A review on the indigenous multipurpose agroforestry tree species in Ethiopia: management, their productive and service roles and constraints

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ABSTRACT

Tree planting has a long history in Ethiopia and managing indigenous multipurpose trees is widely adopted by farmers, as a dominant feature of agricultural landscapes. Farmers manage different indigenous multipurpose tree species within agroforestry practices. But variability in agroecological conditions causes inconsistency on tree species selection, their intended benefits and ecological services. Management practices and current constraints on them were also the major issues on indigenous multipurpose agroforestry tree species in Ethiopia. Therefore, this article was initiated to review on indigenous multipurpose agroforestry tree species in Ethiopia, management practices applied to them, their productive and service roles and constraints. It found that Cordia africana, Millettia ferruginea, Erythrina brucei and Olea capensis are the major indigenous multipurpose tree species used in agroforestry systems in southern Ethiopia. Croton macrostachyus, Vernonia amygdalina, Faidherbia albida, Acacia nilotica, Acacia seyal and Grewia bicolor are found in the northern part of Ethiopia. Albizia gummifera, Cordia africana, Croton macrostachyus, Ricinus vasta and Vernonia amygdalina are also found in the central highlands of Ethiopia. They are established through natural regeneration and farmers apply pruning, pollarding and coppicing tree management practices to harmonize their survival with integrated crops. Fruit, fodder, wood, timber and cash generation are the major productive roles of these tree species. In addition to these, they also have agroecological services through improving soil fertility, controlling erosion, mitigating climate change and conserving biological diversity. Despite their considerable uses and services; inadequate research and extension; shortage of knowledge; the expansion of cash crops and the small size of land holdings constrain the sustainability of these tree species. The government could encourage the wider use of agroforestry practices by policies to expand research and extension services. In addition to this, policy makers and agricultural development interventions should be encouraged to make more informed decisions regarding further research on indigenous multipurpose tree species in Ethiopia.

1. Introduction

Agroforestry is a form of sustainable land use systems that integrates trees with crops or animal husbandry to initiate an agroecological succession (FAO, 2013). Due to its economic, social and environmental benefits (Abrha, 2016); agroforestry is widely promoted throughout the world and is an instrument for diversifying and enhancing production (Mbow et al., 2014). Mixing trees with annual crops also helps farmers to overcome the crop failure due to climate change (Linger, 2014) and land degradation (Leakey, 2020).

In Ethiopia, smallholder farmers practice various agroforestry practices depending on the socioeconomic and biophysical conditions (Jamala et al., 2013; Abrham et al., 2016; Iiyama et al., 2017). These include: coffee shade trees, scattered trees on farmland, homegardens, woodlots, boundary (windbreaks) and silvopastures (Zebene and Agren, 2007).

Selective retention of naturally regenerated trees is probably the oldest and still important way of getting trees into agroforestry that can be intervened as maintaining trees on croplands for their usefulness to provide multiple products (Abebe et al., 2010). Domesticating agroforestry trees involves accelerated and human-induced evolution to bring tree species into wider cultivation through a farmer determined or market-lead process. The selection, retention or deliberately planting and management of trees by farmers can be considered as the beginning of the domestication process of the species (Etefa et al., 2014). It is common for farmers to manage natural regeneration of trees within agricultural

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fields by protecting seedlings and young trees, mostly indigenous tree species that have germinated from soil seed banks. In the sub-humid zones of Ethiopia, managing multi-purpose trees is widely adopted by farmers, as a dominant feature of agricultural landscapes (Yadessa et al., 2009).

The domestication and integration of important indigenous multi-purpose trees in the agroforestry system have several benefits (Negash, 2010; Girmay et al., 2015). They provide more than one significant benefit to the production or service functions of the land-use system. Mostly the people of Ethiopia cultivate indigenous tree species to provide food, charcoal, timber, fuel-wood and farm implements (Robi and Edris, 2017; Solomon and Moon, 2018). When deciding to retain trees, farmers consider different benefits and services which include income generation through selling timber, food in the form of fruit, fuelwood and other watershed benefits such as soil conservation and soil fertility improvement (Efte et al., 2014).

