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REVIEW ARTICLE

DIVERSITY, THREATS AND CONSERVATION STATUS OF COFFEE FOREST IN ETHIOPIA

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ABSTRACT: Arabica coffee (*Coffea arabica* L.) has its centre of origin and diversity in southwest and southeast montane forests of Ethiopia. Moist evergreen Afromontane forests with the occurrence of wild Arabica coffee populations is commonly called 'Coffee Forest'. Coffee forest maintains over 700 species of vascular plant and a diversity of wild coffee genotype. The genetic diversity of wild coffee populations differs within and between populations and regions. Coffee forest is part of the "Eastern Afromontane Biodiversity Hotspot" and has great international importance for biodiversity conservation. The coffee forest is, however, threatened by increasing anthropogenic factor such as agriculture and settlement expansion. Climate change and global warming is also expected to threaten the distribution of the wild coffee populations and its habitat more than ever before. To address these threats, conservation efforts have been ongoing in the last two decades-through forest coffee genetic resource conservation, biosphere reserves and participatory forest management schemes. In addition to the ongoing conservation efforts, in-depth research and trait discovery for conservation and sustainable use of Arabica coffee genetic resources and its habitat is recommended.

Key words/phrases: Coffee, Conservation, Diversity, Ecosystem service, Ethiopia, Forest.

INTRODUCTION

Social-ecological sources indicate that a large portion of the Ethiopian highlands were once covered by dense natural forests (Logan, 1946; von Breitenbach, 1963; IUCN, 1990; Pohjonen and Pukkala, 1990; Friis, 1992; Feyera Senbeta and Demel Teketay, 2002). A great proportion of these highlands are, however, currently devoid of forest vegetation, by and large under cultivation. At the moment a few forest fragments are distributed in southeastern and southwestern part of the country. The majority of these remnant forest fragments are moist evergreen Afromontane forests with the occurrence of wild Arabica coffee populations (hereafter named as "coffee forest"). This coffee forest has long been recognized as centre of origin and

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diversity of Arabica coffee (Strenge, 1956; Meyer, 1965; Kassahun Tesfaye, 2006). Coffee forest, beyond its nucleus of Arabica coffee genetic pool reserves', provides immense ecological and socioeconomic values. It is an important source of timber and non-timber forest products; and repositories of biodiversity. Coffee forest is important for the conservation of highland forest bird species (EWNHS, 1996), plant diversity (Feyera Senbeta *et al*., 2014), diversity of wild Arabica coffee populations (Kassahun Tesfaye, 2006) and provide immense socio-economic values for local communities (Feyera Senbeta *et al*., 2013). Coffee forest is part of the "Eastern Afromontane Biodiversity Hotspot", which is one of the 35 globally important regions for biodiversity conservation.

Despite all these importance, however, coffee forest is already threatened by land use pressure and climate change (Feyera Senbeta, 2006; Dereje Tadesse *et al*., 2008; Davis *et al*., 2012; Feyera Senbeta *et al*., 2014). Over-exploitation, ruthless destruction as well as degradation have made coffee forest to become the most vulnerable and threatened ecosystem (Reusing, 1998; Tadesse Woldemariam *et al*., 2002). To address these threats, conservation efforts have been ongoing in the last two decades through establishing forest coffee genetic resource conservation, biosphere reserves and participatory forest management schemes in different parts of coffee forest areas. This review presents an overview of the diversity, threats and conservation status of coffee forests in Ethiopia. The analysis is based on data drawn from different published and unpublished materials. A recommendation for conservation of the last remaining coffee forests is also proposed.

THE PHYSICAL ENVIRONMENT

Location and distribution

Coffee forest is located in the southwestern and southeastern parts of Ethiopia (Fig. 1). The potential range of coffee forest lies between 6 and 8° latitude and is currently estimated to cover an area of around 200,000 ha. Altitudinally, it occurs between 1000 and 2000 m asl but due to land use pressure, much of this belt has already been degraded and fragmented, and partly converted into non-forest land uses (Feyera Senbeta, 2006). This forest lies on mountainous area with a wide range of ecological gradients. It commonly occurs on the undulating terrains, valley bottoms, and incised rivers to valleys where the topography, soil and geology differ. As a result, large complexes of coffee forest exist forming several distinct vegetation units. The various vegetation units, therefore, support different flora and fauna that can be distinguished by forming unique associations. The coffee forests are interspersed also by patches of various grasslands and wetlands which have their own unique faunistic as well as floristic associations. Some of the recognizable examples of coffee forest fragments include: Belete-Gera, Yayu, Sigmo-Gatira, Harenna, Gergeda in Oromia National Regional State and the Masha-Anderacha, Bonga, Maji, Sheko forests in Southern Nations, Nationalities and Peoples Regional State in Ethiopia.

