

# Review on: Suitable Forest Management Innovations for Enhancing Forest Productivity without Compromising Growing Stock and Subsidiary Ecosystem Services

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**Abstract:** Forest ecosystems provide diverse services and values that contribute to human well-being. Although high proportion of species is still undiscovered, tropical forests alone are thought to host more than 50% of the world's biodiversity. Beyond supporting via direct use of products like timber, fiber and biomass energy, they play an important role in providing a wide range of ecosystem services such as regulating water flow and quality, water purification, improving infiltration, fresh water, erosion control, carbon sequestration and sedimentation control. They are one of the important parts of terrestrial and the largest carbon pool, occupying an integral position in the global carbon cycle. However, these days, deterioration of nature and forest biodiversity is a severe danger to the global environment. This will be accompanied by increased strains on food supply, causing increased pressure on already delicate ecological systems. Thus, better forest management strategies are necessary for managing forests sustainably. Nevertheless, little is known regarding the existing forest management approaches and their associated benefits and challenges. Multidisciplinary approaches are needed to achieve sustainable management of forests. These can be accomplished if suitable forest management innovations are put in place. Various technologies can also be adopted through applying different forest assessment tools like remote sensing using light detection and ranging technology (LiDAR) in forest management. Harnessing such technologies will definitely result in providing increased socio-economy as well as improved environmental sustainability. However, the speed of transformation depends much on level of commitment of stakeholders including policy makers. As a result, this review is intended to explore existing forest management innovations which are suitable both ecologically as well as socio-economically. This shows that while there is a lot to be improved, there are already developed forest management innovations that are already in use including PFM and MFM, which helps to achieve SFM.

**Keywords:** Sustainable; forests; management; innovations; participatory; growing stock; ecosystem services; biodiversity

## 1. INTRODUCTION

Forests are home to more than 80% of the world's terrestrial biodiversity and provide numerous goods and services (FAO 2006; Choi et al., 2019). Deforestation and land degradation, however, are impairing their capacity to contribute to food security and other benefits (Choi et al., 2019; Badege 2001; Tola and Woldeamlak 2007). Although the total global forest area, previously estimated at 4 billion hectares, has decreased alarmingly in the last few decades (FAO 2011); stories of successful large-scale forest restoration are still scarce (Choi et al., 2019). Yet, loss of forest varies according to region, and while the forest area in Europe has increased in the past two decades, it has decreased in Africa (FAO 2011; Garcia and Diez 2012). It is particularly severe in less developed countries in Sub-Saharan Africa (Achard et al., 2002; Takahashi and Todo 2012). For instance, 35% of Ethiopia's land area was covered by forest in early twentieth century (EFAP 1994), but currently it is only around 15.5% (EFCCC 2020).

Protecting tropical forests has become increasingly important given recognition that their loss accounts for 6-17% of global CO<sub>2</sub> emissions (Sunderlin et al., 2005; Wooda et al., 2019). A further vital consideration is that these forests contain valuable animals and plants, both known and still to be discovered (Wooda et al., 2019). They should also be maintained as they house many of the world's marginalized communities whose rights should be respected (Sunderlin et al., 2005).

Ethiopia is a country of great geographical diversity with altitudes ranging from highest peak at Ras Dejen, 4620 m above sea level, down to Afar depression, about 110 m below sea level (EFAP 1994). The lives of many rural communities is directly related to natural resources, forest means everything, and thus, all efforts towards sustainable use is challenging (Badege 2001; Sabogal et al., 2013). The fast-growing population with increasing demand for farmland and wood, insecure land tenure system and lack of awareness are the most common factors for deforestation (Aklilu 2001; Sabogal et al., 2013).

Moreover, wood scarcity is common particularly for forest industries in developed countries and for fuel in developing countries (Christersson and Verma 2006; Shiferaw et al., 2019). For instance, the gap between demand and supply of forest products is expanding in Ethiopia (Lemenih and Kassa 2014). Currently, remaining forests are found in south-western parts of the country (Choi et al., 2019; Nigussie et al., 2017; Zerihun et al., 2020). The depletion of forests in turn resulted in reduced agricultural productivity (Shiferaw et al., 2019). There is also a growing understanding that deforestation will further exacerbate poverty (Yemiru 2011). As a result, there is a need to find innovative approaches of forest management to promote sustainable management of forest resources without compromising the growing stock (Lawrence 2009; Zerihun et al., 2020).

The quantity and quality of forest resources is dependent on the practice of sound forest management (Yemiru 2011; Shiferaw et al., 2019). Being influenced by modernization/traditional approach, conservation policies in Africa have been focused on biological value of forests and ignored the people who depend on it (Carney and Farrington 1999; Hurni and Ludi 2000). In the modernization approach, responsibilities of forest conservation have been vested in the state. This destroyed local forest management systems thereby expedited the rate at which this resource is converted to open access 'property' (Carney and Farrington 1999).