In Ethiopia, farmers generally prefer indigenous multipurpose tree species (Getaahun et al., 2014) because they are adapted to the environment and are already an integral part of the ecosystem (Negash et al., 2012). Besides, they are the paramount resource base for smallholder production systems because they reduce both water and wind erosion. Trees also improve soil fertility through nitrogen fixation and the addition and decomposition of nutrient-rich litter (Ebisa and Abelba, 2017; Latamo and Wondmagegn, 2020). Trees are also a source of fodder, fuel wood, nutrition and serve as insurance to households through income generation (Negash et al., 2012; Girmay et al., 2015; Negese and Motuma, 2021; Habte et al., 2021). They also have an important role in carbon sequestration, biodiversity conservation and micro-climate amelioration for cash crops like coffee (Gebrewahid et al., 2018; Yikunoamlak and Selamawi, 2019; Latamo and Wondmagegn, 2020; Habte et al., 2021).

Despite all these uses and services, the number of indigenous trees in farmland is seriously decreasing in many local communities (Bongers, 2010; Endale et al., 2017; Habte et al., 2021). This is due to a lack of scientific attention to farmers’ needs and the inadequate knowledge of policy makers in Ethiopia. There is also, a tendency to promote exotic species because they fulfill at least one traditional or cultural human need, such as a living fence, or a windbreak, or use in an alley cropping system for fodder or soil fertility restoration. Typically, they have one or more secondary roles, such as: family food (fruits/nuts/leaf), firewood, wood/timber for construction and soil and water conservation (Mulugeta et al., 2011; Diriba et al., 2011; Negash et al., 2012; Girmay et al., 2015).

2. Methods

2.1. Literature included, search methods and screening criteria

This systematic review was conducted between September 2020 and April 2021. A web-based systematic search was made of published research literature from different parts of Ethiopia. Especially documents published 2000-present (mainly from 2015) from Southern, Northern, Eastern, South-western, North-western, mid-rift valley and central highlands were included by using Google search engine, local university websites and international scientific databases. Based on the specified inclusion criteria, a total of 79 published papers were selected for this review, excluding documents that lacked information about the study areas and objectives. The identification of tree species indigenous to Ethiopia and their scientific names was based on the Natural Database for Africa (NDA), Version 2.0 (Ermias, 2011).

2.2. Criteria for selection of the tree species

The search was based on solely on indigenous multipurpose agroforestry tree species providing more than one benefit to farmers in a wide range of different mixtures with other crops and tree species in agroforestry systems and practices. The specific geographic location information was retrieved through internet searches (Google) and/or the database for Africa (NDA) Version 2.0 (Ermias, 2011).

3. Literature review

3.1. Concept of indigenous multipurpose trees

Indigenous tree species are those from the local area, region or biotone. They are presumed to be adapted to the specific ecological conditions predominant at the time of the establishment of the stand (FAO, 2000). They are also termed as native or autochthonous species. Multipurpose trees are defined as all woody perennials that are purposefully grown to provide more than one significant contribution to the production and/or service functions of a land-use system (Wood and Burley, 1991). They are trees deliberately managed for more than one output and classified according to their functional role in the agroforestry technology under consideration.

Multipurpose trees have a greater impact on a farmers’ well-being than exotic species because they fulfill at least one traditional or cultural human need, such as a living fence, or a windbreak, or use in an alley cropping system for fodder or soil fertility restoration. Typically, they have one or more secondary roles, such as: family food (fruits/nuts/leaf), firewood, wood/timber for construction and soil and water conservation (Mulugeta et al., 2011; Diriba et al., 2011; Negash et al., 2012; Girmay et al., 2015).

3.2. Major indigenous multipurpose trees species used for agroforestry in Ethiopia

A common reason for practicing agroforestry is for enhancing soil fertility to improve the productivity of tree and food crops on the same farm field (ICRAF, 2000). In Ethiopia, managing multipurpose trees such as Cordia africana, Millettia ferruginea, Albizia gummifera, Croton macrostachyus and Erythrina brucei is widely adopted by farmers as a dominant feature of agricultural landscapes (Yadessa et al., 2009). In the south of the country, Cordia africana, Ekebergia capensis, Olea capensis, Erythrina brucei, Millettia ferruginea, Citrus medica and Annona senegalensis are also important, especially within the homegardens where they are managed with farmers’ indigenous knowledge (Mesele, 2007; Takele et al., 2014; Alemu et al., 2017; Adane et al., 2019) (Table 1).

| Croton macrostachyus, Cordia africana, Vernonia amygdalina and Erythrina abyssinica are also common indigenous multipurpose tree species in west Hararge zone, on the eastern part of Ethiopia (Desalegn and Zebene, 2016). Millettia ferruginea and Cordia africana are being the most preferred woody species for retention and planting in homegardens in south-western parts of Ethiopia (Getaahun et al., 2014). In contrast, in Tigray, the fruit tree Cordia africana is an indigenous fruit trees and fodder trees Faidherbia albida (Acacia acacia), Acacia nilotica, Acacia seyal and Grewia bicolor are important in agroforestry systems (Efte et al., 2014). In addition to these, Albizia gummifera, Cordia africana, Croton macrostachyus and Vernonia amygdalina are popular in smallholder coffee farms in Ethiopia for coffee shade (Ebisa and Abelba, 2017).