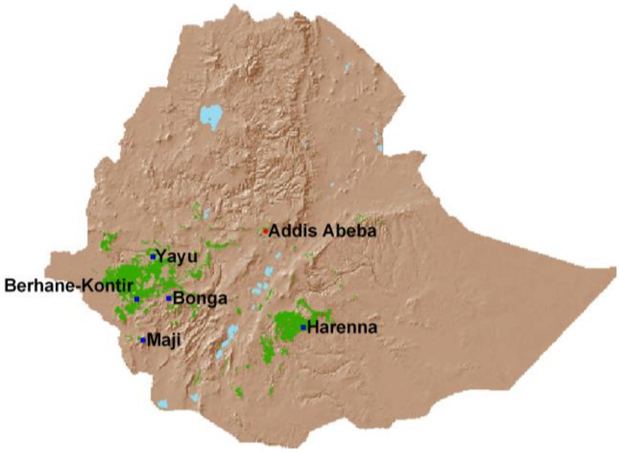

Fig. 1. Map of Ethiopia showing the location of montane forests.

Geology and soils

Geology of Ethiopia has been studied by Mohr (1965; 1971) and Kazmin (1972). The great mass of the coffee forest belt of western Ethiopia is made up of largely volcanic rock, which is composed of mainly alkali olivine basalt and tuffs; whereas the southeastern coffee forests are formed from lava outpourings in the Miocene and Oligocene geological periods (Mohr, 1965). This trap lava covered all previous rock formations and was formed prior to the formation of the Rift Valley, probably about 40–25 million years ago (Mohr, 1965; Mohr, 1971; Umer and Bonnefille, 1998). The soils occurring beneath coffee forest are generally of medium texture, brown or reddish brown, deep and freely draining (Feyera Senbeta, 2006). In most cases, these soils are noted as dark reddish-brown silt-clay rich in basic exchangeable cations. The clay content may increase and the colour becomes redder with depth. A soil study of coffee forest by Feyera Senbeta (2006) showed diverse soil types that include Cambisols, Acrisols, Regosols and Nitosols. Results from the soil chemical analyses also showed a pH of 4.2 to 6.6. These soils are acidic to slightly acidic and have low available phosphorus. Many studies (e.g., Purseglove, 1968; Murphy, 1968; Willson, 1985; Mamo Asfaw, 1992; Paulos Dubale and Tesfaye Shimber, 2000) reported the same findings in different coffee forest fragments. The coffee plants growing on these soils apparently are able to secure their phosphorus requirements from materials released through organic matter decay or weathering.

Climatic conditions

Coffee forest has adapted to a wide range of climate patterns (e.g., around 1000 mm to over 2000 mm total annual rainfall; 11 to 19°C monthly minimum temperature and 23 to 29°C monthly maximum temperature) (Feyera Senbeta, 2006). The distribution patterns of mean monthly rainfall and temperature were similar across the different coffee forest fragments, although the total mean annual rainfall varied. Because of high rainfall in the coffee growing region of the country, there are many rivers that flow in and out of the forest. Apparently, coffee forests capture and store moisture, maintain water quality, regulate river flow, reduce erosion and protect against landslides (Gedion Asfaw, 2003).

COFFEE FOREST STRUCTURE AND COMPOSITION

Forest structure

Forest structure is the attribute of forest that include structural type, size, shape, and spatial distribution (vertical or horizontal). It is both a product of forest dynamics and biophysical processes and a template for biodiversity and ecosystem function (Spies, 1998). Forest structure is shaped by natural forces such as wind, fire, and succession; and forest management. As a result, understanding forest structure can help unlock our outlook about the history, function, and future of a forest ecosystem. Knowledge of patterns of variation in forest structure over time and space can serve as the basis of forest management strategies that seek to sustain a broad array of forest goods and services (Spies, 1997). In this article, density and vertical stratification are used to describe coffee forest structural analysis.

Density: Density refers to the number of plants of a certain species in a particular area and is determined by counting the number of individual plants of a species in uniformly sized sample plots within a site. A study by Feyera Senbeta (2006) in five coffee forest fragments of Ethiopia demonstrated that the density of woody plants ranged from 9,309–69,130 individuals/ha (Table 1). Coffee forest fragments had a high density of individuals, which however differs between sites. These differences may be explained by the complex interactions of the different historic factors in each site. For example, the high plant densities in the Yayu coffee forest might be attributed to the successional stage of the forest (McKinney, 1997). Many natural disturbances, such as fire, may affect the succession processes of a forest. The Yayu forest probably has been subjected to some disturbance in the past. During early successional development, many pioneer species may establish and grow together in high density until they reach the climax stage where many individuals are eliminated due to the Competitive Exclusive Principle (Ewel, 1983). The low density in the Harenna forest is thus related to heavy human-related disturbance (Table 1).

