 2009). Survey was conducted in Gubrih Sub-watershed which encompasses three Sub-districts with total of 15 villages, i.e. Wringin Sub-districts (village: Gubrih, Jambe Wungu, Wringin, Ampelan, Sumber Malang, Jatisari, Banyuwuluh, and Banyuwuluh 2), Tegal Ampel Sub-districts (village: Tanggul Angin, Klabang Agung, Karanganyar, Mandiro, Sekar Putih, Klabang), and Pakem Sub-districts (village: Pakem). Total number of villagers being interviewed was 98 with gender composition of 63 males and 35 females. Each respondent was interviewed according to the list of questions contained in the questionnaire.

The questionnaire contains closed questions about tree species to select by the respondent for rehabilitation in Sampean Sub-watershed. The list of tree species was developed by identifying species with specific criteria in terms of ecological and economic perspectives. The ecological perspectives refer to tree species found at natural ecosystems nearby with similar biotic and abiotic factors, or so-called the reference site (Fiqa and Darmayanti 2017). In addition, tree species with high carbon sequestration were also considered to complement the ecological criteria (Danarto et al. 2013). Carbon sequestration is ability of plants to absorb CO_2 from atmosphere and then store it as biomass (Hairiah et al. 2011). From economic perspective, tree species with economic value were considered. In the end, there were 62 species of trees to be selected by the respondents as shown in Table 1.

In addition to species preference, analysis on factors affecting community preference in selecting particular tree species for land rehabilitation was also conducted. Basic information at respondent level was collected including age, gender, education level, access to transportation to their land (i.e. easy, moderate, difficult), topography of their land (i.e. flat, sloping, and steep), and primary occupation. Respondents were also asked about their perception of the importance and benefit of trees in their life, their preferred land management (i.e. timber plantation/*kebun pohon*, agroforestry/*kebun campur*, rice field/*sawah*, non-rice crop field/*tegalan*), and their acceptance for rehabilitation programs implemented on their lands.

Statistical analysis

Collected data were analyzed using Pearson Chi-square test to examine associations between two variables. In particular, we examined association between the variables of transport access versus preferred land management by the respondent, and between land topography versus preferred land management by the respondent. The equation for the Chi-square analysis is as follows:

$X^2_p = \Sigma \frac{(Fij - Eij)^2}{Eij}$, with df (degree of freedom) = (R-1) (C-1),

Where:
X^2_p = chi-square analysis
F_{ij} = observed value
E_{ij} = expected value
R = number of lines
C = number of columns

The level of confidence to determine significance is 95%, meaning that there is a significant association between variables if p value< 0.05 (Egbue and Long 2012).

RESULTS AND DISCUSSIONS

Respondents' composition

Education level varied among villagers with the highest proportions at the level of elementary school (*Sekolah Dasar*) with percentage of 48.97%, followed by no receiving education with percentage of 12.24% (Figure2). Other educational levels, such as middle level, high level, and college level, had fewer percentage. Variable of age also varied among villagers. Most of respondents in this study had age of more than 40 years, while respondents with age of less than 30 years and between 30-40 years old had equal proportion (Figure 2).

Preferred species of trees for rehabilitation programs by local community

One step in rehabilitation of degraded areas is the selection of species of trees for rehabilitation programs which are preferred by local community to enhance community's acceptance and participation. The results of this study showed that among 62 tree species listed in the questionnaire, there were 45 species chosen by the local community for rehabilitation programs in Gubrih Sub-watershed (Figure 3). Most of the selected tree species have economic potentials, including the potential for wood, fruits, cooking spices and stimulants. Highly preferred tree species are sengon (*Paraserianthes falcataria*), durian (*Durio zibethinus*), gmelina (*Gmelina arborea*), teak (*Tectona grandis*), avocado (*Persea americana*), coffee (*Coffea robusta*), jackfruit (*Artocarpus heterophyllus*), mahogany (*Swietenia macrophylla*), and breadfruit (*Artocarpus altilis*) and mangoes (*Mangifera indica*) in which each of them was selected by more than 20% of the respondents. Tree species such as klengkeng (*Nephelium lappaceum*), jeruk bali (*Citrus maxima*), jabon (*Anthocephalus cadamba*), lamtoro (*Leucaena leucocephala*) and kedondong (*Spondias malayana*) were moderately preferred as it was chosen by 6-20 % of the respondents. As many 21 species were less preferred by community with percentage of respondents ranging from 1-5% including manggis (*Garcinia mangostana*), buni (*Antidesma bunius*), matoa (*Pometia pinnata*), sawo (*Manilkara kauki*), buah susu (*Chrysophyllum cainito*), duku (*Lansium domesticum*), and sirsat (*Annona muricata*) (Figure 3).

Fruit trees are mostly cultivated in homegarden as fruit sources and microclimate controllers (temperature and light intensity controller). In addition, some of species are native trees with potentials of medicine, timber, and food, such as klerek (*Sapindus rarak*), pule (*Alstonia scholaris*), wangkal (*Albizia procera*), turi (*Sesbania grandifolia*), and belinjo (*Gnetum gnemon*). However, these species were chosen by only few respondents because they preferred tree species which has economic benefits for their life including commercial timber trees. For example, sengon (*P. falcataria*) is a timber tree that can be harvested at the age of 5-6 years with wood volume reaching 300 m^3 per hectare with potential income of 240 million rupiahs (Mulyana and Asmarahman 2012). In contrast, although species like klerek (*S. rarak*) has the potentials for batik material, cloth cleaner, soap, biopesticides, acne treatment, shampoo, and shade plant and can be harvested at 5-6 years (Udarno 2012), but this species is rarely cultivated by community since it has limited commercial value.

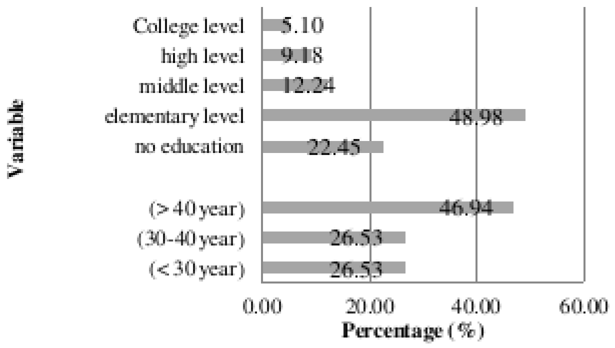

Figure 2. Basic data of respondents (age and education level) at the studied areas in Gubrih sub-watershed, Bondowoso District

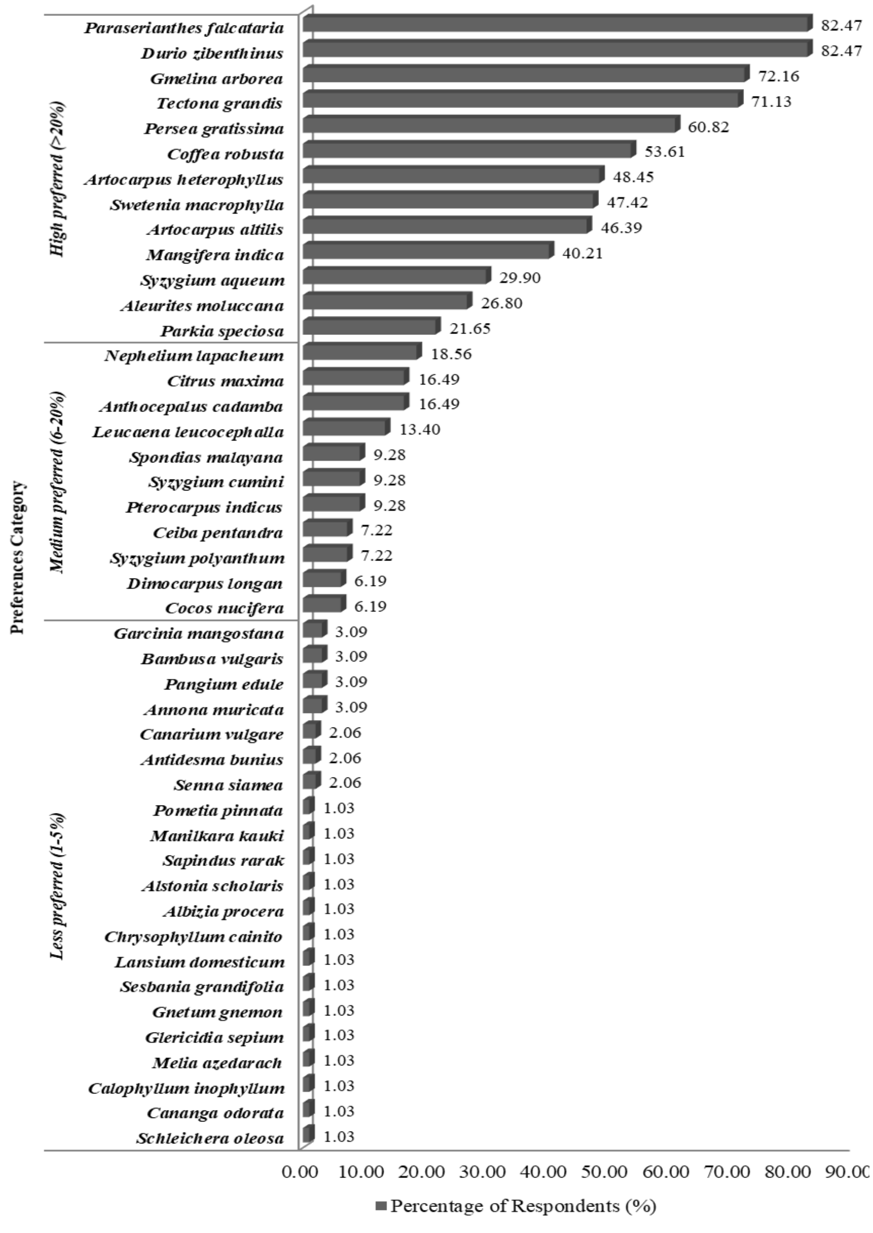

Figure 3. Percentage of respondents and tree species selected (45 species) for rehabilitation programs in Gubrih sub-watershed, Sampean watershed, Bondowoso District, East Java Province, Indonesia

There were 17 species listed in the questionnaire that were not chosen by respondents with most of them are native trees found at the forest of the reference site. Reference site is a site with ecosystem that has similar biotic and abiotic conditions with the land to be restored or rehabilitated. In this study, we referred to trees found at protected forest of RPH Sentul, Probolinggo, East Java that had similar ecosystem conditions with Sampean watershed (Darmayanti and Fiqa 2017). These species included *Bischofia javanica, Buchanania arborescens, Cassia javanica, Diospyros blancoi, Dracontomelon dao, Dysoxylum gaudichaudianum, Erythrina orientalis, Ficus variegata, Litsea glutinosa, Madhuca longifolia, Michelia alba, Parkia timoriana, Peltophorum pterocarpum, Pipturus* sp., *Pterocymbium tinctorium, Saraca indica,* and *Sterculia cordata*. Although these species have biodiversity and ecological values, these species were not chosen by the respondents as they were not familiar with these species. In the other perspective, they assumed that these species lack of economic potentials. Bisbul (*Diospyros blancoi*), cempaka (*Michelia alba*), gerok ayam (*Buchanania arborescens*), gintungan (*Bischofia javanica*), kedawung (*Parkia timoriana*), kedoya *(Dysoxylum gaudichaudianum*), kelumpang (*Sterculia cordata*), walnuts (*Canarium vulgare*), nyamplung (*Calophyllum inophyllum*), krau (*D. dao*), saga (*Peltophorum pterocarpum*) are among 25 tree species that have high potentials in carbon sequestration in dry lowlands ecosystem (Danarto and Yulistyarini 2019). They are also commonly found in water springs of lowland ecosystems, so that the existence of these trees is very important for water conservation (Soejono et al. 2011).

Species of trees with potentials for timber and fruits were chosen by many respondents because these species have economic values. Sengon is one of timber tree categorized as fast-growing species so that it is widely cultivated by local community in Gubrih sub-watershed (Irawanti et al. 2017). Sengon is native to Indonesia, Papua New Guinea, Solomon Island, and Australia. This species can grow in a variety of habitat from dry to moist soil, even in acidic soil with good drainage. In Java, this species can be found on various types of soil with altitudes 0-1200 m above sea level (Soerianegara and Lemmens 1993). Besides sengon, other species which has timber potential in Bondowoso are teak (*T. grandis*), sonokeling (*Dalbergia latifolia*), and gmelina (*G. arborea*). Both jati and sonokeling are species that contribute to high timber production in Bondowoso if compared to other timber trees such as sengon, mahogany, and pine. Data from Bondowoso Statistical Office in 2017 showed that production of timber in 2016 in the form of teak commodities reached 917.9 m^3 with sonokeling wood production reaching 3,049 m^3 (BPS Bondowoso 2017). Teak has been chosen by many people as a long-term investment and has high economic benefits. This tree species is native to India, Indonesia, Laos, Myanmar, Thailand. Teak trees are able to grow in dry to moist habitats with rainfall of 600-4000 mm/year at altitudes of 0-1200 m above sea level with an average annual temperature of 14-36°C. The most suitable soil type is deep, well-drained soil, fertile alluvial-colluvial soil with a pH of 6.5-8 with high levels of calcium and phosphorus (Orwa et al. 2009). Most commercial timber trees planted in Bondowoso are cosmopolitan tree species that have wide adaptation to various climatic conditions and soil types.