From the tree species listed in Table 1 Acacia abyssinica, Albizia schimperiana, Citrus medica, Celtis africana, Erythrina brucei, Ficus vasa, Millettia ferruginea, Schefflera abyssinica, Vernonia schimperti and Oxytenanthera abyssinica are not included among the 670 species recorded in the ICRAF Agroforestry Database (http://apps.worldagroforestry.org/treedb/index.php?keyword=Boundary_barrier_support). From tree included in this review, only Acacia nilotica, Acacia seyal, Acacia tortilis, Olea europaea and Faidherbia albida are included in the ‘top-100’ tree species prioritized for planting in the tropics and subtropics (Kindt et al., 2021), with Olea europaea and Faidherbia albida being the species accorded high priority for conservation (Khoury et al., 2019). Trees such as Cordia africana, Acacia nilotica and Albizia gummifera are recognized as being commercial timber species in international timber trade (Mark et al., 2014).
3.3. Management strategies of indigenous multipurpose agroforestry trees species

3.3.1. Establishment of indigenous multipurpose trees in agroforestry systems

Farmers use naturally regenerated seedlings and cuttings as a source of planting material for indigenous tree species. These can be acquired from both garden and natural forest (Getahun et al., 2014) at minimal cost and grown in seedbeds and/or prepared sites. Alternatively, desirable naturally regenerated seedlings can be protected, marked and transplanted directly in farmland (Mesele, 2007; Nigussie et al., 2014). This use of seedlings from natural regeneration is a common way to replace old trees in their crop fields purpose (Nigussie et al., 2014; Desalegn and Zebede, 2016).

The size of open canopy gaps in the farms is a factor considered by farmers when deciding on the retention and/or planting of tree species (Mesele, 2007). Another source of planting stock is seedlings from government nurseries (Nigussie et al., 2014). The practice of protecting the existing natural regeneration, rather than raising seedlings in nurseries and then replanting them, has many advantages as it reduces labor and cost (Desalegn and Zebede, 2016).

3.3.2. Management practices for indigenous multipurpose trees in agroforestry systems

To maximize and harmonize survival with crops and animals, farmers in Ethiopia typically, prune, pollard, coppice or thin them in traditional agroforestry practices to ensure compatibility with different crops (Nigussie et al., 2014; Getahun et al., 2014; Desalegn and Zebede, 2016; Latamo and Wondmagegn, 2020). Such management practices in agricultural fields is important for soil fertility improvement through mulching, animal feed as fodder, shade reduction over integrated crops and to facilitate air circulation in stands for fuel wood, timber and construction wood (Getahun et al., 2014; Nigussie et al., 2014; Desalegn and Zebene, 2016; Latamo and Wondmagegn, 2020). These practices are also conducted when harvesting wood for fencing, house construction, firewood and also for market (Getahun et al., 2014). Pruning is especially important for managing tree crowns that have become too big, or when removing branches from the lower part of the crown for better tree-crop interaction (Nigussie et al., 2014; Desalegn and Zebene, 2016).

Pollarding involves cutting branches from the top of the tree to control the level of shade on coffee and Enset. Farmers in Sidama and Geddo in southern Ethiopia often pollard Cordia africana to promote the formation of shoots useful as construction poles and/or timber, as it is believed that pollarded Cordia africana tree provide more durable timber and wood products (Mesele, 2007; Latamo and Wondmagegn, 2020). Similarly, coppicing is also a traditional method of tree management to promote new growth from the stump or roots of felled trees. Coppice shoots are suitable for firewood, fencing and tool handles. This reduces the need to replant trees after harvesting (Desalegn and Zebene, 2016; Latamo and Wondmagegn, 2020).

Thinning is the process of removing unwanted shoots that are too slender for the desired size or economic value. The cut shoots can be used as building material, firewood, or even for sale (Latamo and Wondmagegn, 2020). In Gedeo agroforestry systems in southern Ethiopia, thinning management practices are undertaken when the crowns of trees start to cast excessive shade on crops below the canopy of tree (Mesele, 2007).