In Ethiopia, the state owns largest forest lands (Tola and Woldeamlak 2007; Desalegn 2011). Many scholars argued that conservation efforts which have been tried so far were conventional (Melaku 2003; Tadese and Alemtsehay 2012). Yet, as used to be thought in the past, keeping local households out is not suitable (Lalisa et al., 2018). Hence, the government has launched several forest management initiatives including area enclosure, reforestation, and afforestation. For instance, in Amhara region, plantation forest cover is expanding (CIFOR 2015), making the region the top in Ethiopia in terms of plantation forest (Teshome and Ashebir 2019). Tigray started to practice enclosure due to their strong conviction that this practice protects the environment and supports production of wood (CIFOR 2015). While, Oromia and Southern Nations, Nationalities and Peoples Regional State (SNNPRS) are known in participatory forest management (PFM) (Kassa et al., 2017). In addition, SNNRPS is known with Gedeo's indigenous agroforestry systems (CIFOR 2015).

However, why actual management of tropical forests shows little success inspite of numerous efforts? Recognizing challenges posed by issues surrounding sustainable management of forests, generally, the objective of this review is to analyze suitable forest management innovations for enhancing forest productivity without compromising biodiversity and its services. The review will focus on exploring existing suitable forest management efforts, identifying best practices and gaps, and making recommendations to promote forest productivity. It will also depict the challenges encountered, thereby indicating future directions for promoting sustainable forest development in Ethiopia.

## 2. Methodology

The review was done via critically analyzing and synthesizing the state of knowledge on existing forest management innovations in order to give a clear picture about the role of sustainable forest management. Identification of research gaps was done and then relevant literatures (such as books and journal articles) were searched and analyzed. It was also tried to minimize biases by using explicit and systematic methods, thus providing reliable findings from which conclusions can be drawn. Generally, the basic steps followed were designing; conducting, analyzing, and writing up the review.

### 3. SCOPE OF FOREST MANAGEMENT

Forest management involves planning and implementing practices aimed at fulfilling relevant environmental, economic, social and/or cultural functions of the forest (Wunder et al., 2007; Nybakk et al., 2015; Zerihun et al., 2020). Sustainable forest management (SFM) is management of forests according to principles of sustainable development (Wunder et al., 2007). The concept of sustainability began to increase in importance after the Earth Summit in 1992. But, the previously prevailing notion of sustainability, as applied in forestry for over two centuries, had focused on sustaining timber yields (Sayer et al., 1997; Kant 2003; Næsset 2004). It is known that forests are basically connected to rural livelihoods (Scolesbury 2003; Katila et al., 2014; Zerihun et al., 2020), and local peoples have been managing resources based on their indigenous knowledge before the stewardship role of the state. It played a great role in managing forest resources (Tirhas 2009; Amenu 2018).

Moreover, climate change represents a threat to forests, and protecting forests helps to mitigate its impacts (CRGE 2011). There is a need for stronger climate change adaptation policies and implementation capacity (CIFOR 2015; FDRE 2019). Thus, Ethiopia indicated SFM as main component of forest sector growth towards development, conservation and utilization of forest resources (Wunder et al., 2007; Teshome and Ashebir 2019). However, to date general principles for advancing SFM provided by several studies have not led to sufficient changes at local level (Katila et al., 2014; Teshome and Ashebir 2019). As a result, developing multiple-use forest management (MFM) approaches could offer opportunities to reduce social conflict while also reducing forest degradation and assist in establishing REDD+ programs (García et al., 2008; Sabogal et al., 2013).

### 4. FOREST MANAGEMENT REGIMES IN ETHIOPIA

Forest resources have been managed with different intentions at different times. The first modern legislation came in 1965 which gave recognition for three forms of forests (namely state, private and protected forests) (Nune 2008). Absurdly, natural forests were used as springboards for plantations that outwardly expanded at the expense of peasant holdings during the Derg regime. Plantation forests were mainly for commercial timber (Yeraswork 2001). However, in 2007, the council of ministers adopted forest policy which gives due attention to forest development and conservation considering its significance to sustainable development (Nune 2008; Belay et al., 2019).

Ethiopian forests generated economic benefits equivalent to 12.86% of Gross Domestic Product (GDP) in 2012. The contribution of forest ecosystems to other sectors, particularly agriculture, is valued at 6.77% of GDP (UNEP 2016). However, total wood product demand is projected to increase by about 27% over the next 20 years. This indicates that there is a supply gap of 4.4 million m<sup>3</sup> industrial round wood. But, this challenge presents a considerable investment opportunity, as the gap can be filled through sustainable management of natural forests (Teketay et al., 2010), commercial plantation establishment and expansion of industries (Belay et al., 2019; EFCCC 2020).