Table 1. Density of woody plants in some coffee forests of Ethiopia.

Characteristics*	**Bonga**	**Sheko**	**Harenna**	**Maji**	**Yayu**
Total plots	28	37	24	10	48
Total density	21,540	24,296	8,937	7,273	132,729
Min density/plot	169	303	89	432	955
Max density/plot	1,459	1,756	1,980	1,209	7,684
Median of density/plot	777	570	178	665	2,642
Density/ha	19,232	18,981	9,309	18,183	69,130

*Source: Feyera Senbeta, 2006

Vertical stratification: Stratification refers to the arrangement of vegetation in layers or vertical layering of vegetation. A study by Feyera Senbeta (2006) has shown that most coffee forests have 2–3 strata of tree layers, i.e., emergent/upper stratum (> 30 m tall), middle tree stratum (15–30 m tall) and small trees and shrubs layer (2–15 m tall). A few trees of the upper stratum, which are not in lateral contact, are raised well above the middle tree stratum and have a large number of branches. The middle tree stratum is often narrow and may be either discontinuous or continuous. The lower tree stratum usually forms a dense canopy. The herb layer is usually sparse and consists of forest grasses and ferns. Lianas and strangling epiphytes are abundant. Even so, in different forest patches, the upper canopy layer is occupied by different tree species, which probably explains the difference in climatic, edaphic and/or historical factors. According to Grubb *et al*. (1963) two-layer stratification is common in species-poor forests in Ecuador. In addition to physical environments, human factors can modify the vertical stratification of a forest. There is a long history of logging and human settlements in most coffee forests in Ethiopia. These human activities must have contributed to the reduction of the upper canopy trees, as most of these species are used for timber, e.g., *Pouteria adolfi-friederici* and *Olea welwitschii*.

As an example, the profile diagram of the Bonga Forest reflects the upper canopy of *Olea welwitschii* stand at 1970 m asl (Fig. 2). Except for a few 30–40 m emergent trees (mostly *Olea welwitschii*, sometimes *Pouteria adolfi-friederici*), the height of the canopy varies between 15 and 20 m. The most characteristic species of the middle stratum include *Elaeodendron buchananii*, *Polyscias fulva*, *Millettia ferruginea*, and *Syzygium guineense*. The understory layer consists of small trees and shrubs with dense crowns between 2 and 15 m, with mainly *Coffea arabica*, *Dracaena afromontana*, *Chionanthus mildbraedii*, *Psychotria orophila* and *Galiniera saxifraga*. The herb layer is patchy and the patches are variable in size and density.

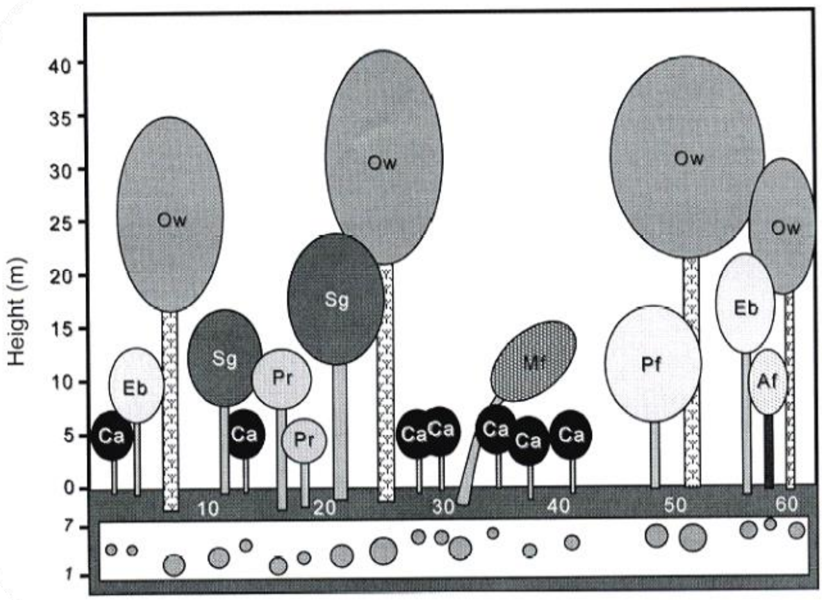

Fig. 2. Profile diagram of an *Olea welwitschii* stand (61 m x 7.6 m) in the Bonga Forest at 1970 m asl Ca = *Coffea arabica*; Eb = *Elaeodendron buchananii*; Ow = *Olea welwitschii*; Da = *Dracaena afromontana*; Pr = *Phoenix reclinata*; Mf = *Millettia ferruginea*; Pf = *Polyscias fulva*; AF = *Podocarpus falcatus*; Sg = *Syzygium guineense*.