3.4. Productive roles of indigenous multipurpose agroforestry trees

A household normally maintains indigenous multipurpose trees in farmland for multiple useful and valuable purposes to optimize the capture and use of environmental resources (Mesele, 2007). This depends on the tangible uses that they render to the household (Negese and Motuma, 2021), such as: food, fodder, firewood, soil fertility, windbreak Abreha and Gebrekidan (2014); Gebrewahid et al. (2019); and a variety of different products (Tesfaye et al., 2010; Negash et al., 2012; Girmay et al., 2015). Other reasons for retaining woody species are associated with bee keeping and other forms of income generation (Mulugeta et al., 2011; Diriba et al., 2011; Getahun et al., 2014; Latamo and Wondmagegn, 2020). According to Abebe et al. (2008) indigenous multipurpose trees provide many benefits including food, fuel wood, construction wood, timber, furniture, resins, domestic uses of tools and honey from bees. Furthermore, trees accessible on the farmland provide socio-economic benefits and they are either planted or retained for provision of poles, construction materials and fodder (Habte et al., 2021).

3.4.1. Timber and construction wood

Fast growing indigenous species are being increasingly integrated in the traditional land-use practices, mainly for pole and construction wood in Ethiopia (Negash et al., 2012; Girmay et al., 2015). According to Desalegn and Zebene (2016), farmers maintained scattered tree species on their crop fields, mainly for its wood products. The walls of majority of rural household houses are constructed from timber of farm land origin in Jimma, southwest Oromia and indigenous trees are the most preferred species for the construction of doors, windows and their frames (Balcha, 2013).

Cordia africana is one of the best known indigenous woods for quality timber in Ethiopia (Diriba et al., 2011; Latamo and Wondmagegn, 2020).

Table 1. Major indigenous multipurpose agroforestry trees species in Ethiopia.

| Major trees species | Area in Ethiopia | Sources |
|---------------------|------------------|---------|
| Annona senegalensis, Citrus medica, Cordia africana, Ekebergia capensis, Erythrina brucei, Millettia ferruginea, Prunus africana, Ficus vauta, Syzygium guineense, Vernonia schimperi, Morenga stenopetalata and Olea capensis | Southern part of Ethiopia | Zebede and Ageres (2007); Mesele (2007); Mathewos et al. (2013); Takele et al. (2014a); Teklu (2016); Alemu et al. (2017); Adamu et al. (2019) |
| Cordia africana, Croton macrostachyus, Erythrina abyssinica and Vernonia amygdalina | Eastern parts of Ethiopia | Gindab et al. (2005); Desalegn and Zebede (2016) |
| Acacia abyssinica, Albizia gummifera, Albizia schimperiana, Cordia africana, Croton macrostachyus, Erythrina abyssinica, Ficus vauta, Schefflera abyssinica, Sesbania sebana and Millettia ferruginea | South-western parts of Ethiopia | Getahun et al. (2014); Nigussie et al. (2014); Tola et al. (2014); Hundera et al. (2015); Getahun et al. (2017); Habte et al. (2021) |
| Acacia nilotica, Acacia seyal, Balanites aegyptiaca, Capparis tomentosa, Carissa edulis, Citrus medica, Cordia africana, Faidherbia albida (Acacia albida), Ficus sycomorus, Grewia bicolor, Oxycarpanthera abyssinica, Dalbergia melanoxylon and Morenga stenopetalata | Northern parts of Ethiopia | Etefa et al. (2014); Gebrewahid et al. (2019); Gebre et al. (2020) |
| Acacia abyssinica, Albizia gummifera, Cordia africana, Croton macrostachyus, Erythrina brucei, Faidherbia albida (Acacia albida), Ficus vauta, Rhamnus prinoides and Vernonia amygdalina | Central highlands of Ethiopia | Yadesa et al. (2009); Duguma and Hager (2009); Ebisa and Abdela (2017); Negese and Motuma (2021) |
| Acacia tortilis, Acacia mellifera, Celtis africana, Grewia bicolor, Olea europaea, Dichrostachys cinerea and Balanites aegyptiaca | Mid Rift Valley of Ethiopia | Shenkute et al. (2012) |
| Acacia abyssinica, Albizia gummifera, Cordia africana, Croton macrostachyus and Erythrina abyssinica | North-western parts of Ethiopia | Linger (2014) |
Multipurpose tree species for house construction timbers are often planted in Gedeo multilayer agroforestry practices (Mesele, 2007), while in the Dawro zone of southern Ethiopia, local people use species such as *Cordia africana*, *Ficus vasta* and *Croton macrostachyus* for building and furniture purposes (Mathewos et al., 2013).