#### 4.1. Natural forest management

Forests are sections of landscapes in which ecological and environmental processes are dominated by perennial plants (Kimmins 1987, Romijn et al., 2015). However, continuous loss of forest cover is a risk to both economic production and ecological systems

(Balana et al., 2010; Kibret et al. 2016). The fundamental causes for this occurrence in Africa are policies that have promoted agricultural expansion, without the appropriate evaluation of possibilities for sustainable management of natural forests (Campos et al., 2001; CBD 2010; Sun et al., 2015). Therefore, formulation of holistic plans is required to consider stakeholder's interests (Mamo et al., 2007; Balana et al., 2010).

The physiographic feature of Ethiopia enabled the ecosystems to host a great diversity of flora and fauna (Sahle 1984). With the inclusion of savanna woodlands, some 66% of the country was originally covered with forests (Wood 1990, Kuru 1990). Currently, the country has about 12.2 million hectares of forests. This is considerably lower than the 20.8% average forest cover for East Africa (Ayana 2014). It has also an estimated one million hectares of natural bamboo forest, the largest in the African continent (Mekonnen et al., 2014; UNEP 2016). On the other hand, dry forests of Tigray are composed of economically important tree species such as *Boswellia papyrifera*, which is known for producing 'Tigray type' frankincense that is widely used in church services (CIFOR 2015).

#### 4.1.1. Protected area management

Since the best way to conserve species is to maintain their habitats, protected areas are an essential means for sustaining diversity (Badege 2001), and constitute the most widespread mechanism used to conserve the remaining natural forests of Ethiopia. They also help in stabilizing local climate, protecting watersheds, and preventing erosion (Badege 2001; Tola and Woldeamlak 2007). Though many protected areas have been designated in developing countries, the acreage of natural forests continues to decline. This is because the system neglected use of the resource and solely focused on protection. For instance, Wof Washa in Northern Shoa has been identified as priority forest area that must be conserved for biodiversity and ecological benefits (CIFOR 2015). But, a multi-disciplinary approach is decisive for adequate natural resource research and extension (Badege 2001; Klaus and Asferachew 2009).

#### 4.1.2. Participatory Forest Management

It is a new paradigm management system which is adopted and implemented to fulfill the interest of traditional users (Engida and Mengistu 2013). The literature often applies it as an umbrella term to refer to various systems developed in different countries, including community forest management, collaborative forest management, and joint forest management (CIFOR 2015). It is a mechanism that enables people with a direct involvement in all aspects of forest management including policy formulation process (FAO 2015; Dereje and Mulugeta 2019). It recognizes local people as economic decision-makers, where their forest protection efforts are directly correlated with the value they feel for the forest (Said and Peter 2010; Windberg 2011) and fills the legal gap that prevents communities from making decisions (Farm-Africa 2000; Atmadja et al., 2019).

A key element of PFM is creating community institutions, often called Forest User Groups (FUG), which are required to establish bylaws governing forest utilization and benefit-sharing (Kassa et al., 2009; Atmadja et al., 2019). It is much less costly to implement (FAO 2001; Belay et al., 2019), while also contributing to improved food security and poverty reduction via achieving millennium development goals (FAO 2011). It is now widely adopted across East and Southern Africa (Wily 2010).

In Ethiopia, PFM was adopted for three basic reasons: constitutional as the rights of communities to use resources is recognized; practical as the government is unable to protect all forest resources; and effectiveness as it is successful in reducing deforestation rates compared to other methods (Kassa et al., 2009, Lemenih and Kassa 2014). An estimated 1.5 million ha of forests have been put under PFM since the mid-1990 (Lemenih and Kassa 2014). The best example of PFM is in Afromontane forests of Bale Highlands in Dodola. The establishment process has evolved through long process, in order to seek solutions to practical problems. It ensures proper validation at initial stage, by allocating sufficient time, and making the process as transparent as possible (CIFOR 2015). For this reason, forest degradation has shown substantial decline and tree regeneration has im-

proved. Although economic returns have been slow to materialize, PFM members are now able to access forest resources legally (Tesfaye et al., 2015). However, agricultural expansion, utilization of forests for energy and overgrazing are challenging PFM (CIFOR 2015), thus there is still need to address such undermining challenges (Kassa et al., 2017).

Future PFM initiatives should be guided by a scaling up strategy, formulated based on lessons from selected practices (Tesfaye et al., 2015; Kassa et al., 2017). It can be practiced in all types of forests including communal plantations, area enclosure sites, etc. For instance, based on PFM experiences in Oromia, new PFM guidelines comprise three major phases; mobilization; planning, and implementation (CIFOR 2015). However, in selecting candidate sites for scaling up, the conditions under which these practices proved to be successful should be compared with the context of potential sites (CIFOR 2015; Kassa et al., 2017). For instance, one of the improvement measures taken in Bonga PFM is allowing members to use some timber products (CIFOR 2015).