Our findings suggest that there is a gap between ecological needs and socio-economic interests in the selection of species for land rehabilitation, especially in watershed landscapes. This is indicated by a mismatch between the list of species with ecological-biodiversity values and species with socio-economic preferences. Previous study in Rejoso watershed, Pasuruan District, East Java, local communities had several criteria in selecting tree species for rehabilitation under PES (Payment for Ecosystem Service) scheme (Leimona et al. 2018). The criteria included the tree species must be suitable with local habitat, it has good prices and accessible market to deliver high revenues, it must-have benefit for domestic consumption and the species possesses environmental and conservation values. Also, local communities preferred trees species that are consistent with their current farming system. Fruit and timber trees were preferred by smallholders downstream while agroforestry was mostly cultivated upstream (Leimona et al. 2018).

In various rehabilitation programs of degraded areas in Indonesia, tree species such as sengon, teak, gmelina, and jabon are widely planted by communities because these species have economic values. However, the lifetime of these species is not long because they would be harvested for their timber yield so that the rehabilitation goals for environmental improvement are not achieved (Soejono and Budiharta 2013). One of alternative for rehabilitation of degraded areas is using non-timber producing species which has long-term economic and environmental improvement potentials. From the selection of the villager population at the study sites, we propose several species of non-timber produced species that can be used for land rehabilitation in the studied area, including durian (*D. zibethinus*), avocado (*P. americana*), coffee (*C. robusta*), jackfruit (*A. heterophyllus*), mango (*Mangifera indica*), water guava (*Syzygium aqueum*), candlenut (*Aleurites moluccana*), petai (*Parkia speciosa*), rambutan (*N. lappaceum*), jeruk bali (*C. maxima*), and lamtoro (*L. leucocephala*). When cultivated, these species can be combined to form multi-strata agroforestry which not only can deliver non-timber products but also contributes to conserve water and soil (Budiharta et al. 2016).

Planting tree species for rehabilitation needs to consider habitat suitability, soil type, texture, soil structure and depth, climate, and water use efficiency (Soejono et al. 2011). Based on interviews with local community at the research location supported by literature studies from Orwa et al. (2009), Krisnawati et al. (2011), Harja et al. (2009), Soerianegara and Lemmens (1993), suitable habitat of trees species selected by the local community can be divided into three ranges of altitudes, namely low (0-400 m asl), medium (500-900 m asl) and high altitudes (mountainous with altitude > 900 m asl). Most of the tree species chosen by the local community at the studied areas can be planted from lowland to highland areas, including sengon (*P.*

falcataria), gmelina (*G. arborea*), teak (*T. grandis*), avocado (*P. americana*), jack fruit (*A. heterophyllus*), mahogany (*S. macrophylla*), bread fruit (*A. altilis*), mangoes (*Mangifera indica*), guava (*S. aqueum*), candle nut (*Aleurites moluccana*), and lamtoro (*L. leucocephala*). On the other hand, the preferred species that can be cultivated from lowland up to medium altitudes are durian (*D. zibethinus*), guava (*S. aqueum*) and rambutan (*N. lappaceum*). While jeruk bali (*C. maxima*) can only be cultivated in lowland ecosystems. Suitable habitat for the preferred trees by the local community in the studied area is shown in Table 2.

The research location has an average rainfall of 1000-2500 mm/year with soil is categorized as clay and loam soil. Durian (*D. zibethinus*) is cultivated by villager from middle to highland combined with other fruit trees such as avocado (*P. americana*), coffee (*C. robusta*), banana (*Mussa accuminata*), rambutan (*N. lappaceum*), and jeruk bali (*C. maxima*). Bondowoso is one of district that supplies durian in Indonesia with total production of 11.196 tons (Fitri and Islahudin 2018). Other species such as coffee (*C. robusta*) are cultivated from middle to highland and can be combined with other fruit trees within agroforestry system. Coffee is suitable to be cultivated within the range of altitude from 1300 to 3000 m asl with temperature of 15-25^{0}C and average rainfall 500-2000 mm/year. Soil classes suitable for coffee cultivation are loamy soil with deep solum, slightly acid, and well drainage. The soils should be rich in nutrients especially potassium with generous supply of organic matter (Orwa et al. 2009). Agroecologically, both plants are suitably cultivated in Bondowoso. A previous study showed that avocado, durian, clove and perennial crops that were combined in agroforestry systems in Bondowoso were profitable with NPV (Net Present Value) of Rp. 21.483.580 per hectare (Hariyati 2013).

Local community perception toward land rehabilitation

The results of the survey indicated that local community in Gubrih sub-watershed, Sampean watershed has a different perception regarding land rehabilitation in their area (Figure 4). The figure shows that the respondents in the area understood the importance of trees in their lives and trees deliver benefits to them. However, there were some respondents saying that trees are not important for their lives and they also have poor knowledge about the benefits of trees.

The perception of local people about the importance of trees in their lives indicates that local people use trees for various needs, including as income sources, conserving spring water, and disaster mitigation with most of them stating that trees are important for the purpose to increase income. Bondowoso is one of the poor regions (*daerah tertinggal*) in Indonesia with problems including low human development index, poverty, and lack of basic facilities, such as health, education and road infrastructure (Bondowoso Spatial Plan Agency 2011; Puspasari and Koswara 2016). Community welfare in Bondowoso needs to be increased to reduce the poverty level. There is 90.08% of total land area in Bondowoso used for agricultural land, including rice fields, non-rice crop fields (*tegalan*), plantations, forestry, swamps, and ponds. Most villagers in Bondowoso work in the sector of agriculture, forestry, and fisheries. Commodities cultivated in plantations in Bondowoso include coconut, areca nut, kapok, cashew nut, arabica coffee, robusta coffee, cloves, kasturi tobacco, sugar cane, and tobacco, whereas fruit species include mango, banana and durian (BPS Bondowoso 2018). Since most of the communities in the survey locations utilized trees and plants as a source of income, this can be combined with efforts to rehabilitate land by focusing on species with multiple benefits, not only to improve environment quality (i.e. ecological objective) but also to enhance community's welfare (socio-economic objective). The potential land management system to support rehabilitation efforts in the study region includes plantation of timber species and agroforestry system which can be implemented in land management currently under non-rice crop field (*tegalan*).

Influencing variables of community's preference

Land topography and access influenced the preference of land use systems by local community in Gubrih sub-watershed. Based on the results of Chi-square Pearson statistical analysis, there was a correlation between topography and the selection of land management systems by local community (p-value<0.05). Dryland agricultural systems, either in the form of *padi gogo* rice field or other crops field (*tegalan*) were mostly preferred by villagers from low to medium altitudes and on flat locations, but this was not the case in the area with steep topography in which most respondents preferred agroforestry (Figure 5).

There was also a correlation between variable of access and the selection of land management systems by community with Chi-square Pearson value of 10.33 (p-value<0.05). For all categories of access (i.e., easy, moderate and difficult), many villagers preferred plantation of timber species and agroforestry system because they assumed that both systems of land use were profitable (Figure 6). Yet, for all categories of access, land use system of dry land rice cultivation (*padi gogo*) was still chosen by the villagers although the percentage was smaller than plantation of timber species and agroforestry.

The finding of the relationship between land management and accessibility is in accordance with other studies. The more difficult is the access of a land management system, the higher is the likelihood a land being managed for tree-based land-use systems such as forest and agroforestry. Vice versa, the easier is the access to transportation, the more likely a land is managed under intensive agriculture, such as rice field and non-rice crop fields (*tegalan*). Several factors that influence land use functions in watersheds include the presence of infrastructure, agricultural expansion, timber extraction. Access to transportation triggers migration and forest clearing for plantations (Geist and Lambin 2002; Verbist et al. 2005; Busch and Gallon 2017).

Table 2. Environmental suitability for 14 species preferred by local community in Gubrih sub-watershed, Sampean watershed, Bondowoso District, East Java Province, Indonesia

Species	**Altitude (m asl)**	**Soil type**	**Potentials**	**References**
Paraserianthes falcataria	0-1200	Deep, well-drained fertile soils, such as friable clay loam. Prefers alkaline to acid soils.	Timber	Orwa et al. (2009)
Gmelina arborea	0-1200	Preference for moist, fertile, freely drained soils; acid soils, calcareous soils and laterite soils.	Timber	Orwa et al. (2009)
Tectona grandis	0-1200	Their most suitable soil is deep, well-drained, fertile alluvial-colluvial soil with a pH of 6.5-8 and a relatively high calcium and phosphorous content. The quality of growth, however, depends on the depth, drainage, moisture status and fertility of the soil. Teak does not tolerate waterlogging or infertile lateritic soils.	Timber	Orwa et al. (2009)
Persea americana	0-2500	Requires well-drained aerated soil. A pH of 5-5.8 is optimal for growth and fruit yield.	Fruit	Orwa et al. (2009)
Artocarpus heterophyllus	0-1600	Deep, alluvial, sandy-loam or clay loam soils of medium fertility, good drainage and a pH of 5-7.5. This species tolerance to saline soils	Timber, fruit and vegetable	Orwa et al. (2009)
Swietenia macrophylla	0-1500	Well-drained soils.	Timber	Orwa et al. (2009)
Artocarpus altilis	0-1550 (optimum growth at 600-650)	Alluvial and coastal soils, deep, fertile, well-drained sandy loam or clay loam soils.	Timber, fruit and vegetable	Orwa et al. (2009)
Mangifera indica	0-1200	Mango trees thrive in well-drained soils with pH ranging from 5.5 to 7.5 and are fairly tolerant of alkalinity. For good growth, they need deep soil to accommodate the extensive root system.	Fruit	Orwa et al. (2009)
Syzygium aqueum	0-1200	The trees prefer heavy soils and easy access to water instead of having to search for water in light deep soils.	Fruit	Panggabean (2016)
Aleurites moluccana	0-1200	Sandy, clay, loam soil with pH 5-8.	Spices	Krisnawati et al. (2011)
Leucaena leucocephala	0-1500	Optimal growth on calcareous soils but can be found on saline soils and on alkaline soils up to pH 8; it is not tolerant of acid soils or waterlogged conditions. *L. leucocephala* is known to be intolerant of soils with low pH, low phosphorus, low calcium, high salinity, high aluminum saturation and water-logging and has often failed under such conditions.	Fruit, firewood	Orwa et al. (2009)
Durio zibethinus	300-800	Deep soil, well-drained, light sandy or loamy soil.	Fruit, timber	Orwa et al. (2009)
Nephelium lappaceum	0-600	Clay loam soil, pH 5-6.5.	Fruit	Orwa et al. (2009)
Citrus maxima	0-400	Tolerate from coarse sand to heavy clay	Fruit	Orwa et al. (2009)

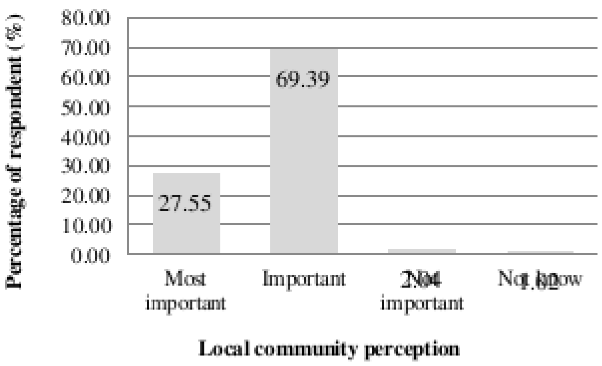

Figure 4. Perception of local community on the benefit of trees in their life

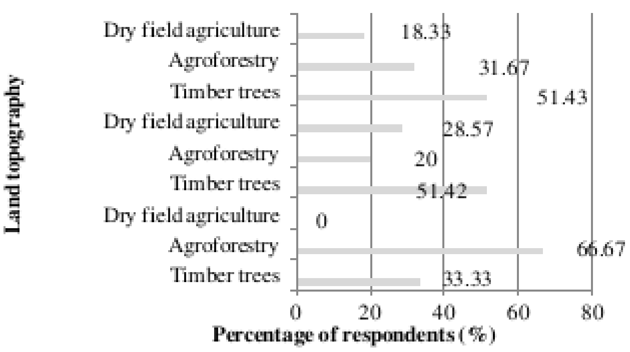

Figure 5. Land use system preferred by local community based on categories of land topography

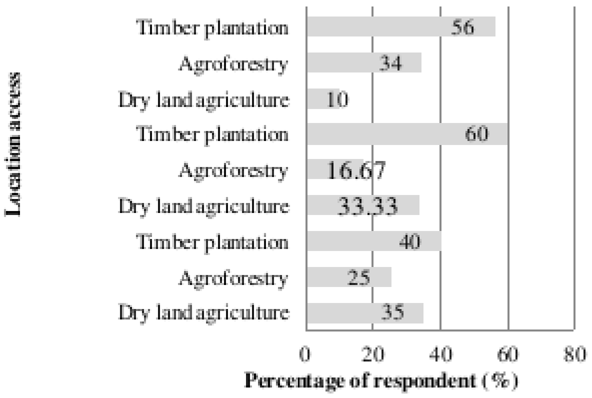

Figure 6. Land use system preferred by local community based on categories of location access

Based on interviews with respondents, timber plantation and agroforestry were considered to have economic advantages compared to other land uses. Agroforestry system is ecologically and economically beneficial. Agroforestry system at the studied area was a mixed system of combination of several species of fruit trees and seasonal crops. The villagers at the survey location stated that the agroforestry system increased income of their life. Difficult access to transportation to traditional markets causes local communities preferred for agroforestry and timber plantation for economic investment purposes.