### 3.4.2. Household utensils and farm tools

People in Ethiopia make materials for their day-to-day uses from trees found in their agroforestry system. Agroforestry trees are also an important source of wood for household utensils and the handles of farm implements (Mesele, 2007), as well as for making beds, seats, baskets, plate and grinders, ploughs, cattle yokes and tool handles; to till the soil and remove weeds (Balcha, 2013; Latamo and Wondmagegn, 2020).

For instance, *Albizia schimperiana*, *Cordia africana* and *Prunus africana* are used to make ploughs while *Croton macrostachyus* and *Syzygium guineense* are used to make yokes. Tree species like *Millettia ferruginea* and *Prunus africana* are also preferred for constructing farm implements (Mesele, 2007).

### 3.4.3. Food value and cash generation

Multipurpose fruit trees are primarily consumed as food, especially during difficult times of drought. In north-western Ethiopia, the fruit tree species frequently used were indicators of how farmers are highly dependent on home grown food (Linger, 2014) and for marketed tree species frequently used were indicators of how farmers are highly dependent on home grown food (Linger, 2014). Indigenous tree species are also important as bee forage and wood from these trees is used in honey production, mainly conducted using traditional techniques and tools, with species like *Picus sur*, *Millettia ferruginea* and *Croton macrostachyus* used locally to make beehives (Mesele, 2007) and beehives are hung up on the branches of trees in agricultural land. Thus, the season of honey harvesting is associated with the flowering of trees like *Vernonia amygdalina*, *Schefflera abyssinica* and *Croton macrostachyus* (Tola et al., 2014) and *Cordia africana*, *Acacia spp* and *Vernonia schimperi* in Sidama and Gedeo agroforestry systems of southern Ethiopia (Teklu, 2016). *Cordia africana* is also a valuable fodder plant for honeybees due to its abundant supplies of pollen and nectar throughout the day (Latamo and Wondmagegn, 2020).

### 3.4.4. Fuel wood and fences

In rural Ethiopia, the dominant form of household energy is fuel wood and therefore there is a need to cultivate trees in farmland, where there is the opportunity to integrate trees with food crops in the land use system. Two common indigenous trees, *Millettia ferruginea* and *Prunus africana* are popular for fuelwood in Gedeo, southern Ethiopia (Tadesse, 2002), with both twigs and branches of these tree species being useful (Mesele, 2007).

Lines of densely planted trees are also important around farmyards and field boundaries as fencing in different parts of Ethiopia. *Syzygium guineense* and *Cordia africana* are the top two trees for this purpose in Gedeo and Sidama southern Ethiopia (Mesele, 2007; Latamo and Wondmagegn, 2020).

### 3.4.5. Fodder and bee forage values

Animal fodder from indigenous multipurpose tree species is consumed by animals, especially during dry season (Etefa et al., 2014). The edible parts of indigenous fodder trees are mostly leaves and in some species young tips, twigs and fruit pods rich in crude protein, minerals and energy (Takele et al., and 2014b) providing an important resource for small-scale farmers. They can maintain their feeding value for extended time due to their deep root system (Zomer et al., 2009).

In the mid rift valley of Ethiopia, indigenous trees such as *Acacia tortilis*, *Acacia mellifera*, *Celitis africana*, *Grewia bicolor*, *Olea europaea*, *Dichrostachys cinerea* and *Balanites aegyptiaca* are most favored by goats and also utilized by cattle and sheep (Shenkute et al., 2012). In southern Ethiopia, *Millettia ferruginea*, *Cordia africana*, *Erythrina brucei* and *Vernonia amygdalina* are also used for livestock feed and have potential to increase milk production at household level (Mesele, 2007; Takele et al., 2014b). In Tigray, *Faitheria albida* (*Acacia albida*), *Acacia nilotica*, *Acacia seyal* and *Grewia bicolor* are major indigenous fodder trees (Etefa et al., 2014).

Indigenous multipurpose trees are also used as honey bee forage. In Ethiopia, flowering indigenous trees important as bee forage and wood from these trees is used in honey production, mainly conducted using traditional techniques and tools, with species like *Picus sur*, *Millettia ferruginea* and *Croton macrostachyus* used locally to make beehives (Mesele, 2007) and beehives are hung up on the branches of trees in agricultural land. Thus, the season of honey harvesting is associated with the flowering of trees like *Vernonia amygdalina*, *Schefflera abyssinica* and *Croton macrostachyus* (Tola et al., 2014) and *Cordia africana*, *Acacia spp* and *Vernonia schimperi* in Sidama and Gedeo agroforestry systems of southern Ethiopia (Teklu, 2016). *Cordia africana* is also a valuable fodder plant for honeybees due to its abundant supplies of pollen and nectar throughout the day (Latamo and Wondmagegn, 2020).