#### 4.1.3. Indigenous forest management practices

Forest resources are often well managed by local communities mainly through their own initiatives using traditional institutions (Belay et al., 2019; Shiferaw et al., 2019). In some traditions, forests are considered to serve as link between the sky and earth and are associated with human creation. For instance, Dai people of Yunnan in China believe that the cradle of human life is the forest (UNFF 2004). The Jola society of Senegal stated “We are Jola, people of the forest and think that all life comes from the forest” (Madge 1995). The Oubangui tribe of Central Africa plants a tree for each new born baby and baby’s health is related to trees development. If its growth decreases, there is fear about healthiness of the baby. As a result, such trees are protected from any damage for many years (Vergiat 1969).

##### 4.1.3.1. Gadaa system

Traditional institutions govern resources and decide institutionally how best they could be utilized in equity (Atmadja et al., 2019). The Gadaa system is one of the oldest known traditional systems for managing natural resources (Tadesse and Woldemariam 2007; Atmadja et al., 2019; Belay et al., 2019). Borena Gadaa is the most useful in this regard (Shiferaw et al., 2019; Atmadja et al., 2019). By-laws are revised and formulated every eight years during ‘Gadaa’ assembly. Through this hierarchy, different traditional management practices such as controlled grazing, fire protection and reducing settlement expansion are practiced. For instance, epiphytes which are growing on *J. procera* and other old tree species is named by ‘Borana’ people as ‘*Areeda jaarsaa*’ mean that elders’ hair and the old tree of this species is also believed to represent elder of the people. In addition, the society value forest resources particularly some tree species for spiritual purposes (Atmadja et al., 2019). When there are conflicts, it is managed by ‘Gadaa’ system every time (Shiferaw et al., 2019). However, conflicts with other community groups, population growth, farm land expansion and urbanization are some of the causes for deterioration of forest conditions (Atmadja et al., 2019).

##### 4.1.3.2. Ethiopian church forests

In northern and central Ethiopia, sacred groves are associated with Ethiopian Orthodox churches and monasteries. They are often remnants of earlier more continuous forests (Bhagwat et al. 2014). Although main purpose of churches is as places for worship, burials and meditating religious festivals, they also provide unique and secured habitats for plants and animals. The Church perceives nature in a holistic manner (Alemayehu 2002; Alemayehu et al., 2005; Bongers et al., 2006). These forests are virtually all that is left of the Afromontane forest (Alemayehu et al., 2005; Aerts et al., 2016), and local people rely on them for provisioning of fodder, seedlings, fuelwood, honey, clean water and other ecosystem services including climate regulation (Alemayehu 2002; Alemayehu et al., 2005; Bongers et al., 2006).

Various studies suggest that church forests might be blueprints of ancient and largely lost forest ecosystems which might serve as priority areas for in-situ conservation of indigenous species (Alemayehu 2002; Alemayehu et al., 2005; Bongers et al., 2006). From vegetation sampling done on churches in South Gondar, total number of woody species and families ranged from 18 and 22 to 22 and 42 respectively (Alemayehu et al., 2005). Local communities do have higher respect and trust in the church than other institutions (Alemayehu 2002). Generally, the church is a model in forest management as it has been in the fore-front of the fight against deforestation. However, conservation via only the church has become difficult to save the forests from pressure of local people. Some species are now under threat and declining in numbers (Alemayehu 2002; Alemayehu et al., 2005; Aerts et al., 2016).

#### 4.1.3.3. Gedeo's indigenous agroforestry practices

Agroforestry can improve the livelihood of rural communities, and reverse environmental degradation (Nair 1993; Mendez et al. 2010). The increased plant and animal diversity represents greater diversity in food, fuel, fodder, medicinal plant and income for smallholder farmers (Nair et al., 2009; Mendez et al. 2010). Traditional practices in SNNRPS provide an excellent case study to demonstrate potential of the system to address the needs of limited-resource farmers (Mesele and Achalu 2008). Traditional agroforestry systems have been practiced across the world with varying structure and function. Invariably in almost all systems, native trees appear to predominate and have a major structural, functional and service role. The Gedeo agroforestry practices are the product of Gedeo indigenous knowledge and integral part of their culture and belief (Mulugeta and Mabrate 2017). The practice is developed through domestication of natural forest, so that most of the woody species present in the area are indigenous (Mesele and Achalu 2008; Abiyot et al., 2013). The practices are self-sufficient and fully packaged with production and ecological services (Tadesse 2002; Mesele and Achalu 2008). They have potential of carrying high population size per unit area without any natural resource and environmental degradation (Mulugeta and Mabrate 2017), while also providing 40% of Ethiopia's premium grade coffee and sequestering CO<sub>2</sub> (Mesele and Starr 2015). Hence, the system has rich potentials of production as well as ecological services (Mulugeta and Mabrate 2017).

Based on altitudinal ranges Gedeo agroforestry systems were classified into three categories: enset-tree, enset-coffee-tree, and coffee-fruit crop-tree based agroforestry (Mesele and Starr 2015). However, nowadays the practices are under pressure mainly due to population explosion. In addition, the incentive for investing in soil-fertility improvement for the future is low unless the benefits accrue to the tree planter (Nair et al., 2009). Thus, all stakeholders especially young generation have to make all possible endeavors to maintain such practices (Mulugeta and Mabrate 2017). Recommended improvement measures are introduction of improved germplasm; promoting suitable trees/shrubs, applying proper management and market linkages (CIFOR 2015).