Agroforestry increases community income and environmental services compared to conventional farming systems (Mercer et al. 2014). A previous study showed that coffee farming in Bondowoso is beneficial with R/C is 1.85. Another study showed that commercial agroforestry in India is profitable with Benefit to Cost (B/C) ratio is 6.59 for annual crop-based tree agroforestry (Sangeetha et al. 2015). A case study in East Kalimantan, vanilla and agarwood agroforestry are also profitable with profit rate of 15% and IRR of 21.5% (Kunio and Lahjie 2015) while agroforestry in Sukoharjo Pringsewu Village contributes to the income of farmers with benefit percentage of 88.31% (Olivi et al. 2015).

In conclusion, of the 62 tree species listed in the questionnaire, there were 45 species of trees selected by respondents in Gubrih sub-watershed with 13 species were highly preferred. The respondents understood the importance of trees as a source of income as well as a measure to conserve spring water and mitigate disasters, such as landslides and floods. This selection of species was strengthened with land-use systems they preferred, which were tree-based land-use systems such as plantation of timber species and agroforestry. This preference is influenced by access to transportation and land topography. The findings of this study suggest that there is opportunity in rehabilitating degraded lands in Sampean watershed using tree species preferred by local communities under the land use system of timber plantation or agroforestry. A list of species resulting from this study can provide insights when establishing nurseries and producing seedlings for rehabilitation programs.

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Review: Floral resources diversity and vegetation types important for honeybees in Ethiopia

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Abstract. *Addi A, Bareke T. 2019. Review: Floral resources diversity and vegetation types important for honeybees in Ethiopia. Asian J For 3: 64-68.* The high biodiversity of Ethiopia is attributed to its wide range of altitude and great geo-morphological diversity. This has resulted in the existence of a high diversity of floral resources of which majority of them are visited by honeybees. This paper aimed to review existing studies on bee floral resources in Ethiopia to understand the types of bee plants, floral diversity, flowering period and food source offered by the plants. Over 1500 species of indigenous and exotic plants belonging to 105 bee plant families have been identified. The growth form of bee forage comprises 41.6% herb, 28.7% shrubs, 21.7% trees, and 8% climbers. The majority of bee plant species flower from September to November and April to May, resulting in two major honey flow periods in the country. From this information, Ethiopia has rich bee forage diversity across different vegetation types, however, further collection and documentation of bee flora are required in unaddressed areas of the country. Thus *in situ* conservation by ecological restoration, and raising and planting of seedlings of bee forages should be promoted for sustainable honey production.

Keywords: Bee forages, honeybee, honey flow, pollen

INTRODUCTION

Ethiopia is one of the countries in the world endowed with rich biodiversity, including its natural vegetation. Natural vegetation in Ethiopia can be classified into 13 vegetation types (Friis et al. 2012), namely: (i) Desert Vegetation, (ii) Semi-Desert Scrub, (iii) *Acacia-Commiphora* Bushland and Thicket, (iv) *Acacia-Commiphora* Narrow-leaved Deciduous Woodland and Forest, (v) Dry Evergreen Montane Forest, (vi) Afro-alpine and Sub-Afro alpine vegetation, (vii) Moist Evergreen Montane Forest, (viii) Transitional rainforest, (ix) *Combretum-Terminalia,* (x) Broad-leaved Deciduous Woodland and Forest**,** (xi) Fresh-water lakes and open water vegetation, (xii) freshwater marshes and swamps flood plain, and (xiii) Lakeshore vegetation. These vegetation types are found in different climatic regions, comprising different flora. In total, there are 6000 species of flowering plants recorded to be found in Ethiopia, most of them are bee plants that have apicultural importance (Admassu et al. 2014a; Ensermu and Sebsebew 2014).

Each vegetation type in Ethiopia comprises different plant species associated with particular bee species, as such each vegetation type is not of equal importance for honey production due to suitability of climate, availability of food source to *Apis mellifera* subspecies and other environmental factors (Tura and Admassu 2018). The large variety of floral vegetation types in Ethiopia results in the existence of higher population density of honeybees and makes the country one of the 10 largest honey producers and the 3rd largest beeswax producer's worldwide (Fitchl and Admassu 1994; Gidey and Mekonen 2010; USAID 2012). The estimated honey production potential of the country is 500,000 metric tons per annum and *Apis mellifera* also contributes to pollination of plants for crop production and biodiversity conservation.

However, there is decreasing trend of honey production in Ethiopia with annual honey production is recently only 54,000 metric tons and 5000 tons of beeswax (CSA 2017)**.** In view of this problem, the major aim of this paper is to study the important findings that have been achieved during the last two decades in area of bee forage research. In this review, identification, distribution, and diversity of bee resources, preparation of flowering calendar, characterization, and evaluations of herbaceous, shrubs, and tree plants, and the role honeybees in natural resource conservation and agroforestry systems are discussed**.**

IMPORTANT VEGETATION TYPES IN ETHIOPIA FOR BEEKEEPING

The vegetation types and associated bee flora of Ethiopia are presented in Table 1. Based on the table, desert and semi-desert vegetations are characterized by highly drought-tolerant species but limited contribution for beekeeping due to erratic rainfall and extreme drought. However, *Acacia-Commiphora*, bushland, and thickets are important for beekeeping production which is predominately found escarpment of Afar, Oromia, Amhara and SNNP, and Somalia regional state (Admassu et al. 2014a). This area is highly vulnerable to crop production due to the moisture deficit and recurrent drought, as such beekeeping is alternative livelihood option.

The central and mountainous chains and some parts of eastern and northern Ethiopia are covered by Dry Evergreen Montane vegetation. This vegetation type represents a complex system of successions involving extensive grasslands rich in legumes. Ethiopian agriculture is developed in these areas for thousands of years (Zerihun 2012). The intensive utilization of the areas for agriculture has resulted in loss of forests and it has been replaced by bushland and weeds. The vegetation is relatively suitable for apiculture due to availability of both natural plant species and cultivated crops such as oil crops, cereals, pulses and horticultural crops. Currently, this area faces bee forage scarcity due to high human population and livestock pressure and also intensive application of pesticides for crop agriculture (Admassu et al. 2014a).

Afroalpine, particularly Ericaceous belt, is physiognomically characterized by the dominance of shrubs such as *Erica arborea*. The *Erica arborea* honey is well known in this vegetation but the area is affected by overgrazing and massive soil erosion. The *E. arborea* honey is commonly found in Wochi district in West Shoa zone of Oromia regional states Gemechis 2014).

The moist evergreen Afromontane forest occurs mainly in the southwestern part of the Ethiopian highlands. The Afromontane rainforests in southwestern Ethiopia are one of potential areas for commercial and small-scale beekeeping production due to a great density of vegetation cover and high honeybee population. Beekeeping activity is a major source of income for the community surrounding the forest and contributes to up to 95% of a household's annual cash income including for payment of government tax, clothing, and for school fees (Paulos 2011).

The *Combretum-Terminalia* Broad-leaved Deciduous Woodland and Semi-evergreen low land Forest are found in Gambella, Beneshangul Gumuz Region, and along the Tekeze River basin in Tigray and Amhara regional states. In this forest, *Manilkara butugi* and *Terminalia brownii* honey types are well known from Gambella region (Tura 2018) and Sheko district in Bench-Maji zone of Southern Nations and Nationalities. Moreover, *Ziziphusspina christi* honey is also reported from North West of Gondar in Amhara regional state along the Sudanese border (Zewdu et al. 2016).

BEE FLORA SPECIES DIVERSITY IN ETHIOPIA

In apiculture, identification and documentation of nectar and pollen source plants are the most limiting factors for honey production (Tura and Admassu 2018). In this regard, Holeta Bee Research Center has identified and characterized bee forages grown at different climatic regions of the country. Accordingly, more than 1500 bee plant species are identified, belonging to 670 genera, and 105 families, accounting 10% of the total flora of Ethiopia and Eritrea of which 310, 440 and 750 species of trees, shrubs and herbs respectively (Fitchl and Admassu 1994; Admassu et al. 2014a; Tura and Admassu 2018a) (Figure 1).

Among the identified plant families, Asteraceae, Acanthaceae, Fabaceae, Rubiaceae, Poaceae, Lamiaceae, and Euphorbiaceae are the most frequent families, represented by the highest number of bee forage species (Figure 2). The Asteraceae becomes one of the dominant families in angiosperm phylogeny due to mode of pollination, seed dispersal and adaption to different ecological niches. Moreover, this family has attractive flower color which enables the plant to be pollinated by different insect pollinators including honeybees, favoring them to colonize wide ecological ranges for honey production (Tura et al. 2014; Tura and Admassu 2018a).

Regarding the distribution of plants, the highest number of species has been collected from Oromia, Southern Nations and Nationalities People region, Amhara, Tigray and Gambella and no collection has been made from Somali and Afar regional states (Figure 3). It shows that there is a need for further extensive bee forage collection and documentation from Northern Ethiopia and remote areas of Oromia, Somali, Afar and Beneshangul Gumuz regional states.

Table 1. Major vegetation categories of Ethiopia with bee flora species

Vegetation types	Altitudinal range (m)	Major bee flora
Acacia-Commiphora bushland and thickets	400-1800	*Hypoestes forskaolii, Aloe* spp., *Acacia tortolis, Acacia senegal* and *Acacia brevispica*
Dry Evergreen Montane vegetation	1800-3000	*Olea europaea* subsp.*cuspidata, Eucalyptus globulus, Trifolium* spp., *Becium grandiflorum, Hypericum revolutum,* and *Guizotia scabra*
Afro alpine and Ericaceous belt	3000-3200	*Erica arborea, Hypericum revolutum, Geranium arabicum, Helichrysum citrispinum, and Anthemis tigreensis*
Moist evergreen Afromontane forest	1500-2600	*Schefflera abyssinica, Croton macrostachyus, Coffea arabica* and *Vernonia amygdalina*
Transitional rain forest	1000-1900	*Coffea arabica, Pouteria analifolia, Manikila butji*
Combretum terminalia Broad forest	400-600	*Manilkarabutugi, Terminalia brownii, Combretum molle, Grewia bicolor, Anogeissus leiocarpa, Acacia tortolis, Hypoestes forskaolii*, and *Ziziphus spina-christi*

Note: Admassu et al. (2014a); Tura et al. (2014); Tura et al. (2017); Tura and Admassu (2018)

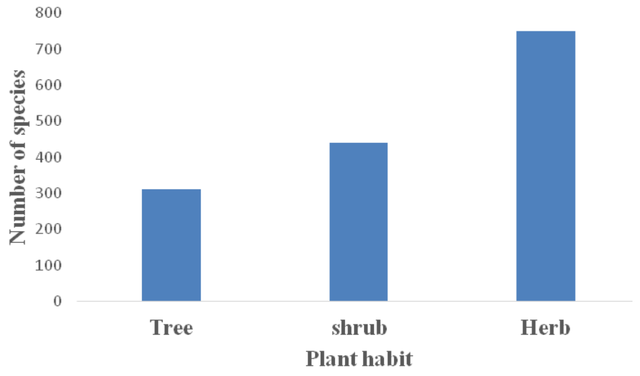

Figure 1. The habit of bee plant species identified from different parts of Ethiopia

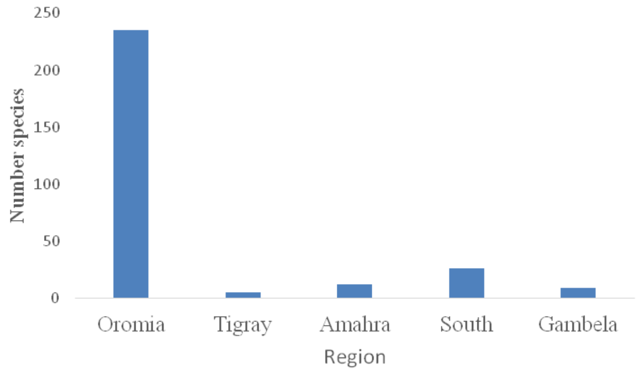

Figure 3. Distribution of bee forage in regional states of Ethiopia

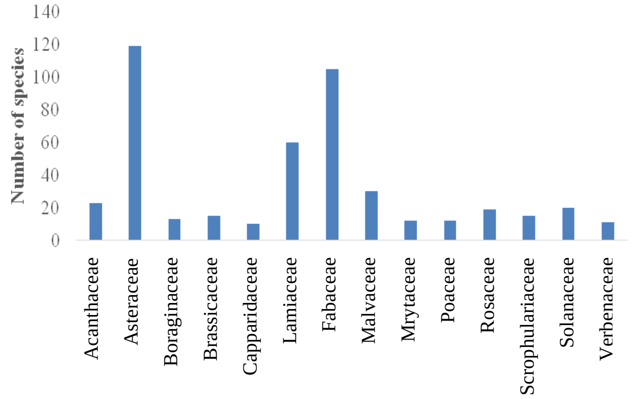

Figure 2. Number of bee flora species in major plant families in Ethiopia

Table 2. Bee forage diversity in different floristic regions of Ethiopia

Floristic region	Richness	H´	Evenness
SNNP	89	3.7	0.82
Oromia	99.3	3.9	0.85
Amhara	79	3.8	0.87
Tigray	29.2	2.9	0.8
BeneshangulGumuz	60.3	3.6	0.89
Gambella	50.2	1.93	0.81