Species composition

A floristic study of coffee forest was made by several researchers (e.g., Lisanework Nigatu and Mesfin Tadesse, 1989; Kumilachew Yeshitela, 1997; Tadesse Woldemariam, 2003; Schmitt, 2006; Ensermu Kelbessa and Teshome Soromessa, 2008; Ermias Lulekal *et al*., 2008). However, the study by Feyera Senbeta (2006) was most comprehensive; and included five coffee forest fragments namely, Bonga, Sheko, Yayu, Harenna and Maji, and apparently recorded over 700 vascular plant species. As per the author account, 50 pteridophytes, two gymnosperms and 649 angiosperms species were recorded that represents about 118 families. Out of the total 118 families recorded, only 40% occurred in all five forests and 21% occurred in one forest only. The implication is that many of these species are rare and restricted in their range of distribution. Rare taxa are those having low abundance or small ranges (Gaston, 1994). Any combination of biological or physical factors or both could restrict the species in terms of either abundance or area coverage (Cowling, 1990; Goldblatt, 1997). Apparently, to capture the diversity of plants within the different coffee forests, conservation areas have to be replicated across the different coffee forest fragments.

The characteristic species of coffee forests are illustrated as follows. The emergent canopy or emergent layer of coffee forest occupies the layer above a height of 30 m and is usually discontinuous. **Emergent canopy** is characteristically made up of a mixture of *Podocarpus falcatus* and broad-leaved species. Noteworthy is that *Podocarpus falcatus* is predominant in the southeast and gradually becomes rare towards the southwest, while *Pouteria adolfi-friederici* becomes more prominent there in the southwest. The southeast coffee forest is floristically closely related to the southwest coffee forest except for a few forest tree species not known in other parts of Ethiopia, e.g., *Filicium decipiens*. Among the most frequent **canopy tree** species of coffee forest are *Albizia schimperiana*, *Albizia gummifera*, *Apodytes dimidiata*, *Celtis africana*, *Cordia africana*, *Croton macrostachyus*, *Ekebergia capensis*, *Ilex mitis*, *Millettia ferruginea*, *Mimusops kummel*, *Olea welwitschii*, *Polyscias fulva*, *Prunus africana*, *Sapium ellipticum*, *Schefflera abyssinica*, and *Trichilia dregeana*. The most frequent **smaller tree** species include *Allophylus abyssinicus*, *Bersema abyssinica*, *Blighia unijugata*, *Bridelia micrantha*, *Cassipourea malosana*, *Chionanthus mildbraedii*, *Dracaena afromontana*, *Ehretia cymosa*, *Elaeodendron buchananii*, *Lepidotrichilia volkensii*, *Maesa lanceolata*, *Nuxia congesta*, *Oxyanthus speciosus*, *Rothmannia urcelliformis*, *Schrebera alata*, *Strychnos mitis*, *Coffea arabica*, *Teclea nobilis*, and *Vepris dainellii*. Most species usually occur as **shrubs** but some of them often form smaller trees which include *Allophylus macrobotrys*, *Crossopteryx febrifuga*, *Galiniera saxifraga*, *Psychotria orophila*, *Psydrax parviflora*, *Rytigynia neglecta*, and *Vangueria apiculata*. Some of the most frequent **lianas** include *Gouania longispicata*, *Hippocratea africana*, *Hippocratea goetzei*, *Jasminum abyssinicum*, *Landolphia buchananii*, *Oncinotis tenuiloba*, *Rubus* *apetalus*, *R. steudneri*, *Tiliacora troupinii*, and *Toddalia asiatica*. Epiphytes are very common and include *Aerangis luteoalba*, *Arthropteris monocarpa*, *Asplenium aethiopicum*, *A. sandersonii*, *Loxogramme abyssinica*, and *Peperomia tetraphylla*.