#### 4.2. Plantation forest management

Most African countries are highly dependent on biomass for producing energy. 90% of Ethiopia's industrial and fuel wood supply comes from natural forests (Maru et al., 2019). Biomass fuels constitute 95% of the total energy consumption, of which firewood and charcoal combined account for more than 77% (EREDPC 2008). The fuel wood requirement of Ethiopians is estimated to be 0.8 m<sup>3</sup> per person per annum, which is impossible with current deforestation rate. In this regard, plantations are often considered as a "quick fix" solution (Abayneh et al., 2012; Lemenih and Kassa 2014), as they can meet the required needs of society provided right species are planted on the right places and that proper management practices are put in place (Abayneh et al., 2012; Wubalem et al., 2019).

One third of world's land surface is covered by forests, of which, 6% are plantations (FAO 2010). In Ethiopia, most plantations are found in Oromia, Amhara, SNNPRS and

Tigray (CIFOR 2015). However, contrary to growing interest in tree planting, application of silvicultural practices is limited (EPA 2003; CIFOR 2015). Thus, setting clear objectives and preparing management plans (Wubalem et al., 2019), as well as proper land use planning are crucial (Abayneh et al., 2012; Wubalem et al., 2019). To minimize impact of wood scarcity, greater attention should be given to short-rotation forestry as it could offer enough timber and fuel wood while also conserving natural forests (Christersson 2005; Christersson and Verma 2006). Technical advances in energy efficiency are also critical (Teketay 1999; Maru et al., 2019). To promote sustainable plantation use of selected seed sources and improved seedling production techniques, value addition and strong forestry intuitions are required (CIFOR 2015).

#### 4.2.1. Woodlot establishment

In Ethiopia, woodlots were mainly planted on small patches through campaigns by mobilizing peasants and urban dwellers (Teshome and Ashebir 2019). Community woodlots in Tigray have been developed through a more participatory process. Most are managed at village level by a village council and are used only by members of that village (Gebremedhin et al., 2000). However, low survival rate and lack of maintenance resulted in the failure of many of these plantations mainly due to absence sense of ownership by community members (Teshome and Ashebir 2019; Zerihun et al., 2020). As a result, devolving responsibility of managing natural resources to local administrations may lead to more equitable and sustainable use of natural resources (Zerihun et al., 2020).

##### 4.2.1.1. *Acacia decurrens* woodlots

*Acacia decurrens* (Willd) is a fast-growing tree that reaches up to 6-12m and regenerates via both coppicing and seeds. It grows well in high rainfall areas with 600-1400 mm per year; it is thus more adapted to temperate coastal to cool inland but not dry areas (Teshome and Ashebir 2019). The species can be used for environmental management, and chemical and wood products. Specifically for charcoal, firewood, poles, forage, shade, soil conservation, wind break, and live fence (Zerihun et al., 2020).

Low investments in land management practices are major concern in the Ethiopian highlands (Teshome and Ashebir 2019; Zerihun et al., 2020). Many watersheds in the Upper Blue Nile Basin are experiencing substantial land-use change driven by farmer's interest in improving their economic gains (Zerihun et al., 2020). For instance, following severe reduction of land productivity and land degradation in Awi zone, Fagita Lekoma district, it resulted in complete leaching of soil nutrient making the soil unproductive. Hence, farmers often suffered from the failure of crop production (Teshome and Ashebir 2019). Nevertheless, planting *A. decurrens* on their lands have earned positive feedback for their ability to prevent soil erosion (Kindye 2016; Reubens et al., 2011), improve soil fertility (Kassie 2015; Reubens et al., 2011), and enhance water quality (Reubens et al., 2011).

During plantation establishment phase, farmers traditionally tend to intercrop acacia trees with annual crops (e.g., teff [*Eragrostis tef*], wheat, or barley) and later grass for hay, a practice known as taungya farming (Kassie 2015; Nigussie et al., 2017). The intercropping basically starts in the first year of seedling plantation on the quarter hectare of land (one khada). This will help the farmer to get one seasonal harvest of food crops. Farmers do not allocate the whole of their land to plant seedlings at one time, rather they divide it to use it wisely and get different products. Seedlings are planted mostly at closer spacing (on average about 60cm) and survival rate is close to 96% (Teshome and Ashebir 2019). Such farming practice offsets income loss in the first couple of years while also contributing to soil fertility improvement (Nigussie et al., 2017; Wondie and Mekuria 2018).