Table 4. t-Test comparison and ANOVA for species diversity and species richness and evenness

Factors	Beekeeper home gardens	Non-beekeeper home gardens	t-Test	ANOVA	Mann-Whitney U test
Shannon species diversity	2.05 ± 0.08	1.40±0.06	***	***	
Evenness	0.87 ± 0.03	0.79 ± 0.03	N.S.	N.S.	
Species richness	12.58 ± 0.81	6.5 ± 0.53	***	***	***

Note: ***Highly significant at (P<0.001), N.S. - Not significantly different (P>0.05) (Source: Debissa, 2006)

Table 5. Types of plant species preferred for Galessa watershed management

Plant species	Family	Local name	Habit	Other uses
Urtica simensis	Urticaceae	Dobbi	Herb	Food
Buddleja polystachya	Buddlejaceae	Anfare	Shrub	Fuelwood
Chamaecytisus proliferus	Fabaceae	Treelucern	Shrub	Fodder and fuelwood
Dombeya torrida	Sterculiaceae	Dannisa	Tree	Fuelwood and fences
Eucalyptus globulus	Myrtaceae	Bargamo	Tree	Construction, fuelwood
Hagenia abyssinica	Rosaceae	Hexxo	Tree	Medicine and timber
Maesa lanceolata	Myrsinaceae	Abbayyi	Shrub	Fence and fuelwood
Solanecio gigas	Asteraceae	Osole	Shrub	Fences
Vernonia amygdalina	Asteraceae	Ebichaa	Shrub	Fuelwood and medicine

Source: Tura et al. (2014b)

The analysis of vegetation data using the Shannon Wiener diversity index using natural logarithm revealed that Oromia has the highest species diversity (3.97) followed by South nations and Nationalities People region, (3.7) Amhara (3.4) and Tigray (2.5) and Gambella (1.93) (Table 2). The species richness also varied significantly among the regions and the same pattern is followed for the species evenness.

FLORAL CALENDAR OF BEE RESOURCES

Floral calendar is a timetable that indicates the approximate date and duration of the blossoming periods of the important honey plants (Diver 2002; Tura and Admassu 2018a). Flowering calendars can be applied to various beekeeping management activities such as placing hives near to particular crops and deciding the best time for honey harvest or colony swarming. Hence, adequate knowledge about bee flora in association with floral calendar is the prerequisite in beekeeping (Bista and Shivakoti 2001; Tura and Admassu 2018a). Every region in Ethiopia has its own active and dearth periods of short or long duration depending on intensity of rainfall. The majority of bee plants flower after the heavy rainy season from July to September and most of the Ethiopian highlands are covered with golden-yellow flowers of *Bidens* spp., *Guizotia* spp. and *Trifolium* spp with many different colors (Fitchl and Admassu 1994; Tessega 2009; Tura and Admassu 2018a). Following the flowering period, the end of October and early November is the major honey flow period in central and northern parts of Ethiopia. On the other hand, in southwest and southeastern parts of Ethiopia, the major honey flow period occurs from May–June (Admassu et al. 2017). There are also some minor honey flow periods during January and march from *Vernonia amygdalina* and *Coffea arabica* flowers (Tura and Admassu 2018a).

BEE FORAGE PERFORMANCE EVALUATION

An attempt of screening major bee forage source plants has been done on the most common herbaceous plants existing in highlands and mid altitudes of the rift valley regions of Ethiopia based on germination rate, number of flower heads per plant, foraging intensity of honeybees and duration of flowering (Tura et al. 2014a; Tura and Admassu 2018b). Accordingly, *Guizotia scabra*, *Guizotia abyssinica, Brassica carinata*, and *Caylusea abyssinica* are found more potential for highlands while *Echium plantaginium*, *Becium grandiflorum*, *Melilotus alba*, and *Fagophyrum esculentum* are more potential in semi-arid parts of Rift valley of central Ethiopia

THE ROLE OF BEEKEEPING IN CONSERVING NATURAL FOREST, AGROFORESTRY AND BIODIVERSITY

The significance of apiculture in agroforestry and vegetation conservation, as well as the contribution of apiculture in household livelihood improvement, have been reported (Debissa 2006). Accordingly, the majority of the beekeeper households (83.9%) are growing and conserving plants for their honeybees and other economic uses. Beekeepers have maintained higher plants diversity as compare to non-beekeepers (Table 4). As the result of the introduction of beekeeping technology with forest conservation at Menagesha Subaforest, beekeepers increased the yield of honey by four folds (411%) and the revenue increased by 5.76 folds (576%) (Admassu et al. 2014b). Therefore, integration of beekeeping technology with conservation of forests will enhance the income of household and encourage planting of bee forages which directly contributes for sustainable forest management.

In most cases, success in beekeeping depends on the availability of sufficient bee forage in terms of both quality and quantity. Hence, beekeeping is more dependent on the existing ecological conditions of an area than any other livestock activity. In areas, where beekeeping is not suitable, other improved management skills and advanced technologies alone cannot make beekeeping successful. Thus a number of interventions have been made in country to restore degraded areas to protect from massive soil erosion to increase the productivity of ecosystem including apicultural production. For instance, bee forage developments and rehabilitation in degraded areas through reclamation and enclosure approach in northern Ethiopia can be mentioned as best practice for conservation of natural resources which improves appropriate conditions for apiculture. In view of this, an attempt has been made to assess the role of beekeeping in watershed conservation around the Galessa watershed area with active involvement of the community (Tura et al. 2014) resulted in two-fold increase in bee forage as listed in Table 5.

CONCLUSION AND RECOMMENDATION

This review indicated that Ethiopia is rich in botanical diversity for beekeeping. However, most of the identifications are limited to central highlands and from western Ethiopia. Thus, further collection and documentation of bee flora are required in unaddressed areas of the country**.** In addition to this, distribution of major bee forage species needed to be mapped and protected for sustainable honey production and evaluation of the carrying capacity of agro-ecosystem for honey production. Furthermore, the integration of beekeeping with watershed management has brought impact on the livelihood of the community through income generation and planting of trees and shrubs for honey production. Thus, we recommend to scaling up of integration of beekeeping technologies with natural resource conservation is important to conserve the biodiversity of Ethiopia, other bees, plants and animals.

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Bee flora resources and honey production calendar of Gera Forest in Ethiopia

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Abstract. *Bareke T, Addi A. 2019. Bee flora resources and honey production calendar of Gera Forest in Ethiopia. Asian J For 3: 69-74.* Gera forest, Ethiopia contains substantial coverage of natural forest and is known as a Key Biodiversity Hotspot area for *Coffea arabica* conservation and one of the potential areas for beekeeping. The study was carried out to assess the bee flora and flowering calendar that produce more honey following the flowering plant cycle. Semi-structured questionnaires, participatory Rural Appraisal (PRA) techniques, and field observation were used for data collection. Honey samples collection was also made to identify the botanical origin of honey through honey pollen analysis. Seventy-four bee plant species were identified which belong to 41 families. Among the identified plant families, Asteraceae (29.3%), Lamiaceae (14.6%), Acanthaceae (12.2%), and Fabaceae (9.8%) were the most frequent families represented by the highest species composition in the area. Four major honey harvesting durations were identified (January, March, April, and early June for *Vernonia, Coffee, Schefflera*, and *Croton* honey respectively) using the flowering calendar in Gera Forest. The pollen analysis of honey revealed that four types of monofloral honey were identified comprising *Schefflera abyssinica, Vernonia amygdalina, Coffea arabica*, and *Croton macrostachyus* in Gera forest. This is due to their abundance and potentiality for honey production. Therefore, the beekeepers should follow the flowering calendar of the plant to exploit the potential of the forest for honey production. Furthermore, market promotion for monofloral honey of the Gera forest should be made as an incentive for the beekeepers to sell honey with premium prices and branding and labeling of honey of the area

Keywords: Bee forage, floral calendar, honey, monofloral honey, pollen analysis

INTRODUCTION

Ethiopia has a great potential for beekeeping development. The ideal climatic conditions, diversified floral resources, and huge water bodies allow the country to sustain around 10 million honeybee colonies (Amssalu et al. 2004). Beekeeping contributes to food security through pollination, economic and natural resource conservation, and creating better employment opportunities (Admassu et al. 2014a; Tura et al. 2014; EIAR 2016; Tura et al. 2018; Tura and Admassu 2019a). Despite the great opportunity in beekeeping and honey production, the beekeepers in Ethiopia have not yet well benefited from the subsector. This is mainly attributed to the inadequate introduction of improved technologies and skills that enhances the quantity and quality of bee products. Currently, Oromia Region contributes the highest for honey production in Ethiopia with 41% of the total honey production of the country (CSA, 2015). The Oromia region represents approximately 70% of the forest resources of the country, yet its closed high forests are diminishing due to shifting cultivation, fuelwood collection, urbanization, and logging (CSA 2015).

Gera forest is one of the remaining forest resources in the southwestern part of Oromia. The Gera forest contains substantial coverage of natural forest and is known as a Key Biodiversity Hotspot Area for *Coffea arabica* conservation and potential area for beekeeping (Kitessa 2007). Apart from its dense natural forest, the district is dominated by agroforestry comprised of spices plants and fruit trees. As a result, a large volume of honey is produced annually. In addition to this, honey is an important source of income for smallholder farmers in the area (Chala et al. 2012). Even though the forest has a lot of major bee flora, the beekeepers of the area could not understand the flowering calendars of the honeybee plants.

A flowering calendar is a timetable for a beekeeper that indicates the approximate date and duration of the blossoming periods of the important honey and pollen plants (Diver 2002; Tura and Admassu 2018). Knowledge of seasonal availability, length of flowering, and flowering phenology of honeybee plants is very important to boost the production of honey. The seasonal cycles of honeybee colonies are related to the calendar of bee plants in such a way that it will be applied in practical seasonal colony management (Fichtl and Admassu 1994; Admassu et al. 2014b; Tura and Admassu 2018). The timing of management operations corresponding to a phenological pattern of bee plants of the area is critical in building up colony populations before the main nectar flow. Even though bees naturally build up their population during periods when resources are available, the beekeeper must ensure that peak population size before or during the nectar flow. Hence, the flowering calendar is an important tool for determining various beekeeping management operations, such as when to suppering and reduce, time of supplementary feed, insert queen excluder, transferring time, honey harvesting time, and honeybee colony migration time.

So far, there is limited information about honeybee plants and floral calendar of the Gera forest. Therefore, the main objective of this study was to assess honeybee plants and flowering calendar that enables the beekeepers to harvest honey sequentially following the seasonal flowering cycle.

MATERIALS AND METHODS

Study area

Gera Forest is located in Gera District approximately 100 km to the west of Jimma, located in the southwestern part of Ethiopia. Gera forest consists of undulating hills at the altitudinal ranges of 1,000-3,000 m with steep mountainous terrain in some places (Bruk 2015). It has a total area of 80,830.4 ha (Yohannes et al. 2015). The soil in the forest is dystric nitosol type, which is deep, clay-red soil (GDARDO 2012). The mean annual temperature is about 18.4°C, while the mean annual rainfall is 1805 mm (NMSA 2013). Gera Forest contains a number of flowering plant species that are endemic to Ethiopia. Based on the published Flora of Ethiopia, seven endemic species have been identified (Yohannes et al. 2015). In the Gera forest, there are five plant communities, namely *Vernonia auriculifera-Prunus africana* community type, *Schefflera abyssinica-Maytenus arbutifolia* community type, *Coffea arabica-Olea capensis* community type, *Syzygium guineense-Galiniera saxifraga* community type and *Croton macrostachyus-Albizia gummifera* community type (Yohannes et al. 2015).

Data collection

Primary data was collected using semi-structured questionnaires, participatory Rural Appraisal (PRA) techniques, and field observation. The focus group discussions with experts, development agents and beekeepers were conducted to generate relevant information. The information focused on honey production potential, major honey source plants, major honey types, honey harvesting periods, and frequency and honey yield per hive. Field observation was made on bee floras of the forest to identify the plant and the food source provided for bees during the flowering period. A total of 12 pure honey samples (3 samples per harvesting month) were collected during honey flow seasons that have a similar climatic condition. Accordingly, December to February (January), March to May (March and April), and June August (start of June) from the farm gate of the beekeepers. For each honey collection site, three honey samples were purchased. Each honey sample was weighed 500 g. The samples were then stored at 4ºC for further analysis (Tura and Admassu 2019b).