### 3.4.6. Medicinal and cultural values

Indigenous trees throughout the tropics are the main and an important source of medicinal products for the healthcare system of local communities in the rural population. In Ethiopia, the ethno-medicinal healing systems vary across cultures and there is cultural diversity in various patterns of using the flora for medicinal purposes. In southern Ethiopia, multipurpose tree species such as *Vernonia amygdalina*, *Erythrina brucei* and *Millettia ferruginea* are used medicinally (Mesele, 2007) while *Croton macrostachyus* and *Moringa stenopetala* are well known medicinal plants for diseases like toothache and stomach-ache in Southern Ethiopia (Mathewos et al., 2013). *Croton macrostachyus* bark is pounded and dissolved in water and fragments of crushed leaves are inhaled to treat a distended stomach for both humans and animals. The inner bark of *Olea europaea* and *Albizia gummifera* is used to treat a disorder which causes loss of weight and dehydration of the digestive organs in cattle. Young buds of *Vernonia amygdalina* are chewed and swallowed by humans to cure heart diseases and gastrointestinal in Southern Ethiopia (Mathewos et al., 2013). Likewise, the bark of the *Cordia africana* tree is chewed for toothache and swallowed for abdominal pain, while ripe fruits are eaten during the morning for gastric problems. Succulent leaves used as a remedy for wounds (Reta, 2013; Latamo and Wondmagegn, 2020).

Plants are also used in social rituals and religious or spiritual ceremonies. *Cordia africana* and *Ficus sur* are recognized as sacred trees and serve to provide shade for elders during meeting places to resolve various social issues and while praying (Mesele, 2007 and Takele et al., 2014a). Beverages from *Rhamnus prinoides* are used in cultural and religious ceremonies and during family or other informal gatherings (Bongers, 2010). Thus, there is a critical and well recognized need for indigenous trees when conducting ceremonies, social gatherings and celebrating religious holidays (Seta et al., 2013).

### 3.5. Ecological services of indigenous multipurpose agroforestry trees

Both traditional and modern agroforestry are recognized as a land use option in which trees provide both products and environmental services for local people. Trees provide shade and mulch for the integrated enset-coffee systems to control soil erosion, regulate soil moisture and
temperature, improve soil nutrition, provide habitat for biodiversity and
so to create favourable conditions for crop growth (Zebene and Agren,
2007). By enhancing and sustaining the agro-ecological processes of soil
fertility management, indigenous multipurpose trees helps for land
improvement, erosion control and environmental air or atmosphere
balance (Abebe et al., 2008). Thus, farmers considered the existence of
these indigenous species crucial for the provision of ecosystem services in
the form of soil and water conservation (Dagninet et al., 2018), as well as
addressing a wide range of global challenges. In total, they are crucial for
more resilience to ecosystems, the mitigation of climate change and the
conservation of biodiversity (Rosenstock et al., 2019).

3.5.1. Conservation of biological diversity

In traditional Ethiopian agroforestry systems, the trees grown on
different farmlands in the same locality when aggregated bring about an
improved wooded situation that enhances environmental protection
playing a significant role in the conservation and maintenance of native
woody species (Yikunoamlak and Selemaiwi, 2019). According to Kabir
and Webb (2008) homesteads dominated by trees and a diverse array of
other plants in multiple strata make homesteads attractive to, and serve
as an important refuge for wildlife. Thus, they both conserve plant ge-
netic resources and are a form of in-situ conservation for biological di-
versity, both flora and fauna (Mulia et al., 2018; Habte et al., 2021).
Because homesteads are a widespread agroforestry system, they
therefore represent a large-scale land use system with potential for
biodiversity conservation (Kabir and Webb, 2008; Legesse and Negash,
2021), lessens the pressure on natural forests (Yikunoamlak and Sele-
maiwi, 2019).