Through its deep rooting system, *A. decurrens* enables to recycle all subsurface leached nutrients to the top surface by which the soil fertility is substantially improved (Kindye 2016). It has also great land reclamation potential for acidic soils, especially

where Nitisols dominate (Teshome and Ashebir 2019). The main motivation of small-scale farmers for planting the species is to generate additional household income mainly through converting the wood to charcoal (Nigussie et al., 2017; Wondie and Mekuria 2018; Zerihun et al., 2020). Thus, farmers have fully accepted and practiced development and utilization of the species (Teshome and Ashebir 2019). However, charcoal production is solely practiced using traditional carbonization processes. Therefore, appropriate and safe charcoal production system and technology is required (Teshome and Ashebir 2019; Zerihun et al., 2020).

Moreover, recent studies showed that the system has also other advantages in terms of ecological sustainability. Sultan et al., (2018) uncovered it has lower runoff coefficient value (25%) as compared to grazing and cultivated lands (36% and 26%, respectively), implying that the species reduces flood risks. It has significantly higher organic matter and nitrogen, as compared to adjacent crop lands as the species, is nitrogen-fixer (Kassie 2015; Zerihun et al., 2020). Part of the tree not suitable for charcoal is usually used as fuelwood, which otherwise would have to be collected elsewhere (Kassie 2015; Nigussie et al., 2017). Its contribution informs the potential to be scaled up in different parts of the country with similar conditions (Teshome and Ashebir 2019). However, some of the challenges are: currently, almost all harvest is used only for charcoal; farmers do not have cooperatives; and limited scientific studies. Thus, the species should be studied well and there is a need to establish *A. decurrens* grower farmers' cooperative for better benefit and market link (Teshome and Ashebir 2019; Zerihun et al., 2020).

#### 4.2.1.2. Determinants of woodlot establishment

Development of woodlots as an additional source of livelihood and land management option is challenging (Bewket 2007; Adimassu et al., 2012). Some of the factors that significantly influence the decision to adopt woodlots were tree tenure security, quality of seed, contact with extension agents and size of land holdings (Bekele 2011; Zerihun et al., 2020). Woodlots require farmers to set aside part of their land for growing trees that results in the cultivable area under food crops being reduced. Thus, farmers with smaller land may view tree planting as competing with food crops. Control over the allocation of harvesting rights is limiting the economic potential of woodlots. In Ethiopia, farmers have ownership right to trees growing on their land, but needs to get permission to cut trees (Dessie et al., 2019). Additionally, woodlots that are managed by households/individuals are estimated to yield higher rates of return than those managed at administrative levels due to greater management intensity (Zerihun et al., 2020; Teshome and Ashebir 2019).

#### 4.2.2. Community forest

Community forestry intimately involves local people in a forestry activity (FAO 2011). For instance, in Amhara region, it is developed and managed by kebeles on communal lands, to promote rehabilitation of degraded areas as well as to generate economic benefit out of it (Teshome and Ashebir 2019). It embraces a spectrum of situations ranging from woodlots in areas with short of wood and other forest products for local needs through the growing of trees at farm and community level to provide cash crops (Badege 2001). For instance, among 11 communal plantation sites in the region, the one in Shabra village, South Achefer in West Gojam was found to demonstrate some of the best management practices as the management is organized and participatory (CIFOR 2015).

#### 4.2.3. Commercial forest

A commercial forest is mainly developed for economic purpose (EFCCC 2020). Out of the total plantations in Ethiopia, 80% are non-industrial plantations. Sawmilling is the main forest industry and the main product is sawn timber (Bekele 2011). However, existing forest-based industries are scattered and lack sufficient resource supply (Bekele 2011; NFSDP 2017), and they are characterized by low utilization capacity, obsolete equip-

ment, and large amounts of waste (Bekele 2011). There is no inter-industry linkage as industries are often not strategically located with respect to distribution of forest resource base (NFSDP 2017). To supplement the limited supply of products from domestic sources, the country is importing timber; pulp, etc. (Bekele 2011; Lemenih and Kassa 2014). This could be related to the lack of sufficient domestic production in the country. Nevertheless, most of the existing commercial plantation stands are over mature and poorly managed (NFSDP 2017).

There are two commercial forest enterprises established by the Ethiopian government in Oromia and Amhara (Wubalem et al., 2019; EFCCC 2020). These enterprises engage smallholder farmers through an out-grower scheme, by creating jobs, and generating annual revenue of \$10.5 and \$4.5 million, respectively (EFCCC 2020). For example, the Amhara Forest Enterprise (AFE) owned about 25,000 ha of natural and plantation forests (Wubalem et al., 2019). The best practice is in Debre Tabor, which is owned by a group of licensed individuals. It was established in cluster form (i.e. four blocks-10.5 ha). The owners of three of the blocks are inhabitants of Debre Tabor, and the fourth block is owned by a group of police officers. The plantation owners chose to plant their cluster with *E. globulus*. Each of the plantation blocks has its business plan, and each group has tree nursery. Silvicultural factors, such as site preparation, protection, and species-site matching are well managed (CIFOR 2015).