Beyond the floristic listing, the coffee forest also harbours many economically important plant species (Feyera Senbeta, 2006) that include: *Aframomum corrorima*, *Capsicum frutescens*, *Carissa spinarum*, *Clematis simensis*, *Cordia africana*, *Dioscorea praehensilis*, *D. sagittifolia*, *Ensete ventricosum*, *Ocimum lamiifolium*, *Ficus mucuso*, *F. sur*, *Manilkara butugi*, *Mimusops kummel*, *Passiflora edulis*, *Phoenix reclinata*, *Piper capense*, *P. guineense*, *Rhamnus prinoides*, *Rubus apetalus*, *R. rosifolius*, *R. steudneri*, *Solanum nigrum*, *Syzygium guineense*, *Trilepisium madagascariense*, *Trichilia dregeana* and *Urtica simensis*. According to Feyera Senbeta *et al*. (2013) coffee forest also support many medicinal plant species that are used by the local community to treat various kinds of ailments of human and livestock such as rabies, viral disease, headache, stomach ache, wound, etc. in different areas. Some of these species include *Argomuellera macrophylla*, *Cassipourea malosana*, *Celtis africana*, *Cucumis jeffreyanus*, *Elaeodendron buchananii*, *Ficus ovata*, *Filicium decipiens*, *Landolphia buchananii*, *Lippia adoënsis*, *Macaranga capensis*, *Maesa lanceolata*, *Mimusops kummel*, *Ocotea kenyensis*, *Paullinia pinnata*, *Pouteria altissima*, *Premna schimperi*, *Rhus ruspolii*, *Ricinus communis*, *Ritchiea albersii*, *Sapium ellipticum*, *Strychnos mitis*, *Trema orientalis*, *Trichilia prieuriana*, *Trilepisium madagascariense*, *Vernonia leopoldi*, and *Warburgia ugandensis*. It can be concluded that coffee forest fragments are gene reserves for many useful forest species in addition to wild Arabica coffee populations.

COFFEE DIVERSITY

Ethiopia is well recognized as a centre of origin and diversity of Arabica coffee. Arabica coffee is native to the coffee forest of southwestern and southeastern Ethiopia. Globally, it is the only forest ecosystem with wild populations of *Coffea arabica*. Several studies (e.g., Strenge, 1956; Meyer, 1965; Esayas Aga *et al*., 2003; Kassahun Tesfaye, 2006) have indicated the presence of high genetic diversity of Arabica coffee in the coffee forest. The wild populations of Arabica coffee in the coffee forest are the most important gene pool of the crop. For example, Kassahun Tesfaye (2006) reported high genetic variability within and between different wild populations in the forest. He further noted that wild coffee plants are genetically distinct and more diverse when compared to the cultivated varieties or landraces grown in Ethiopia and around the world. The presence of such high genetic variation in natural coffee populations in the forest can partly be attributed to the presence of wide ecological variation, ranging from 1000 m to 2000 m in altitude, with highly dissected and rolling topography (Feyera Senbeta, 2006). The average temperature and rainfall also varies with a similar magnitude. These diverse coffee gene pools are of paramount importance for breeding.

However, the global Arabica coffee gene pool is generally narrow as the spread of coffee all over the world was based on a few material introduced to Yemen from Ethiopia centuries ago. Although it is not exactly known when the first coffee was introduced to Yemen, it has been estimated at about 575 A.D. But, the coffee plant was taken from Yemen to Java in late 17^{th} century and then to the botanical garden of Amsterdam in 1706 and introduced to Latin America early in the 18^{th} century (Wellman, 1961; Meyer, 1965; Purseglove, 1968). Hence, the Ethiopian wild coffee populations provide diverse genetic material for future global coffee breeding and selection (Tadesse Woldemariam *et al*., 2002; Tadesse Woldemariam, 2003). These wild coffee genetic resources are important for national and international coffee breeding that aims at increasing productivity, disease resistance and tolerance, low caffeine content, tolerance to drought and water logging (Schoen and Brown, 1993; Nevo, 1998).