3.5.2. Mitigation of climate change

Agroforestry system could play an important role in mitigating
climate change as it sequesters more atmospheric carbon in plant parts
and soil than the conventional mono-cropping farming systems (Mul-
hollem, 2018), enhanced by the presence of perennial trees (Negash
et al., 2012). Hence, a variety of multipurpose trees planted and main-
tained on farmers’ agricultural land have a role on carbon sequestration
(Gebrewahid et al., 2018) due to their above- and below-ground biomass
(Zomer et al., 2016). And is also a major contributor to the carbon pool in
global and national carbon budgets (Zomer et al., 2016). Multipurpose
trees in agroforestry systems also play an important role by providing
sinks for methane at the interface between the decaying fallen leaves and
the soil (Takele et al., 2014a). Together, therefore, scattered trees on
farmland could greatly contribute to the climate resilience of a green
ecosystem strategy (Negash and Starr, 2015; Gebrewahid et al., 2018). In
the south-eastern rift valley escarpment of Ethiopia indigenous agrofor-
estry systems sequestered a total biomass carbon stock averaging 67 Mg
ha
-1
with trees accounting for 39–93 % of carbon stock (Negash and
Starr, 2015). Betemariyam et al. (2020) have reported that homesteads
and adjacent coffee based agroforestry systems reduce emissions and
enhance carbon sinks on agricultural landscapes and so can be used in
other mixed cropping systems on cropland, pastureland, or rangeland
to address the threats of climate change while also improving microclimatic
conditions (Teketay and Teginhe, 2012).

3.5.3. Conserving and improving soil fertility

Trees usually become centers of variation in soil properties or islands
of fertility and indigenous agroforestry trees in traditional agroforestry
system are acknowledged for their capacity to restore fertility to
degraded land and so to boost crop yields. Part of this is due to the for-
mation of symbiotic associations with certain soil bacteria, rhizobia and
arbuscular mycorrhizal fungi (Zebene and Agren, 2007). These benefits
are linked to in-situ processes such as litter fall, root activities and
nutrient cycling (Yadessa et al., 2009). Mulching with tree leaves and
small shoots of species such as Ficus sur and Cordia africana also plays a
role in soil fertility management (Ebisa and Abdela, 2017) as has been
described by Tadesse (2002) for trees integrated into Gedeo’s agrofor-
estry systems to conserve soils and add organic matter.

Examples of the contribution of scattered trees of Cordia africana
to improve soil fertility in traditional agroforestry systems has been docu-
mented in Ethiopia (Teketay and Teginhe, 2012) with species like Cordia
africana, Millettia ferruginea and Croton macrostachyus (Hailu et al., 2000;
Gindaba et al., 2005; Desalegn and Zebede, 2016; Latamo and Wond-
magegn, 2020). In North Central and southern Ethiopia Cordia africana
and Milletta ferruginea have been considered the best for improving soil
fertility (Hailu et al., 2000; Kiroso et al., 2015) although Oxystemthera
abyssinica and Dalbergia melanoxylon trees are also highly regarded on
smallholder farms (Gebrewahid et al., 2019).

3.5.4. Serving for coffee shade

Ethiopia is an important country in coffee production, so trees
customly used for provision of coffee shade are widely retained/planted
and integrated in farming systems for both shade and for their socio-
economic roles (Nigussie et al., 2014; Hundera et al., 2015). The
preferred ‘shade’ species are morphologically characterized by whorled
and spreading crowns which regulate the interception of sunlight for
healthy coffee growth, while contributing leaf litter for fast decomposi-
tion (Hundera, 2016). These ‘shade’ species include Acacia abyssinica,
Albizia gummifera, Milletta ferruginea, Croton macrostachyus and Sesbania
sesban (Habte et al., 2021), although Cordia africana and Ficus sur are also
found growing in homesteads for providing shade for underneath
crops (Yadessa et al., 2009; Le mage and Legesse, 2018). Another
important function of species such as Cordia africana, Milletta ferruginea
and Erythrina abyssinica is that they protect coffee from heavy rain
(Nigussie et al., 2014). Acacia abyssinica is considered to be the most
favourable tree species for coffee shade in south-western Ethiopia
(Mulugeta et al., 2011) with Ficus vasta appreciated for its’ large canopy
(Dagninet et al., 2018).

3.6. Constraints on indigenous multipurpose agroforestry tree species

Despite the considerable uses and services provided to the household,
there are a number of constraints that cause the decrease of the indige-
nous tree species in farmland, such as inadequate research and extension
services, the expansion of exotic trees, land and tree tenure insecurity,
increased strategy towards market-oriented mono-cropping, the small
size of individual land-holdings and the expansion of invasive alien
species (Rongers, 2010; FAO, 2013; Endale et al., 2017).

