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Review article

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 bicolour* are found in the northern part of Ethiopia. *Albizia gummifera, Cordia africana, Croton macrostachyus*, *Ficus 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 multipurpose 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 (Etefa et al., 2014).

In Ethiopia, farmers generally prefer indigenous multipurpose tree species (Getahun 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 Abdela, 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 Selemawi, 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 tree species with different uses (FAO, 2013; Molla and Kewessa, 2015). This review focuses on the role of indigenous multipurpose agroforestry tree species found in different parts of Ethiopia and examines relevant management strategies. It also investigates their productive and service roles to farmers and identifies constraints on these important agricultural resources, which are economic bases of smallholder farmers.

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 biotope. 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., 2014a; 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 (Getahun et al., 2014). In contrast, in Tigray, the fruit tree *Cordia africana* is an indigenous fruit trees and fodder trees *Faidherbia albida* (*Acacia albida*), *Acacia nilotica, Acacia seyal* and *Grewia bicolour* are important in agroforestry systems (Etefa 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 Abdela, 2017).

From the tree species listed in Table 1 *Acacia abyssinica, Albizia schimperiana, Citrus medica, Celtis africana, Erythrina brucei, Ficus vasta, Millettia ferruginea, Schefflera abyssinica, Vernonia schimperi* 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).

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 vasta*, *Syzygium guineense*, *Vernonia schimperi*, *Moringa stenopetala* and *Olea capenssis*	Southern part of Ethiopia	Zebene and Agren (2007); Mesele (2007); Mathewos et al. (2013); Takele et al. (2014a); Teklu (2016); Alemu et al. (2017); Adane et al. (2019)
Cordia africana, *Croton macrostachyus*, *Erythrina abyssinica* and *Vernonia amygdalina*	Eastern parts of Ethiopia	Gindaba et al. (2005); Desalegn and Zebene (2016)
Acacia abyssinica, *Albizia gummifera*, *Albizia schimperiana*, *Cordia africana*, *Croton macrostachyus*, *Erythrina abyssinica*, *Ficus thonningii*, *Ficus vasta.*, *Schefflera abyssinica*, *Sesbania sesban* 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 bicolour*, *Oxytenanthera abyssinica*, *Dalbergia melanoxylon* and *Moringa stenopetala*	Northern parts of Ethiopia	Etefa et al. (2014); Gebrewahid et al. (2019); Gebru et al. (2020)
Acacia abyssinica, *Albizia gummifera*, *Cordia africana*, *Croton macrostachyus*, *Erythrina brucei*, *Faidherbia albida* (*Acacia albida*), *Ficus vasta*, *Rhamnus prinoides* and *Vernonia amygdalina*	Central highlands of Ethiopia	Yadessa 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)

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 Zebene, 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 Zebene, 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 Zebene, 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 Gedio 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; Negese and Motuma, 2021). 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., 201; Latamo and Wondmagegn, 2020).

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 macrostachys* 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 products to improve family financial status and cash income to buy food and clothes, as in the west Hararge zone, Oromia region, Ethiopia (Desalegn and Zebene, 2016). Indigenous tree species are also intentionally retained and planted for their fruit in Tigray region, northern Ethiopia (Etefa et al., 2014). *Citrus medica* and *Annona senegalensis* are important indigenous fruit tree species in Sidama, southern Ethiopia (Adane et al., 2019). In Tigray, fruits of *Cordia africana* tree are collected and eaten or sold by women and children when grown in farms or backyards (Tewoldeberhan et al., 2013).

Cash from on-farm trees helps farmers to meet unexpected expenditure, particularly during seasonal droughts and off seasons (Mesele, 2007). Trees create opportunities for employment and contribute to the both regional and national economy. Children and women make money by selling fruits of some tree species found in agricultural landscapes in Tigray region, northern Ethiopia (Etefa et al., 2014). Indigenous multipurpose fodder trees are providing marketable products and creating opportunities to improve household incomes in southern Ethiopia (Takele et al., 2014b). Some of the mentioned advantages such as wood, honey, timber, and medicinal importance have high commercial values and improve cash generation potential for farmers (Diriba et al., 2011). Trees like *Cordia africana* are used by farmers as a security which can provide cash income and used as risk aversion alternative during poor rainy seasons (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*, *Celtis 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 ferru*ginea, *Cordia africana, Erythrina brucei* and *Vernonia amygdalina* are also used for livestock feed andhave potential to increase milk production at household level (Mesele, 2007; Takele et al., 2014b). In Tigray, *Faidherbia albida* (*Acacia albida*), *Acacia nilotica, Acacia seyal* and *Grewia bicolour* 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 *Ficus 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 ferrugine* 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 fragrances 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 gastroenteritis 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 Selemawi, 2019). According to Kabir and Webb (2008) homegardens dominated by trees and a diverse array of other plants in multiple strata make homegardens attractive to, and serve as an important refuge for wildlife. Thus, they both conserve plant genetic resources and are a form of *in-situ* conservation for biological diversity, both flora and fauna (Mulia et al., 2018; Habte et al., 2021). Because homegardens 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 Selemawi, 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 (Mulhollem, 2018), enhanced by the presence of perennial trees (Negash et al., 2012). Hence, a variety of multipurpose trees planted and maintained 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 economy strategy (Negash and Starr, 2015; Gebrewahid et al., 2018). In the south-eastern rift valley escarpment of Ethiopia indigenous agroforestry 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 homegardens 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 Tegineh, 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 formation 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 agroforestry 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 documented in Ethiopia (Teketay and Tegineh, 2012) with species like *Cordia africana, Millettia ferruginea* and *Croton macrostachyus* (Hailu et al., 2000; Gindaba et al., 2005; Desalegn and Zebene, 2016; Latamo and Wondmagegn, 2020). In North Central and southern Ethiopia *Cordia africana* and *Millettia ferruginea* have been considered the best for improving soil fertility (Hailu et al., 2000; Kiros et al., 2015) although *Oxytenanthera 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 commonly 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 decomposition (Hundera, 2016). These 'shade' species include *Acacia abyssinica, Albizia gummifera, Millettia ferruginia, Croton macrostachyus* and *Sesbania sesban* (Habte et al., 2021), although *Cordia africana* and *Ficus sur* are also found growing in homegardens for providing shade for underneath crops (Yadessa et al., 2009; Lemage and Legesse, 2018). Another important function of species such as *Cordia africana, Millettia 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 indigenous 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 (Bongers, 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 multidisciplinary approach at policy level are also constraining using indigenous multipurpose agroforestry tree species. Although, across Africa there have been numerous studies to overcome the lack of sufficient information about indigenous trees, their characteristics and functions (Leakey, 2017). With poverty a big issue in Africa, it is also important for policy makers to be better informed about the income generation capacity 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 restrictions imposed by Government to prevent the harvesting; cutting and

selling 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 trees in the country (Guyassa and Raj, 2013; Molla and Kewessa, 2015). Studies conducted in different areas of Ethiopia have found that more than 30% tree species in farm land are exotic tree species (Bajigo and Tadesse, 2015; Endale et al., 2017); indicating the expansion of the exotic tree species into the croplands at the expense of the native trees. However, in contrast, Legesse and Negash (2021) have found that in Kachabira district of southern Ethiopia; native species comprise a larger portion than introduced species. With species like *Catha edulis, Coffea arabica* generating cash income (Habte et al., 2021), although a mono-cropping approach is negatively affecting the traditional parkland agroforestry systems (Endale et al., 2017).

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 gummifera*, *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.

Declarations

Author contribution statement

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

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