Honey pollen analysis

For honey pollen analysis, the method recommended by the International Commission for Bee Botany (Louveaux et al. 1978) was adopted. Ten grams of each honey was dissolved in 20 ml of warm water (40ºC). The solution was centrifuged for 10 min at 2500 r/min, the supernatant solution was decanted, and the sediments were collected into a conical tube for the study (Erdtman 1960). The sediments were rinsed with distilled water to enhance further extraction of pollen from honey, centrifuged for 5 min at 2500 r/min, and preserved for study. To analyze the pollen content of the honey samples, two slides were prepared from each sample, and the picture of the pollen was taken by the camera connected to the microscope (Carl ZEISS microscope Germany). Pollen types were identified by comparison with reference slides of pollen collected directly from the plants in the study area. For quantification of the pollen types, at least 500 pollen grains were counted from each sample (Oliveira et al. 2010). The percentage frequency of the pollen taxa in all the samples was calculated, excluding polleniferous plant species, which were observed during honey pollen analysis. The types of pollen were allocated to one of four frequency classes for nectar source plants: predominant pollen types (>45% of the total pollen grains counted); secondary pollen types (16%-45%); important minor pollen types (3%-15%); and minor pollen types (3%) (Louveaux et al. 1978). Honey with predominant pollen types was considered as monofloral. Finally, descriptive statistics were used to analyze the collected data.

RESULTS AND DISCUSSION

Pollen analysis of honey

The pollen analysis of honey from 12 monofloral honey of the Gera forest indicated that 13 plant species were identified, ranging from 2% to 60% of the pollen count. The monofloral honey of *C. arabica* was contributed by four plant species (*C. arabica, Vernonia amygdalina, Rumex* spp, and *Vernonia auriculifera* (Figure 1). *C. arabica* honey is a new emerging monofloral honey in the area and produced in coffee agroforestry and forest coffee production system. It has a very short flowering period usually stays in flower for 5 to 7 days, and *C. arabica* honey is mostly harvested from February to March.

Vernonia honey was mainly dominated by *V. amygdalina* (Ebicha), and the pollen count from honey ranged from 1.9 % to 50.4%. The other bee forage plants contributing to *Vernonia* monofloral honey were *Eucalyptus* spp., *C. arabica, Vernonia auriculifera* (Rejji), and *Caesalpinia decapetala* (Figure 1). *Vernonia* honey is very dark in color even after crystallization, and it tends to granulate uniformly. The honey has a very strong flavor and bitter test, traditionally the honey is well known for its medicinal property (Admassu et al. 2014b).

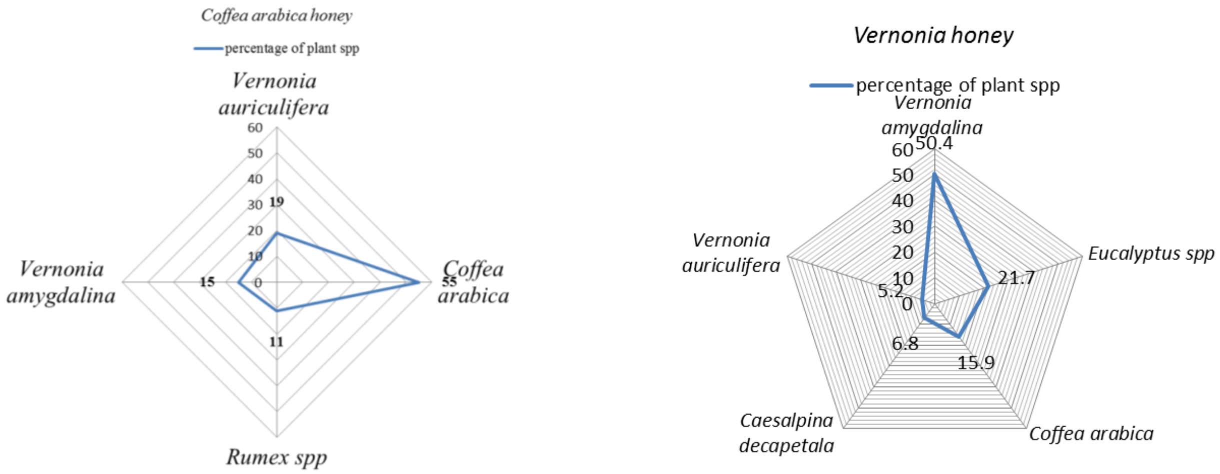


Figure 1. Pollen analysis of honey of *Coffea arabica* and *Vernonia amygdalina* honey with other species contributed for both honey in Gera forest, Ethiopia

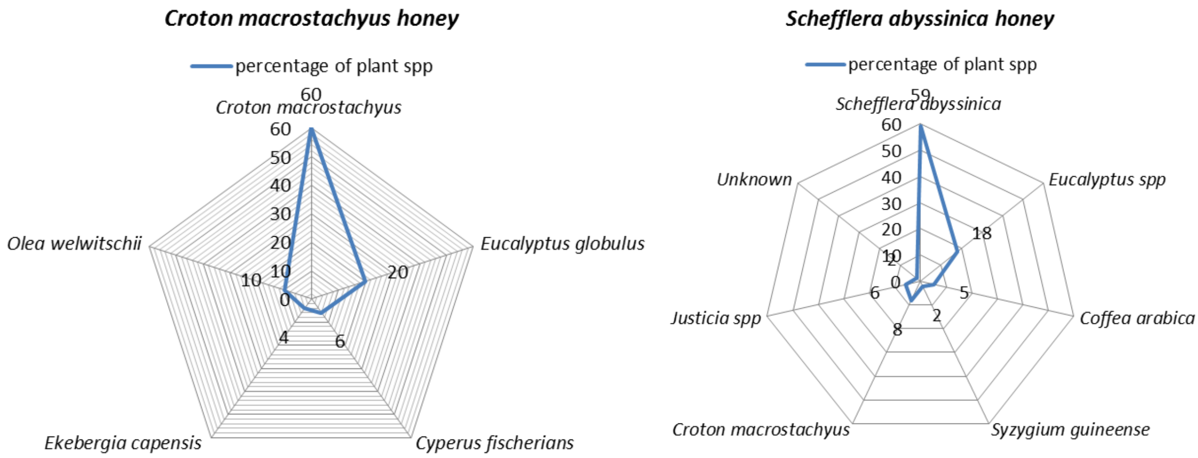


Figure 2. Pollen analysis of honey of *Croton macrostachyus* and *Schefflera abyssinica* honey with species contributed for both honey in Gera forest, Ethiopia

The honey of *Schefflera* was harvested from April to May after the minor rainy season. *Schefflera* honey was mainly dominated by *Schefflera abyssinica*. The pollen count from *S. abyssinica* honey ranged from 2% to 59% in which pollen count percentage of S. abyssinica was 59%. *C. arabica*, *Eucalyptus* spp., *Justicia* spp., *Syzygium guineense* and *Croton macrostachyus* were other bee plants that contributed to this honey production (Figure 2). The honey from this plant is extra white with a characteristic aroma and a very pleasant test.

On the other hand, the honey of *Croton* was harvested in June at the end of the minor rainy season. *Croton* honey comprised 5 species of which *C. macrostachyus*, *Eucalyptus globulus*, *Cyperus fischeriana*, *Ekebergia capensis*, and *Olea welwitschii* are the species contributing to *croton* honey in which the highest pollen count percentage was the *C. macrostachyus* (60%) (Figure 2). Monofloral honey of *S. abyssinica* and *C. macrostachyus* species were produced because of their abundance in addition to their potential for honey production. Tura and Admassu (2018) also reported that the dominancy of monofloral honey source plant species in honey samples was due to their abundance and nectar potentiality.

Pollen pictures of major bee flora plants that provide monofloral honey in the Gera forest are presented in Figure 3.

Bee flora resources in Gera forest

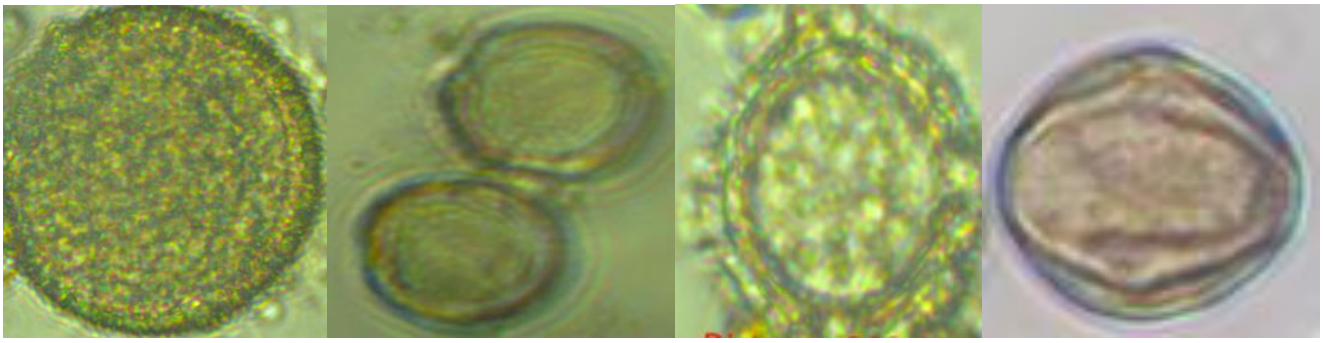
The result of the study revealed that 74 honeybee forages were identified which belong to 41 families. Among the identified plant families, Asteraceae (29.3%), Lamiaceae (14.6%), Acanthaceae (12.2%), and Fabaceae (9.8%) were the most frequent families, represented by the highest species composition in the area. Admassu and Tura (2019) also reported that Asteraceae, Acanthaceae, Fabaceae, Rubiaceae, Poaceae, Lamiaceae, and

Euphorbiaceae are the most frequent families, represented by the highest number of bee forage species (Table 1). However, a study conducted by Yohannes et al. (2015) in the Gera forest indicates that the Fabaceae family was the most dominant while Asteraceae was the second dominant. All species of Fabaceae family are not bee forage plants. Due to this, it is not a dominant honeybee plant family in the Gera forest. On the other hand, the dominance of the Asteraceae family could be attributed to the potential of its species for honey production. The life forms of bee forages showed that herbs represented the highest floristic composition, 35.1% followed by shrubs and trees 25.7% each, and climbers/lianas were 10 %. The dominance of herbs is due to disturbance and the presence of canopy gaps in the forest. The dominance of herbaceous flora was also reported by Ensermu and Teshome (2008), and Yohannes et al. (2015).

Flowering season bee flora resources

Eighty-one percent of honeybee plant species in the Gera forest were flowered from September to November, followed by March to May (10.8%) and December to February (6.8%) (Figure 4). Even though many honeybee plant species were flowered from September to November, monofloral honey was harvested from December to February and March to May in the Gera forest. This is because 72.5% percent of flowered honeybee plant species from September to November were provided pollen for honeybees. Whereas, the majority of flowered honeybee plant species from March to May and December to February were provided nectar of 56.25% and 50%, respectively (Figure 4). Pollen is used to increase the population of the bee colony, while nectar is used for honey production. Thus, the number of nectar sources is very important to produce honey.

The presence of a higher number of flowering herbaceous plant species from September to November is due to the availability of moisture following the main rainy season, which lasts from June to August. This is in agreement with a study conducted by Tura and Admassu (2018) in the Guji zone of the Oromia region which indicated that herbaceous honeybee forage species were the dominant honey source plants from September to November. On the other hand, the second flowering period occurs after a small rainy season, which starts from March to May, in which the majority of honey source plants were trees and shrubs in comparison to herbaceous. For example, the tree species such as *S. abyssinica, Syzygium guineense, C. macrostachyus*, and *Eucalyptus* spp. are flowered in this season (Tura and Admassu 2018). Admassu et al. (2014b) also stated that *S. abyssinica, Syzygium guineense,* and *C. macrostachyus* are the most important honey-producing trees and flowers from April to March to April and hence the major honey flow period in southwest parts of Ethiopia occurred during March-June. The lower number of flowering plants was observed from June to August, which is the main rainy season throughout the country and plants tends to produce more vegetative biomass rather than producing flowers and the high scarcity of honeybee forage was observed in July to mid of August (Tura and Admassu 2018). This is in agreement with a similar study in central parts of Ethiopia (Debissa and Admassu 2009) reported that during the rainy season, low temperatures possibly inhibit flower production.