Also, there is a common belief in many communities that introducing
trees into fields will negatively affect the growth of agricultural crops,
while the many positive effects of the trees in farmland are seldom
recognized (FAO, 2013). In Ethiopia, inadequate forestry and natural
resource education, research, and extension service and a lack of multi-
disciplinary approach at policy level are also constraining using indige-
nous multipurpose agroforestry tree species. Although, across Africa
there have been numerous studies to overcome the lack of sufficient in-
formation about indigenous trees, their characteristics and functions
(Leakey, 2007). With poverty a big issue in Africa, it is also important for
policy makers to be better informed about the income generation ca-
pacity of indigenous tree products, their environmental benefits (FAO,
2013) and some unique species specific characteristics that enhance
overall rural development and sustainability (Reubens et al., 2011).

Successful long-term agroforestry and tree planting strategies require
land tenure systems that guarantee continued ownership of land. Land
and tree tenure insecurity may also discourage people from planting trees
on farmland (FAO, 2013). In addition to these, there can be legal re-
strictions imposed by Government to prevent the harvesting; cutting and
sells of tree products of some species (EPN, 2005). Such protective measures further discourage farmers from planting and protecting new seedlings in their farm land. If people do not have title to land, there is no point in investing in trees which can take a long time for benefits to be realized. Farm household landholding size is also found to be the most important influencing factor that affects the diversity and planting tree species in farm lands (Legesse and Negash, 2021).

Another constraint to indigenous multipurpose tree species is the expansion of exotic tree species in the country (Guyassa and Raj, 2013; Molla and Kewessa, 2015). Studies conducted in different areas of Ethiopia have found that more than 50% tree species in farm land are exotic tree species (Bajigo and Tadesse, 2015; Endale et al., 2017); indicating the selling of tree products of some species (EPN, 2005). Such protective indigenous multipurpose tree species in Ethiopia are: producing marketable products for smallholder farmers, while at the same time playing important ecological roles. The most important indigenous multipurpose tree species in Ethiopia are: Cordia africana, Millettia ferruginea, Ficus vasta, Albizia gumifera, Croton macrostachyus, Faidherbia albida, Vernonia amygdalina, Acacia nilotica and Erythrina brucei. Farmers introduce these tree species by protecting naturally regenerated seedlings through marking and transplanting desirable ones into desired open spots on the farmlands. After establishment as mature trees, different management practices like pruning, pollarding, coppicing, thinning and lopping are applied to ensure compatibility of trees with different crops in agroforestry practices. Indigenous multipurpose trees provide many benefits including food, fuel wood, construction wood, timber, furniture, resins, domestic uses of tools and honey from bees. In addition to these, they also play major ecological roles through improving soil fertility, controlling erosion, mitigating climate change and conserving biological diversity. In spite of the considerable uses and services they provide to local households, inadequate research and extension service, expansion of exotic trees, little scientific attention towards indigenous tree species, land and tree tenure insecurity, increased strategy towards market-oriented mono-cropping and landholding size constrained them and declined their abundance in farmland. Therefore, agroforestry practice with indigenous multipurpose tree species should be encouraged by the government through improving research and extension services. In addition to this, informed and guiding decisions should be made by policy makers and agricultural development interventions regarding further research on indigenous multipurpose tree species.

4. Conclusion

Indigenous multipurpose agroforestry tree species are intensively being integrated in agroforestry practices in Ethiopia due to their role in producing marketable products for smallholder farmers, while at the same time playing important ecological roles. The most important indigenous multipurpose tree species in Ethiopia are: Cordia africana, Millettia ferruginea, Ficus vasta, Albizia gumifera, Croton macrostachyus, Faidherbia albida, Vernonia amygdalina, Acacia nilotica and Erythrina brucei. Farmers introduce these tree species by protecting naturally regenerated seedlings through marking and transplanting desirable ones into desired open spots on the farmlands. After establishment as mature trees, different management practices like pruning, pollarding, coppicing, thinning and lopping are applied to ensure compatibility of trees with different crops in agroforestry practices. Indigenous multipurpose trees provide many benefits including food, fuel wood, construction wood, timber, furniture, resins, domestic uses of tools and honey from bees. In addition to these, they also play major ecological roles through improving soil fertility, controlling erosion, mitigating climate change and conserving biological diversity. In spite of the considerable uses and services they provide to local households, inadequate research and extension service, expansion of exotic trees, little scientific attention towards indigenous tree species, land and tree tenure insecurity, increased strategy towards market-oriented mono-cropping and landholding size constrained them and declined their abundance in farmland. Therefore, agroforestry practice with indigenous multipurpose tree species should be encouraged by the government through improving research and extension services. In addition to this, informed and guiding decisions should be made by policy makers and agricultural development interventions regarding further research on indigenous multipurpose tree species.

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Author contribution statement

Lamamo Lelamo have significantly contributed to the development and the writing of this article.

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