Improved management of existing forest plantations can be achieved via various approaches, including involving private sector either in form of joint venture with government enterprises and/or by upgrading capacity of public enterprises (NFSDP 2017; EFCCC 2020). However, private participation in commercial forest production is very low mainly due to property right arrangements such as land tenure issues and the fact that trees have long gestation period to reach maturity (Bekele 2011; EFCCC 2020). As a result, Ethiopia needs to develop globally competitive forestry industries, and this is possible by adopting an industry cluster approach: i) A sub-sector approach which involves providing a package of incentives to potential investors in a well-defined specific sub-sector without confining them to one geographical region, and ii) Flagship approach which involves the government defining a few projects with specific land allocated with specified location for processing (NFSDP 2017; EFCCC 2020).

#### 4.3. Forest restoration

Despite all the efforts carried out to protect tropical forests, their degradation continues unabated. Though not adequate to reverse the trend at global level (Klaus and Asferachew 2009), various measures are being taken, including restoration of degraded lands. South east Asian countries, notably China and Vietnam, have made significant gains in tree planting initiatives. The area of forest plantation in Africa increased by less than 5%, while in Asia it grew by about 20% (FAO 2003). Common methods include establishing area exclosures, agroforestry and tree plantations (Lemenih and Kassa 2014; Atmadja et al., 2019). The Ethiopian government initiated re-greening efforts including recent initiative by Prime Minister Abiy Ahmed which has mobilized the people across the country to plant 4 billion seedlings in a season (EFCCC 2020). However, restoration must be linked with income-generating activities that benefit all stakeholders (Lemenih and Kassa 2014; EFCCC 2020).

##### 4.3.1. Area exclosure

Area exclosure involves exclusion of human and livestock interference on degraded lands (EPA 2003), to allow the land to restore itself through natural self-repairing process (Lemenih et al., 2007; Mekuria et al., 2007). It has gained wide spread acceptance in many of the world (Verdoodt et al. 2009). For example, Yong-Zhong et al. (2005) showed that excluding grazing livestock is an option for restoring vegetation in semi-arid Horqin sandy grassland of northern China. It has also been fostered by establishing exclosures in Tanzania (Barrow and Shah 2011) and Kenya (Mureithi et al. 2014).

Studies revealed that establishing exclosures has also emerged as promising in Ethiopia (Bekele 2011; Melkie 2020). In response to degradation, communities in Tigray started to practice exclosure (CIFOR 2015). There is strong argument that the region has become greener in the last few decades through area exclosure (Bekele 2011). In this region alone, close to 1.3 million ha are under area exclosure (BoARD 2013). There are also some successful exclosures, where commercial honey production is collected in Amhara region (e.g: Lasta and Sekota). Based on experiences in Tigray, to improve performance of exclosures enrichment planting, soil scarification, broadcasting with native flora, water harvesting structures, species-site matching, fair benefit-sharing are needed (CIFOR 2015).

There are two strategies biological and assisted (Lemenih and Kassa 2014; MEFCC 2017). The biological one simply protects the area against livestock and human interference (Asefa et al. 2003; EPA 2003). Whereas, assisted strategy involves enrichment planting to speed up succession (Asefa et al. 2003; Mekuria et al., 2007; Yami et al., 2007). Grass is harvested for fodder once a year, using a cut and carry system. Honey production and medicinal plant collection are also allowed (CIFOR 2015). However, as the exclosure age increases, tree canopy cover expands suppressing herbaceous plants. Farmers find this discouraging since it significantly reduces livestock feed (Lemenih and Kassa 2014).

Government initiatives to encourage free mobilization and existence of huge tracts of degraded areas are decisive opportunities to promote exclosures (CIFOR 2015; Mekuria et al., 2020). Yet, the major challenge is that reclamation takes long time, particularly in dry climates (Lemenih and Kassa 2014; MEFCC 2017). In this regard, following a business model approach can be crucial; for instance, can be based on three revenue streams for application within an exclosure: beekeeping, livestock fattening and cultivation of high-value plants (Mekuria et al., 2020).

#### 4.3.2. Experience from South Korea's restoration strategies

The Republic of Korea is a mountainous country where the people have traditionally had a high reliance on forests mainly for fuelwood (FAO 2011; Bae et al., 2016). This is similar to the Ethiopian context. The period of Japanese occupation resulted in excessive harvesting of wood in South Korea's forests (WRI 2015). In the 1950s, it was one of the poorest and least developed countries in the world (Bae et al., 2016). Coupled with this, extreme degradation of forests became a huge obstacle to attaining national restoration goals (KFS 2007). Until the late 1950s, 58% of the mountains in the Republic of Korea were bald, while 11% of the land was barren like a desert (Lee et al., 2018). However, due to the effectiveness of the restoration done by the government, Ecologist Lester Brown called South Korea's afforestation project as "in many ways model for rest of world" (Brown 2016).