A **B** **C** **D**

Figure 3. Pollen pictures of some major bee flora that provide monofloral honey in Gera forest, Ethiopia. A. *Croton macrostachysyus,* B. *Schefflera abyssinica,* C. *Vernonia amygdalina,* D. *Coffea arabica*

Table 1. Bee forage plants with their family, habit, flowering period and food source for honeybees in Gera forest

Family	Plant species	Local name (A/Oromo)	Habit	Flowering period	Rewards
Acanthaceae	*Acanthopale ethio-germanica*	Gosa dergu	Herb	Sept-Nov	Nectar & Pollen
Acanthaceae	*Acanthus eminens*	Korati Boye	Herb	Sept-Nov	Nectar
Acanthaceae	*Hypoestes triflora*	Dargu	Herb	Sept-Oct	Pollen
Acanthaceae	*Isoglossa somalensis*	Gosa dergu	Herb	Sept-Nov	Nectar & Pollen
Acanthaceae	*Justicia schimperiana*	Dumuga	Climber	Sept-Nov	Nectar & Pollen
Amaranthaceae	*Achyranthes aspera*	Maxxanne	Herb	Sept-Dec	Pollen
Aquifoliaceae	*Ilex mitis*	Hangadhi	Tree	Sept-Oct	Pollen
Araliaceae	*Polyscias fulva*	Tul'a	Tree	Sept--Nov	Nectar & Pollen
Araliaceae	*Schefflera abyssinica*	Gatama	Tree	March-Apr	Nectar
Arecaceae	*Phoenix reclinata*	Zambaba	Tree	Sept-Nov	Pollen
Asclepiadaceae	*Periploca linearifolia*	Borino	Climber	Sept-Nov	Pollen
Asteraceae	*Acmella caulirhiza*	Yemidir berbere	Herb	Sept-Nov	Pollen
Asteraceae	*Ageratum conyzoides*	Introduced	Herb	Sept-Dec	Pollen
Asteraceae	*Aspilia mossambicensis*	Arbi	Herb	Sept-Nov	Pollen
Asteraceae	*Bidens prestinaria*	Kello	Herb	Sept-Nov	Pollen
Asteraceae	*Bothriocline schimperi*	Shitto (Kafficho)	Herb	Sept-Dec	Pollen
Asteraceae	*Cirsium schimperi*	Kore Harre	Herb	Sept-Oct	Pollen
Asteraceae	*Galinsoga quadriradiata*	Abbadebo	Herb	Sept-Oct	Pollen
Asteraceae	*Guizotia scabra*	Tufo	Herb	Sept-Nov	Nectar & Pollen
Asteraceae	*Mikaniopsis clematoides*	Kattisa	Climber	Sept-Nov	Pollen
Asteraceae	*Solanecio gigas*	Nobe (Kafficho)	Herb	Sept-Nov	Pollen
Asteraceae	*Vernonia amygdalina*	Ebicha	Shrub	Dec-Jan	Nectar & Pollen
Asteraceae	*Vernonia auriculifera*	Reji	Shrub	Dec-Jan	Nectar & Pollen
Basellaceae	*Basella alba*	Lebo	Climber	Sept-Oct	Pollen
Boraginaceae	*Cordia africana*	Wadessa	Tree	Sept-Nov	Nectar & Pollen
Boraginaceae	*Ehretia cymosa*	Ulaga	Shrub	Sept-Nov	Nectar & Pollen
Brassicaceae	*Brassica carinata*	Rafu	Herb	Sept-Oct	Nectar & Pollen
Combretaceae	*Combretum paniculatum*	Begge	Climber	Sept-Nov	Pollen
Dracaenaceae	*Dracaena afromontana*	Emmo (Kafficho)	Shrub	Sept-Nov	Nectar & Pollen
Euphorbiaceae	*Croton macrostachyus*	Bakkannisa	Tree	April-Jun	Nectar & Pollen
Fabaceae	*Albizia gummifera*	Mukarba	Tree	Sept-Oct	Nectar & Pollen
Fabaceae	*Desmodium repandum*	Silver leaf	Herb	Sept-Nov	Nectar & Pollen
Fabaceae	*Glycine wightii*	Gurra Hantuta	Climber	Sept-Nov	Pollen
Fabaceae	*Millettia ferruginea*	Birbirra	Tree	Sept-Nov	Nectar & Pollen
Hypericaceae	*Hypericum revolutum*	Garamba	Shrub	Sept-Oct	Nectar
Icaccinaceae	*Apodytes dimidiata*	Chalalaka	Tree	Sept-Nov	Nectar & Pollen
Lamiaceae	*Achyrospermum schimperi*	Bala dullacha	Herb	Sept-Nov	Pollen
Lamiaceae	*Plectranthus garckeanus*	Gogoro	Herb	Sept-Nov	Nectar & Pollen
Lamiaceae	*Plectranthus punctatus*	Motijo (Kafficho)	Herb	Sept-Nov	Nectar & Pollen
Lamiaceae	*Psycnostachys eminii*	Ashoal (Hadiya)	Herb	Sept-Nov	Nectar & Pollen
Lamiaceae	*Salvia nilotica*	Sokoksa	Herb	Sept-Oct	Pollen
Lamiaceae	*Satureja paradoxa*	Teneddam	Herb	Sept-Oct	Nectar & Pollen
Loganiaceae	*Buddleja polystachya.*	Anfara	Shrub	Sept-Oct	Nectar & Pollen
Loganiaceae	*Nuxia congesta.*	Irba	Shrub	Sept-Nov	Nectar & Pollen
Lauraceae	*Persea americana*	Avocado	Tree	Sept-Nov	Pollen
Meliaceae	*Ekebergia capensis*	Sombo	Tree	Jan-Feb	Nectar & Pollen
Melianthaceae	*Bersama abyssinica.*	Lolchisa	Tree	Sept-Nov	Nectar & Pollen
Myrsinaceae	*Maesa lanceolata*	Abayyi	Shrub	Sept-Oct	Pollen
Myrtaceae	*Eucalyptus globulus*	Bargamo adi	Tree	Mar-April	Nectar & Pollen
Myrtaceae	*Syzygium guineense*	Badessa	Tree	Mar	Nectar & Pollen
Oleaceae	*Olea capensis*	Gagama	Shrub	April-May	Pollen
Oleaceae	*Olea welwitschii*	Gosa Ejersa	Tree	April-May	Nectar & Pollen
Phytolaccaceae	*Phytolacca dodocandra*	Andode	Climber	Sept-Nov	Pollen
Piperaceae	*Piper capense*	Turfo	shrub	Sept-Nov	Pollen
Poaceae	*Andropogon abyssinicus*	Ballami	Herb	Sept-Oct	Pollen
Ranunculaceae	*Clematis simensis*	Hidda fiti	Climber	Sept-Dec	Pollen
Ranunculaceae	*Ranunculus multifidus*	Hogio (Kafficho)	Herb	Sept-Nov	Pollen
Rhamnaceae	*Gouania longispicata*	-	Climber	Sept-Nov	Pollen
Rhamnaceae	*Rhamnus prinoides*	Gesho	Herb	Sept-Nov	Pollen
Rosaceae	*Prunus africana*	Homi/Gurra	Tree	Sept-Nov	Nectar & Pollen
Rosaceae	*Rubus steudneri*	Gora	Climber	Sept-Nov	Nectar & Pollen
Rubiaceae	*Coffea arabica*	Buna	Shrub	March	Nectar & Pollen
Rubiaceae	*Galiniera saxifraga*	Dido(Kef)	Shrub	Sept-Nov	Nectar
Rutaceae	*Clausena anisata*	Ulumaya	Shrub	Sept-Dec	Nectar & Pollen
Rutaceae	*Vepris dainellii*	Hadhessa	Shrub	Dec-Jan	Pollen & nectar
Sapindaceae	*Allophyllus abyssinicus*	Sarara	Tree	Sept-Oct	Pollen
Sapotaceae	*Pouteria adolfi-friedericii*	Keraro	Tree	April-May	Nectar
Simaroubaceae	*Brucea antidysenterica*	Nukesho (Kafficho)	Shrub	Sept-Oct	Nectar & Pollen
Solanaceae	*Brugmansia suaveolens*	Ababo Turba	Shrub	Dec- Jan	Nectar & Pollen
Sterculiaceae	*Dombeya torrida*	Dannisa	Tree	Sept-Nov	Nectar & Pollen
Tiliaceae	*Grewia ferruginea*	Haroressa	shrub	Sept-Nov	Nectar & Pollen
Ulmaceae	*Celtis africana*	Amalakka	Shrub	Sept-Nov	Nectar & Pollen
Verbenaceae	*Premna schimperi*	Urgessa	Shrub	Sept-Oct	Nectar & Pollen
Zingiberaceae	*Aframomum corrorima*	Korrorima	Herb	Sept-Nov	Nectar & Pollen

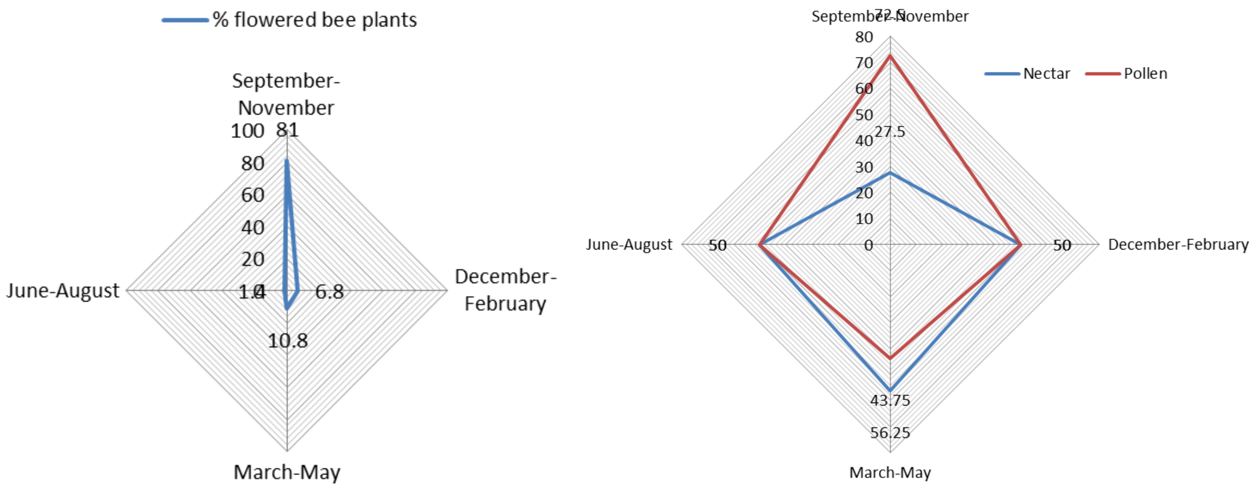


Figure 4. Percentage of flowered honeybee plant species in different major four seasons and food sources in Gera forest

In conclusion, from the identified bee forage plants, four plant species were produced monofloral honey due to their abundance and high nectar yielding potential of the species in the Gera forest. These were *S. abyssinica*, *C. arabica*, *V. amygdalina*, and *C. macrostachyus*. Majority of flowered bee forage plants were used for colony maintenance during October and November. On the other hand, at the end of December and start of January *Vernonia* honey was harvested; at the end of February and start of March Coffee honey was harvested; in mid-April or beginning May *Schefflera* honey was harvested; and at the start of June, *Croton* honey was harvested. July and August were identified as dearth periods due to heavy rain. Generally, the Gera forest has a high potential for honey production. Therefore, the beekeepers should follow the flowering calendar of *S. abyssinica*, *C. arabica*, *V. amygdalina* and *C. macrostachyus* to exploit the potential of the forest for honey production. Furthermore, market promotion for monofloral honey of the area should be made as an incentive for the beekeepers to sell honey at premium prices and branding and labeling of honey of the area.

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Short Communication: Diversity of medicinal plants used to treat human ailments in rural Bahir Dar, Ethiopia

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Abstract. *Mazengia E, Beyene T, Tsegay BA. 2019. Short Communication: Diversity of medicinal plants used to treat human ailments in rural Bahir Dar, Ethiopia. Asian J For 3: 75-82.* Survey of traditional medicinal plants used to treat human ailments by the rural community of Bahir Dar City Administration was conducted from November 23, 2017 to May 30, 2018 with the aim of identifying and documenting plants and the associated knowledge used to treat humans. We collected data from six study sites using semi-structured interviews, field observation and group discussion. Data analyses were made using preference ranking, direct matrix ranking and fidelity level index. A total of 77 medicinal plants were identified. The majority of plants (58.4%) were harvested from the wild. The largest number of plants were herbs (42.6%) followed by shrubs (32.6%). The most frequently used plant parts in human disease treatments were leaves (54%) followed by roots (18%). Most remedies were prepared by pounding and mixing (concoction) (36%). The remedial administration was mostly oral (51%) followed by dermal (31%). *Allium sativum* and *Ocimum lamiifolium* were the most frequently used. The community in the study area used considerable diversity of plant species for maintaining their health care system. Nonetheless, conservation for those plants whose roots are harvested is necessary.

Keywords: Ethnobotany, ethnomedicine, *ex-situ*, *in-situ,* traditional healer, use value

INTRODUCTION

People have used plants for multiple purposes, i.e., as sources of food, medicines for human beings, livestock fodder, and as materials for household utensils, fuel, etc. Traditional medicine is culturally-based cure system different from modern (scientific) medicine and is usually considered as indigenous, alternative or folk medicine, which is largely transmitted by words of mouth from elders to the young generation (Martin 1995). Most people in the world (70-90 %) use herbal remedies as their primary healthcare system (Nair and Nathan 1998).