ECOSYSTEM SERVICES OF COFFEE FOREST

Forests provide diverse goods and services that are essential to human wellbeing. The ecosystem services that forests provide make life on this planet possible. According to Millennium Ecosystem Assessment (2005), ecosystem services are categorized in to four: provisioning, regulating, cultural, and supporting. Likewise, the coffee forest provides these services at different scales. Many people living in and around the forest derive their livelihoods from coffee forest (Feyera Senbeta *et al*., 2013; Tola Gemechu *et al*., 2014; Dorresteijn *et al*., 2017; Girma Shumi *et al*., 2019a; b). According to these authors, other than coffee, many non-timber forest products like honey, spices, wild food, medicine, timber, fresh water and genetic resources are among popular provisioning services obtained from the coffee forest. Accounting for uncertainty and protection of the existing genetic materials, especially for Arabica coffee, are all due to coffee forests. The coffee forest fragments are the only natural habitat of wild Arabica coffee populations. These wild coffee genetic resources are important both for national and international coffee breeding programs that aim at increasing productivity, disease resistance and tolerance, low caffeine content and tolerance to drought and the like. For example, the economic value of coffee genetic resources was estimated on the basis of assessing for three breeding programs which include resistance to coffee berry disease and coffee rust, low caffeine contents and increased yields. The resulting economic value of coffee genetic resources amounts to around US$ 0.5–1.5 billion (Hein and Gatzweiler, 2006). This demonstrates the high economic value of coffee genetic resources in Ethiopia, and it underlines the need for urgent action to halt the currently ongoing rapid deforestation of coffee forest. A study by Feyera Senbeta *et al*. (2013) and Demel Teketay *et al*. (2010) in the coffee forest of southwestern Ethiopia has recorded over 61 plant species that are used as a food (wild edible plants) and over 70 plant species, highly important for different uses. There are also many medicinal plants in the coffee forest. However, very few species have been domesticated so far. In terms of cultural services, coffee forest offers aesthetic enjoyment, spiritual enrichment and fulfillment, recreational activities, and ecotourism opportunities. Coffee forest also offers biodiversity repository.

Coffee forest also provides diverse regulating services such as watershed protection, maintaining water quality, mitigating climate change, sequestering carbon, and shading streams for lower stream temperatures that help to support wildlife. Coffee forests are important in watershed management including a role in the capture and transport of water and protection of soils against erosion. Coffee forests haven important role in stabilizing water quality and maintaining the natural flow patterns of the streams and rivers originating from them (Umencdeo *et al*., 1993). Evidence suggests that coffee forest performs a watershed function that is somewhat different from that performed by other forests. This difference relates to the presence and the occurrence of high precipitation regimes in the region where coffee forest occurs. The tree crowns act to intercept wind-driven cloud moisture on leaves and branches that drips to the ground. The absolute increase in net precipitation is a result of the presence of trees. This can add to the groundwater and stream flow levels, but its precise effect on the hydrological cycle is difficult to determine. The impact will, in any case, vary from place to place depending on factors such as incidence of wind-driven clouds, wind speed, size and orientation of mountains, altitude, type of vegetation, and other climatic variables (Kerfoot, 1968; Stadtmüller, 1987; Umencdeo *et al*., 1993).

THREATS TO COFFEE FORESTS

Deforestation and forest degradation have and are still the major threats to the forest resources of Ethiopia. The main driving forces behind deforestation have been the expansion of agricultural land, uncontrolled exploitation of forest resources, logging, non-forestry investment and establishment of new settlements in the forested lands. These and related activities have led to the degradation and fragmentation of coffee forest in many areas where they used to occur. For example, in southwest Ethiopia, since the 1970s over 50,000 ha of intact coffee forest has been cleared and converted into tea and/or coffee plantations (Tadesse Woldemariam *et al*., 2002; Feyera Senbeta *et al*., 2007). According to Logan (1946), a vast block of forest covered large parts of southwestern Ethiopia in the 1940s and 1950s. After 60–70 years, only fragmented forest patches exist in the region. Many of these fragments are under further fragmentation as they are close to the agricultural frontiers.

In the past seven decades, at least four settlement programs have been implemented in Ethiopia that led to a widespread change in land use cover across the country. First, the nationalization of rural land after the change of government in 1974 and with the new land reforms, all land was nationalized and peasant associations created that determined land allocation among peasant members. This proclamation caused migrants to flood from the northern highlands to the western highlands, because the change in land ownership allowed peasants access to land for the first time (McCann, 1995). Again, because of the 1984/85 drought, the government developed a resettlement policy that allowed the movement of people from drought-prone areas to areas not affected by drought. Following this, in 1985/86, the Ethiopian Ministry of Planning announced a new settlement policy, i.e., villagization. The purpose was to move dispersed homesteads into compact settlements so that people would have better access to health centres, clean water and electricity (McCann, 1995). Yet again, in the late 1990s and in the early 2000s, a large number of people were settled in non-drought-prone areas due to drought related problem. All these policies/strategies and changes were spontaneous and mostly not well planned. As a result, the consequences for the forest resources and especially of the coffee forest were very significant. As a result, many people migrated and settled in coffee forest and converted the forest into non-forestland.

On top of these, commercial logging was one of the major causes of forest destruction in Ethiopia and extensive logging has destroyed a large tract of coffee forest in southwest parts of the country. In addition to logging, the roads established for logging enables landless people to enter the forest. In many parts of the southwest coffee forest, land being cleared by farmers was land that had been logged by saw millers once.