The experience in Korea demonstrates that achieving food security through forest rehabilitation can be successful if holistic approach is in place to ensure that all relevant sectors work towards the same goals (Bae et al., 2016). The Saemaul (New Village) movement was a mind-changing movement for creation of better village life (Lee et al., 2018). Forest cover grew from 35 to 64% of the country's total land area in the period between 1952 and 2007. Growing stock grew from 3.4 to 6.2 million ha (Bae et al., 2016). The restored forests have also provided many valuable ecosystem services (KFS 2013; Brown 2016). This showed that afforestation is possible in a relatively short time, despite imperfect administrative methods or low economic development. Thus, this could have implications on Ethiopia's forest restoration. However, while South Korea successfully replaced forest fuels with alternative energy sources, Ethiopia is still developing alternative fuels and at the same time re-greening degraded areas.

## 5. FUTURE CHALLENGES AND OPPORTUNITIES

What will dictate management of the remaining forests in the 21<sup>st</sup> century? Forest management is facing complex challenges and potential goal conflicts between timber

production and provision of other ecosystem services (Wolfslehner and Seidl 2010; Nybakk et al., 2015). There is no 'silver bullet' that can be applied universally (Sayer et al., 1997; Wolfslehner and Seidl 2010). To ensure that future developments are sustainable (EPA 2003; EFCCC 2020), establishment of plantations is essential. This can be best achieved through private sector involvement by establishing industrial plantations (Badege 2001). However, average annual area of plantation establishment is very low (Bekele 2011).

Some of the challenges are problem of enforcing laws and regulations (e.g. control of illegal logging) (Katila et al., 2014), absence of better information technologies (Sayer et al., 1997), and the gap between demand and supply (Bekele 2011). Although growing indigenous trees is ecologically sound, they are being depleted mainly due to unwise exploitation and lack of scientific knowledge about their reproductive biology (Bekele 2011). Thus, it is necessary to develop techniques for rapid propagation of such species (Zegeye 2010). Furthermore, land is most vital production factor in an agrarian-dominated society (Mekonnen 2009). However, governments usually encouraged foreign investment in extractive ventures (Katila et al., 2014), mainly due to conflicting policies. To reverse this situation, reconciliation of different land uses (Katila et al., 2014; Zerihun et al., 2020).

In contrast, one of potential opportunities of forestry development in Ethiopia is presence of large land size and diversified agroecology (Shiferaw et al., 2019; Melkie 2020). The country has approximately 26.8 million ha suitable land for commercial forests (Amenu 2018; EFCCC 2020). The forestry sector has also been identified via Kyoto Protocol as one of fast-track implementation pillars for achieving high CO<sub>2</sub> sequestration (Dereje and Mulugeta 2019). However, property right arrangements should be clear and there should be reliable legal mechanism to protect community's interests (Gada 2014).

Apart from timber, Ethiopia has diverse non-timber forest products (NTFPs) from both natural forests and woodlands across the country. For instance, gum and incense are applied in a wide variety of industrial applications like in food and beverages, cosmetics and pharmaceutical products as refined ingredients fetch higher market prices (NFSDP 2017), which is lost value for Ethiopia. It is also crucial to raise awareness about potential of payments for environmental services (PES), starting with erosion control in upper catchments of hydroelectric dams, and water supply for companies producing bottled drinks (Wunder et al., 2007; Atmadja et al., 2019). Technologies such as light detection and ranging technology (LiDAR) will also help to address the challenges (Næsset 2004; Sayer et al., 1997).

## 6. CONCLUSION AND RECOMMENDATIONS

Forests are home to more than 80% of world's terrestrial biodiversity, and provide numerous goods and services. Tropical forests house most marginalized communities whose rights should be respected. Thus, the relationship between society and nature should result to a positive sum game. Deforestation and degradation, however, are impairing capacity of forests to contribute to food security and other benefits. The past centralized management system has made local communities to be suspicious. Nevertheless, SFM can keep balance between three main pillars: ecological, economic and socio-cultural values of forests. This review shows that while there is a lot to be improved, there are already developed forest management innovations that are already in use including PFM and MFM, which help to achieve SFM.

Technical development and research will have a positive effect in developing new management approaches in the future. The objective of protecting forests while also generating economic benefits may involve trade-offs that need to be reconciled. It is clear that depletion of forest resources will result in reduced agricultural productivity. Hence, despite doubts about economic feasibility of forestry, the next generation will inevitably rely on forestry development. However, to promote such innovations, there is a need to maximize public benefit while also minimizing adverse effects. It is also recommended that a better outcome in terms of poverty alleviation can be achieved if pro-poor forest-

based activities are specifically considered in planning conservation interventions. Restoration efforts must be paired with incentives for people to maintain plantations.

Furthermore, while there is a definite economic as well as ecological benefit from forests, there is still a need to improve the policies in order for them to address land and tree tenure issues. Thus, it is suggested to actively promote forest management which is a 'long hanging fruit' for achieving sustainable development. Generally, for properly enhancing forest development and to fully seize its potential across the country, the following are needed: collaboration between different government agencies, development partners, private sector, and local communities; proper land use planning; implementation of clear rules and regulations and establishing viable market information systems.

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