Ethiopia is endowed with a wide range of topographic features enabling it to have a variety of ecosystems. These varied ecosystems possess high diversity of flora and fauna which include good number of potentially useful medicinal plants (Abebe 1986; Seid and Tsegay 2011). Majority of Ethiopians (about 80%) use herbal medicine as their primary healthcare system (Giday 1999). However, high rate of land-use conversion (deforestation for agricultural land expansion), over-harvesting and/ or indiscriminate harvesting and unmanaged population growth with increasing demand and consumption are the principal problems that aggravate the rate of disappearance of medicinal plants from their habitat and the consequent loss of significant number of plant species (Seifu et al. 2006).

All culturally useful medicinal plants have not been surveyed and documented in Ethiopia. The traditional knowledge and practices around Bahir Dar City are part of the non-surveyed ones. This study aimed to identify and document the medicinal plants used by the rural community of Bahir Dar and the associated knowledge used to treat humans. Such a study would be of paramount importance in conserving the plants and ensuring their sustainable use. Moreover, bequeathing the traditional knowledge to the next generation and developing it for new insights is necessary.

MATERIALS AND METHODS

Study location

Ethnomedicinal study was conducted in Bahir Dar rural *kebeles* (smallest administrative units in Ethiopia) (Figure1) from November 23, 2017 to May 30, 2018. Bahir Dar is located at 11°59' North latitude and 37°39' East longitude as determined from the city center. The elevation ranged from 1650 m.a.s.l at Tisabay to 2100 m.a.s.l at Meshenti. From the 26,295 hectares area of the rural *kebeles*, 19,969 hectares of the land is being cultivated (ANRS RLUM, 2018 personal communication). According to fourteen years' metrological data obtained from Bahir Dar city weather station, the study area received mean annual rainfall and temperature of 1423.2 mm and 27.5ºC, respectively (ANRS RLUM, 2018 personal communication).

Informant selection

Six *kebeles* (small local administrative units) were selected purposely based on the availability of local healers as advised by community elders (Figure 1). Totally 72 informants, consisting of 35 men and 37 women, were selected for this study. Seven key informants, one from each *kebele* except 2 from TisAbay, were selected based on the advice from local authorities, traditional healers and local farmers. The remaining 65 general informants were randomly selected.

Ethnobotanical data collection

The primary data were collected directly from the informants in the study area by semi-structured interviews, group and individual-focused discussions, field visits and informal conversations. During group discussion, necessary information related to medicinal plants, mode of preparation, method of application, types of disease treated, plant parts used for preparation of remedies were documented to obtain detailed quantitative and qualitative data. The plants were identified using different volumes of "*Flora of Ethiopia and Eritrea"* (https://www.nhbs.com/series/flora-of-ethiopia-and-eritrea) (Edwards et al. 2000; Hedberg and Edwards 1989, 1995; Hedberg et al. 1995, 1997, 2003, 2007, 2009a, 2009b; Tadesse. 2005), as well as Bekele-Tesemma (2007) and Dagne (2009). Online references were also used (Table 1).

Data analysis

Descriptive statistics (Microsoft Excel 2010) was used to analyze data. Information provided by respondents was determined using preference ranking, direct matrix ranking and fidelity level index following the method from Alexiades (1996) and Martin (1995).

RESULTS AND DISCUSSION

Most of the medicinal plants used by the traditional healers in rural *kebeles* of Bahir Dar are presented in Table 1. Seventy-seven (77) ethnomedicinal plant species belonging to 75 genera and 42 families were collected with the guidance of local healers. Out of the 77 species, 58.4% were from the wild and 27.3% were cultivated while 14.3% were both wild and cultivated.

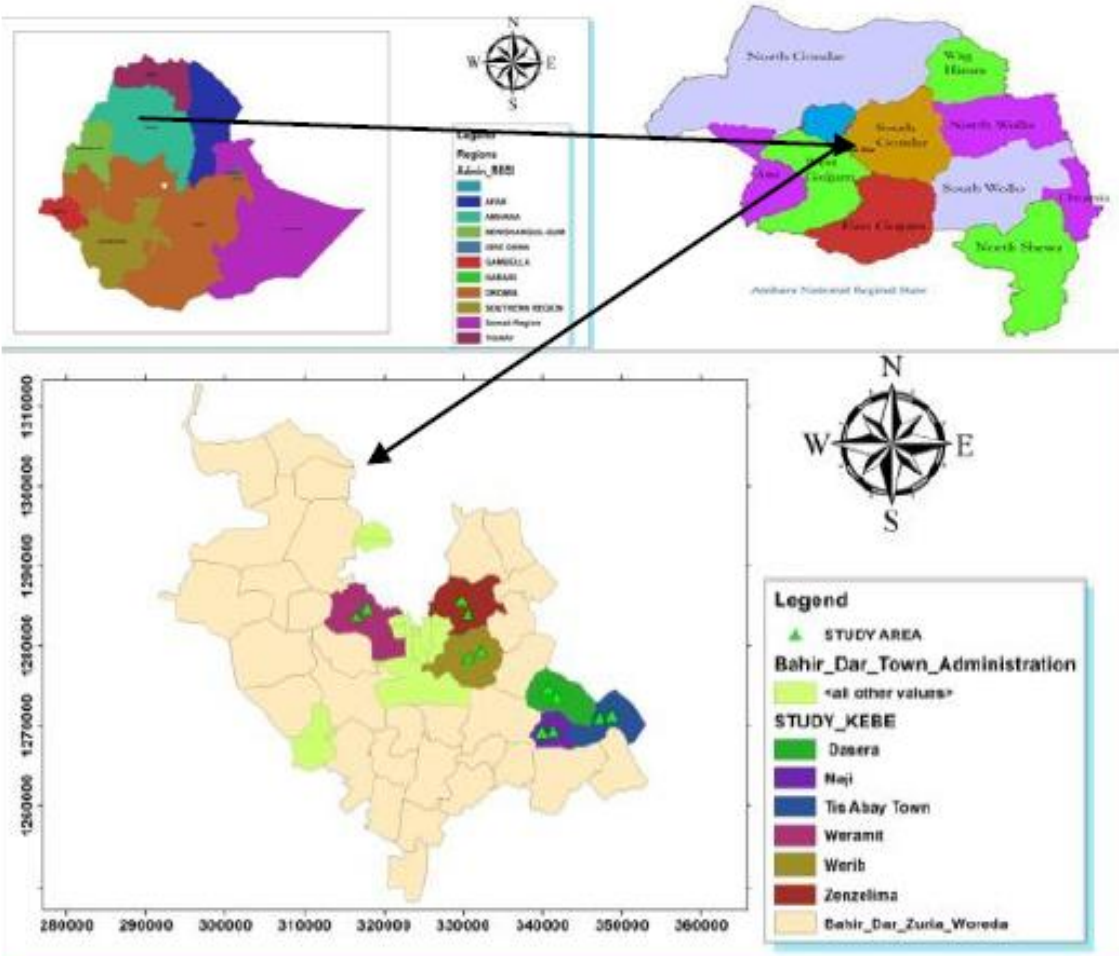

Figure 1. Map of the study area (drawn by Andargachew Baye, member of the GIS team, Amhara National Regional State, Ethiopia)

Table 1. List of major traditional medicinal plants used to treat human ailments in rural community of Bahir Dar City Administration, Ethiopia. In total there were 77 medicinal plants recorded.

Botanical and family name	Online reference	Local name (Amharic)	Ailment treated	Part used for preparation and their application as reported by healers.
Achyranthes aspera L (Amaranthaceae)	https://keys.lucidcentral.org/keys/v3/eafrinet/weeds/key/weeds/Media/Html/Achyranthes_aspera_(Devils_Horsewhip).htm	Telenge	Hemorrhoids	The leaf is pounded, squeezed and then creamed on infected part.
Allium cepa L. (Alliaceae)	https://www.prota4u.org/database/protav8.asp?g=pe&p=Allium+cepa+L.	Kei shinkurt	Stomach complaints, Cough	Pound the stem and mix with *A. sativum, R. chalepensis* and honey. Then eat them every morning until getting recovered.
Allium sativum L (Liliaceae)	https://www.sciencedirect.com/topics/pharmacology-toxicology-and-pharmaceutical-science/allium-sativum	Nech shinkurt	Malaria	Pound, mix with *Cicer arietinum* for night long and eat them in the morning.
Argemone mexicana L. (*Papaveraceae*)	https://plants.usda.gov/core/profile?symbol=arme4	Yaheya eshoh	Wound	Apply the latex on the wound or use it as massage cream.
Artemisia abyssinica Shc.Bip.ex.A.Rich (Asteraceae)	https://www.prota4u.org/database/protav8.asp?g=psk&p=Artemisia+abyssinica+Sch.Bip.+ex+A.Rich.	Chikugn	Stomach complaints (ache) with diarrhea	Dried leaf is ground & mixed with water and drunk.
Arundo donax L (Poaceae)	https://www.invasive.org/browse/subinfo.cfm?sub=3009	Shenbeko	Rh factor “shotelay”	The root of *Arundo donax* is tied to neck.
Brassica carinata A. Braun (Brassicaceae)	http://www.africanplants.senckenberg.de/root/index.php?page_id=78&id=3529#	Yabesha gomen	Placental retention (delay)	Roasted and grounded, then mixed with leaf juice of *Ziziphus spina-christi* in hot water. Then drink or place it in vagina.
Brucea antidysenterica J.F.Mil (Simaroubaceae)	https://www.prota4u.org/database/protav8.asp?g=pe&p=Brucea+antidysenterica+J.F.Mill.	Waginose	Wound	The leaf *of Brucea antidysenterica* is pounded, squeezed and then creamed on wounded part until getting recovered.
Carica papaya L (Caricaceae)	https://florafaunaweb.nparks.gov.sg/Special-Pages/plant-detail.aspx?id=2785	Papaye	Swelling	Split the fruit and remove seeds and their content. Use the pulp as massage cream on the infected body part
Carissa spirnarum L. (Apocynaceae)	https://www.gbif.org/species/5536282	Agam	Devil disease	Boil fruit and mix with roots of *P. schimperi, C. macrostachyus & A. schimperiana* and drink the suspension.
Catha edulis (Vahl) Forssk. ex Endl. (Celastraceae)	https://www.prota4u.org/database/protav8.asp?g=pe&p=Catha+edulis+(Vahl)+Forssk.+ex+Endl.	Chat	Asthma/Coughing	The leaf powder is mixed with melted butter and drink it in the morning until getting recovered.
Chenopodium ambrosioides (Chenopodiaceae)	http://bioweb.uwlax.edu/bio203/2011/mccarthy_mega/Medicinal_uses.htm	Amedmado	Infection on swelling	Pounded plant is mixed with *Datura stramonium L* &*Kalanchoe* sp and bandages them on the swelling.
Coffee arabica L. (Rubiaceae)	http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:747038-1	Buna	Wound sore	The seed is roasted & pounded (powdered) and put on the wound until it is healed.
Croton macrostachyus Hochst. ex Delile (Euphorbiaceae)	https://www.prota4u.org/database/protav8.asp?g=pe&p=Croton+macrostachyus+Hochst.+ex+Delile	Bisana	Face fungus (*Tinea faiei*)	Mixed leaf extract with *A. sativum*& honey. Then apply it on the infected body.
Cucurbita pepo L (Cucurbitaceae)	http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:292416-1	Duba	Tape warm	Powdered seed is mixed with butter and eaten

Cyathula polycephala Beker (Amaranthaceae)	http://www.villege.ch/musinfo/bd/cjb/africa/details.php?langue=an&id=34	Chegogot	Skin rash ("chiffee")	The leaf of *Cyathula polycephala* is crushed, squeezed and the pure solution is applied to affected body part until getting recovered
Dovyalis abyssinica A.Rich. (Salcaiaceae)	https://www.pfaf.org/user/Plant.aspx?LatinName=Dovyalis+abyssinica	Koshm	Abdominal pain	Eat six to ten fruits
Embelia schimperi Vatke (Myrsinaceae)	http://www.westafricanplants.senckenberg.de/root/index.php?page_id=14&id=3116	Inkoko	Tapeworm	drink water with powdered seed
Euphorbia ampliphylla L (Euphorbiaceae)	WCSP (World Checklist of Selected Plant Families)	Qulquale	STDs	The drop of latex is collected, mixed with *Eragrostis teff* powdered and backed and then eaten before any food for 3 days
Foeniculm vulgare Miller (Apiaceae)	https://www.hindawi.com/journals/bmri/2014/842674/	Inslal	Gonorrhea	Leaf is mixed with *Lepidium sativum*(seed) and eaten.
Justicia schimperiana (Hochst.ex A. Nees)T.Ander (Acanthaceae)	http://www.africanplants.senckenberg.de/root/index.php?page_id=78&id=5715	*Smiza*	kuruba' stomach ache	The leaf is crushed and drink the leaf latex
Kalanchoe petitiana A.Rich (Crassulaceae)	http://www.africanplants.senckenberg.de/root/index.php?page_id=78&id=5657	Endehula	'Ebach'(lymphadenopathy)	head leaf dressing on the infected part until the tumor is removed
Len sculinaris Medik (Fabaceae)	http://eol.org/pages/647510/overview	Misir	Diabetes	Eat the seed of *Len sculinaris* in the morning
Lepidium sativum L. (Cruciferae)	http://www.tela-botanica.org/bdtfx-nn-75217-synthese	Feto	Stomach complaints	Ground seed is mixed with water and then eat
Linum usitatissimum L (Linaceae)	http://swbiodiversity.org/seinet/taxa/index.php?taxon=2472	Telba	Retained placenta	The seed of *Linum usitatissimum* is mixed with water and boiled and then drink the solution after being cooled.
Lonchocarpus laxiflorus Guill.Perr (Leguminosae)	http://www.westafricanplants.senckenberg.de/root/index.php?page_id=14&id=1989	Amera	Diabetes	Boil a leaf and drink it without sugar
Lycopersicon esculentum Mill. (Solanaceae)	http://www.theplantlist.org/tpl/record/tro-29602513	Timatim	Eye disease	The seed of *Lycopersiconesculentum* is eaten
Mentha x piperita L. (Labiatae)	https://www.avogel.ch/en/plant-encyclopaedia/mentha_x_piperita.php	Nana	Diarrhea	Pound the leaf and mix with A. *sativum, R. chalepensis*, and drink them
Moringa oleifera L (Moringaceae)	http://www.africanplants.senckenberg.de/root/index.php?page_id=78&id=1115#image=57870	Shefrahu	Tumor	Pound the leaf and apply on the tumor
Optica ficus-indica (L) Mill. (Moraceae)	http://www.theplantlist.org/tpl1.1/record/kew-2391911	Beles	Ringworm (*Tinea corporis*)	Add leaf secretion on the infected skin
Otostegiaint egrifilia Benth. (Lamiaceae)	https://botany.cz/cs/rydingia-integrifolia/	Tinjute	Stomach-ache	Juice the leaf with water and drink it
Phytolacca dodecandra L (Phytolacaceae)	http://tropical.theferns.info/viewtropical.php?id=Phytolacca+dodecandra	Endod	Miscarriage (abortion of unwanted pregnancy)	Pound, squeeze and mix with water then drink it
Piper nigra L. (Piperaceae)	http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:682369-1	Qundoberbere	Stomach complaints	Pound the seed and mix with *N.sativa, Z.officinalis, R. chalepensis & A.sativum*; then leave for 7 days and eat every morning during pain