A study by Dereje Tadesse *et al*. (2008) in southwest coffee forest showed that the forest cover close to Mizan Teferi has been reduced from 71% to 48% between the years 1973 and 2005 that makes the overall forest cover loss 30%. The root causes of deforestation identified were political, social or economic, that occurred at various scales. As the study indicated, most farmers converted the forest in their settlement area into agriculture and coffee agroforestry systems.

The government as owner and manager of forest resources has frequently been involved in conflicting activities. On the one hand, the government has been and still is excessively engaged in encouraging farmers in export crops development and settlement programs into forestland, while endorsing different proclamations that support conservation and development of forest resources. The latter action has excluded the local community from exercising their customary land tenure system. In response to such tenure insecurity, the local community has aggressively engaged in changing the forest ecosystem into human modified agroforestry system causing forest degradation and loss of biodiversity. The increasing need to produce more food, fuel wood, and shelter accelerates the rate of deforestation and thereof, environmental degradation. In general, the loss of forest biological resources as a result of human interference has increased double-fold in terms of national economy, social wellbeing, cultural heritage and environmental health.

More notably, local communities have developed different traditional management systems for coffee production. These traditional forest-based coffee production systems mostly focus on the reduction of the density of trees and shrubs in order to improve the productivity of the wild coffee plants. In these management systems, there is no standard and the intensity could also vary from place to place, depending on the interest and preference of the individual owner or farmers. Hence, the management level ranges from none in the undisturbed forest coffee to highly disturbed forest garden coffee system (Tadesse Woldemariam, 2003; Feyera Senbeta and Denich, 2006). The problem of traditional forest-based coffee production, from a biodiversity point of view, has been its tendency to downy the variation in natural forest structures, leading to homogenization of the age, structure, size distribution and species composition of the forest. These reduce the diversity of the forest ecosystem and also accelerate biodiversity loss.

On top of land use pressure, the recent climate change and global warming has put immense pressure on coffee forests and its associated biodiversity. Different models showed vulnerability of coffee and coffee forest to climate change and global warming in the future (Davis *et al*., 2012). Based on known occurrences and ecological tolerances of Arabica coffee, bioclimatic unsuitability would place wild Arabica coffee populations in peril, leading to severe stress and a high risk of extinction in the future due to climate change and global warming (Davis *et al*., 2012). The continuous deforestation and forest degradation is also expected to increase greenhouse gas emission. Studies have shown that loss of forests contributes as much as 30 percent of global greenhouse-gas emissions each year (IPCC, 2007). Reducing deforestation and forest degradation and enhancing sustainable forest management can significantly minimize greenhouse gas emission and at the same time, preserve forest biodiversity.

CONSERVATION STATUS

The efforts to conserve coffee forest and other forest ecosystems’ in Ethiopia go back to the 1980s; when the Department of Forestry designated about 58 Natural Forest Priority Areas (NFPA’s) estimated to cover about 2.5 million ha of natural forest (EFAP, 1994). The designation of NFPA was meant to enhance sustainable forest production, protection and conservation in the country. Many of the coffee forest fragments for instance, Harenna, Setema, Yayu, Belete-Gera, Bonga and Sheko forests were part of the NFPA. However, this conservation effort was not realized and never changed the status-quo of deforestation in many of these NFPAs. The focus was on “protection” and local communities living in and around the forests were barely part of the enterprise; and as a result there was a serious deforestation and forest degradation in many of the designated forests, including coffee forest.

In 1998, three coffee forest fragments, namely Berhan-Kontir in Bench-Maji Zone (ca. 20,000 ha), Boginda-Yeba in Keffa Zone (5,500 ha) and Geba-Dogi in Illubabor Zone (18,600 ha) were recognized for forest coffee genetic resources conservation in the framework of Coffee Improvement Project Phase IV and was funded by the European Union. After 10 years of implementation, the project claimed very little success story mainly due to lack of efficient management and coordination among the implementing partner institutions (Westlake and Rosskamp, 2005; Labouisse *et al*., 2008).

Again, in the late 1990s and early 2000s, Participatory Forest Management (PFM) scheme was initiated as an important forest management strategy in Ethiopia. PFM was meant to stop the relentless deforestation problems and to enhance the livelihoods of forest dependent communities through participatory forest management as compared to the former centralized command-and-control resource management approach. Since then many PFM projects were established by different NGOs in collaboration with regional forestry departments in Ethiopia; for example by FARM-Africa and SOS-Sahel in Bonga forests; by Japan International Cooperation Agency (JICA) in the Belete-Gera Forest, by Non Timber Forest Products (NTFP) research and development project in the Masha Forest and by FARM-Africa/SOS Sahel in the Harenna forest (NFTP, 2005; PFMP, 2006; JICA, 2007). In this regard, various studies have reported positive impact of PFM on forest condition (e.g., Aklilu Ameha *et al*., 2014; Solomon Tadesse *et al*., 2016); and other studies have reported the contrary (Mohamed, 2006). Hence, there is a need to do more assessment to see the real impact of PFM interventions on the preservation of the whole ecosystem and consequently on the conservation of coffee forest in Ethiopia.