Podocarpus falcatus (Thunb) R.Br.ex Mirb. (Podocapaceae)	http://pza.sanbi.org/podocarpus-falcatus	Zegba	Sudden sickness	The leaf of *Podocarpus falcatus* is squeezed and drink it
Rhamnus prinoides L Her (Rhamnaceae)	http://pza.sanbi.org/rhamnus-prinoides	Gesho	Tonsillitis	Pound the seed mix with *Artemisia rehan* then squeeze and drink it
Ricinus communis L. (Euphorbiaceae)	https://plants.usda.gov/core/profile?symbol=rico3	Gulo	Amoeba	Dried seed is chewed during stomach ache
Rumex abyssinica Jacq. (Polygonaceae)	https://www.prota4u.org/database/protav8.asp?g=pe&p=Rumex+abyssinicus+Jacq.	Mekmeko	'Dembizat' (Hypertension)	The leaf powder is boiled with water and drink the juice
Rumex nervosus Vahl. (Polygonaceae)	https://www.prota4u.org/database/protav8.asp?g=psk&p=Rumex+nervosus+Vahl	Embuacho	Hepatitis	A leaf is pounded & boiled and drink a cup of it before breakfast
Ruta chalepensis L. (*Rutaceae*)	http://www.maltawildplants.com/RUTA/Ruta_chalepensis.php	Tenadam	Stroke (Syncope) or Cerebral hypoxia	The leaf is pounded or ground, mix it with water and drink it every morning
Senna singueana Deal Lock (Fabaceae)	https://www.researchgate.net/figure/Photographs-of-Senna-singueana-Del-Lock-Fabaceae-and-the-collected-leaves_fig2_273791660	Gufa	Swelling	Dried leaf, stem, root, bark powder are mixed with butter and applied on swelling part
Sida tenuicarpa Vollesen (Malvaceae)	https://botany.cz/cs/sida-tenuicarpa/	Chifrig	Erectile dysfunction	Boil leaf, mix with *N. Sativa* & leaf of *Withania* sp., *A. Sativum* & honey and eat the mixture at a time of necessity
*Sida rhombifolia*L. (Malvaceae)	https://keyserver.lucidcentral.org/weeds/data/media/Html/sida_rhombifolia.htm	Gorgegit	Wound	Leaf paste is applied on skin diseases and wound; as anti-inflammatory
Solanum dasyphyllum Schumach & Thonn. (Solanaceae)	http://www.westafricanplants.senckenberg.de/root/index.php?page_id=14&id=2608	Embuay	Physical damage	The root is crushed, squeezed, and mix it with water and drink the suspension
Thymus schemperi Ronniger. (Lamiaceae)	http://www.africanplants.senckenberg.de/root/index.php?page_id=78&id=4789	Tosign	Cough	Boiled in water and drink it like tea until the symptom is recovered
Tragia cinerea (pax) M.G.Gillbert & Radcl.-SM. (Euphorbiaceae)	http://www.tropicos.org/Name/12806195?tab=images	Aleblabet	Evel eye	Dried or fresh root is consumed orally
Trigonella foenum-graecum L. (Leguminosae)	http://flora.org.il/en/plants/TRIFOE/	Abish	Diabetic	Dried seed is ground & mixed with water and drink the suspension in the morning.
Triumfetta pilosa Roth. (Tiliaceae)	https://www.prota4u.org/database/protav8.asp?&g=pe&p=Triumfetta+pilosa+Roth	Shemgegit	Evel Eye	Seeds are worn by women as necklace to prevent evil attack
Urtica simensis Host. ex Steudel (Urticaceae)	https://plants.jstor.org/stable/history/10.5555/al.ap.specimen.hal011 0249	Sama	Heart failure	Fresh leaf, stem vapor is used nasally to fumigate the whole body
Vernonia amygdalina Del. (Asteraceae)	https://www.yumpu.com/en/document/view/41885798/vernonia-amygdalina-asteraceae-del-world-agroforestry-centre/2	Girawa	Ascariasis	Eating the crushed leaf when the disease occurred
Withania somnifera (L) Dunal (Solanaceae)	http://flora.org.il/en/plants/WITSOM/	Gizawa	Babies Disease	Bathing with crushed leaf
Zingiber officinale Rosc. (Zingiberaceae)	http://www.globinmed.com/index.php?option=com_content&view=article&id=102052:zingiber-officinale-rosc&catid=209&Itemid=143	Zinjibile	Common cold	Pounding & boiling the rhizome and drink it like drinking tea

Among all plants recorded, Fabaceae was the most dominant family containing 8 species (10.4%) followed by Euphorbiaceae (6 species (7.7%), Liliaceae (6.5%) and Asteraceae (4 species (5.2%), respectively. In terms of plant habitus, the majority (42.8%) was herbs followed by shrubs (32.6%), trees (20.8%) and climbers (3.8%).

Parts and conditions of medicinal plants used

Results revealed that the greatest proportion used as medicine are leaves (54%) followed by roots (18%). Other parts include seeds (16%), latex (7%), stem/bark (3%) and whole plant (2%). The majority of medicinal plants are harvested from wild vegetation that indirectly shows the presence of high pressure on wild vegetation. Wild vegetation is the source of medicinal plants in many places of Ethiopia as shown by Giday (1999) and Amenu (2007) in Lake Ziway and Ejaji areas, respectively.

Method of remedy preparation and application

Traditional healers in the study area used various types of preparations in which pounding/pulverizing (36%) is the major type followed by cooking (14%), squeezing (10%), chewing (7%) and others (33%). Preparations were administered by different routes: oral (51%) dermal (31%), nasal (9%), eustachian (2%), ocular (1%) and fumigation (6%) based on the type of the disease.

Fidelity Level (FL) of medicinal plants

Medicinal efficacy of a species was determined by calculating fidelity level index. In this study, *Pterolobium stellatum* and *Echinops kebercho* have high medicinal value against Evil eye and Devil disease, respectively (Table 2). *Withania somenifera* is reported by 54% of informants, with FL value of 0.50 is found to be the second species next to *Pterolobium stellatum* (FL=0.80) used in the medication of Evil eye.

Preference and direct matrix rankings

Different plant species are used for the treatment of different ailments. In such cases, local people showed preference towards plant species on the basis of their healing power against a given disease. Key informants were asked to show their preference from eight selected plant species on the basis of treating several diseases and they showed that *Allium sativum* is the most preferred one followed by *Ruta chalepensis* (Table 3).

Medicinal plant species that have multiple purposes could be screened using direct matrix. In this study, ten multipurpose species were selected out of the total medicinal plants and eight use-categories were listed for 7 selected key informants to assign use values to each species. The informants listed *Cordia africana* to be highly used by local community for multiple purposes. *Juniperus procera, Ficus carica, and Carissa spinarum* stood at 2nd, 3rd and 4th position, respectively (Table 4). However, the unsustainable use of these plant species for multiple uses made them scarce in the locality.

Major human diseases and corresponding number of plant species used

In the study area, a total of 36 human diseases and health defects (like injuries) are documented. Of these, 30 ailments (83%) are treated using two or more medicinal plant species while 6 ailments (17%) are treated using only one plant species (Table 5). Treatment of ailments by more than a single species was reported by researchers in some parts of Ethiopia (Amenu 2007).

Table 2. Fidelity level index for plant species used to treat Evel eye and Devil disease in the study area

Ailments	% of infor-mants	Species	Np	N	Fidelity index (Np/N)
Evil eye	54	*Withania somenifera*	18	36	0.5
	9	*Pterolibium stellatum*	5	6	0.8
	6	*Triumfetta pilosa*	1	4	0.25
	7	*Tragia cenera*	1	5	0.20
Devil disease	42	*Capparis tomentosa*	12	28	0.43
	9	*Echinops kebercho*	3	6	0.50
	9	*Rosa abyssinica*	1	6	0.20

Table 3. Preference ranking of eight selected medicinal plants on the degree of healing several ailments by key respondents

Species	Family	Respondents								
		A	B	C	D	E	F	G	Total	Rank
Allium sativum	Liliaceae	8	8	7	7	6	7	7	50	1
Ruta chalepensis	Rutaceae	8	8	6	6	7	6	8	49	2
Nigella sativa	Ranunculaceae	8	7	5	7	6	5	7	45	3
Zingiber officinale	Zingiberaceae	8	6	3	6	4	5	6	38	4
Clutia abyssinica	Euphorbiaceae	7	6	4	5	3	5	6	36	5
Euphorbia ampliphylla	Euphorbiaceae	6	6	2	4	2	5	5	30	6
Rumex nervosus	Polygonaceae	4	4	3	4	3	4	4	26	7
Carica papaya	Caricaceae	3	3	2	4	2	2	4	20	8

Note: A-G: key respondents

Table 4. Direct matrix analysis of selected medicinal plants based on a general use-value

Species	Use-category									
	Medicine	Food	Fencing	Forage	Firewood	Charcoal	Construction	Furniture	Total	Rank
Acacia abyssinica	3	0	4	1	4	3	1	0	16	6th
Croton macrostachyus	4	0	3	2	3	0	3	3	15	7th
Piper nigrum	4	0	3	1	3	0	3	3	17	5th
Arundo donax	4	0	0	2	1	0	0	3	10	9th
Pterolobium stellatum	4	0	3	2	0	0	0	0	9	10th
Ocimum lamiifolium	4	0	2	1	3	1	1	0	12	8th
Cordia africana	4	2	1	3	3	3	3	5	24	1st
Ficus carica	4	0	2	3	3	2	3	3	20	3rd
Carissa spinarum	3	3	4	3	3	2	1	0	19	4th
Juniperus procera	4	0	4	1	4	1	4	4	22	2nd

Table 5. Lists of major human diseases and the corresponding medicinal plant species used by rural people of Bahir Dar

Diseases (injuries)	Medicinal plants (number)	Diseases (injuries)	Medicinal plants (number)
Stomach complaints	17	Swelling	4
Devil' disease	7	Tonsillitis	2
Diarrhea	4	Ascaris	2
Eczema	4	Miscarriage (abortion)	1
Hepatitis	4	Infection on swelling	1
Hair fungus	2	Heart disease	1
Febrile (fever)	2	Diabetic	7
Malaria	8	STDS	2
Hemorrhoid	4	Broken leg/hand	3
'Evil eye'	7	Eye disease	2
Erectile dysfunction (Impotence)	3	Sudden sickness	4
Cancer	3	Skin rash	4
Snake biting and scorpion bite	1	Face fungus	2
Ringworm	3	Boil	1
Cough	4	Allergic	1
Wound sore	6	Common cold	5
Headache	4	Tumor	4
Placental retention (delay)	4	Hypertension	2

In conclusion, this study revealed the use of medicinal plants by rural community of Bahir Dar City for maintaining their primary health care. The use of herbals has been an age-long practice in the area. Despite their irreplaceable use, the future existence of medicinal plants resource and the associated knowledge is under question because of the ongoing practice of urbanization, deforestation, agricultural encroachment, overgrazing and overexploitation. So, *in-situ* and *ex-situ* conservation strategies of medicinal plants should be adopted and implemented by training the practitioners. The local government should organize medicinal practitioners in association(s) in such a way that their valuable knowledge can be used along with modern medicine.

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