In 2002, a research project entitled 'Conservation and use of the wild populations of *Coffea arabica* in the montane rainforests in Ethiopia' was launched by Centre for Development Research (ZEF), University, Bonn, in collaboration with Institute of Biodiversity Conservation, Addis Ababa University and Ethiopian Institute of Agricultural Research as main partners. Phase I of the project focused on research and addressed six sub-components: forest biodiversity, coffee genetics and genomics, coffee eco-physiology, coffee pathology, socio-economic and institutions aspect of coffee forest (ZEF, 2006). At the end, the project recommended the UNESCO Man and the Biosphere Programme as an appropriate model for coffee forest conservation (Feyera Senbeta, 2006; Schmitt *et al*., 2009). As a global model, biosphere reserve was initiated in the early 1970s and internationally recognized within the framework of UNESCO's intergovernmental programme on Man and Biosphere (MAB), and remain under sovereign jurisdiction of the States where they are located. It was meant to serve as *in-situ* conservation of all forms of life, along with their support systems, in its totality, so that it could serve as a referral system for monitoring and evaluating changes in natural ecosystems (MAB, 2001). It is an attempt to reconcile the problems of biodiversity conservation and use. It has three inter-connected functions: i) *in-situ* conservation of natural and semi-natural ecosystems and landscapes, as well as the species and genetic diversity within these sites; ii) the establishment of demonstration areas for ecologically and socio-culturally sustainable (land and) resource use; and iii) the provision of logistic support for research, monitoring, education, training and information exchange related to conservation and sustainable development issues.

Following this recommendation, Yayu and Kaffa Coffee Forest Biosphere Reserve were nominated in 2010 to serve as a tool for sustainable development and conservation of coffee forest Ethiopia. Overall, the biosphere reserves were initiated in the coffee forest of Ethiopia to promote *in-situ* conservation and enhance local development and to reduce poverty. The reserve area was divided into three zones with different functions: Core zone (mainly for protection), Buffer zone (use and protection) and Transition zone (mainly for development). Through this approach, certification and value addition for local products and market linkage were meant to enhance local development. The impact of biosphere reserve on coffee forest management is to be seen in the future as the initiatives are still too early to see any real impact on forest management.

To sum up, there are many actions that can be taken to improve conservation of coffee forest and at the same time improve the livelihoods of the local communities living in and around the forest. To improve the conservation of coffee forest the following points should be given due emphasis: (1) transformation of the potential value of the coffee-genetic resource into real benefits for the local communities living in the areas through developing eenvironmental marketing schemes (e.g. eco-labeling), certification of wild coffee, water trading, etc.; (2) Participatory development and conservation of coffee forest-like implementation of biosphere reserve concepts that zone conservation sites into core, buffer, and transitional zones based on their use values; and (3) Promoting financial incentives for sustainable use and conservation of wild coffee and the forests through development of international fund-raising approaches for financing conservation.

CONCLUSION

Coffee forest has proved to be an important ecosystem for biodiversity repository and the only refuge for wild Arabica coffee populations. Coffee forest is the last resort for the perpetuity of wild Arabica coffee populations, and hence its continuation as a forest ecosystem is obligatory for the conservation of an array of species occupying different niches within the forest. Coffee forest also shelters a greater number of other economically useful plant species on which the local communities are dependent for their livelihoods. Despite their ecological and economic importance, however, coffee forests are losing ground due to land use pressure such as habitat modification, over-harvesting, commercial plantations, and agricultural expansion. Climate change and global warming is also expected to threaten the distribution of the wild coffee populations and its habitat more than ever before. To address these threats, conservation efforts have been ongoing in the last two decades- through establishing forest coffee genetic resource conservation, biosphere reserves and participatory forest management schemes in different parts of the country.

The long-term survival of the coffee forests will therefore depend on large-scale conservation efforts. Conservation of forest genetic resources including wild coffee populations will only be possible if use of the coffee forest is sustainable. In addition to the ongoing conservation effort, in-depth diversity study and trait discovery for conservation and sustainable use of Arabica coffee genetic resources and its habitat is required.

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