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Original Article

Review on Socio-Ecological Contribution of Agroforestry Practices in Ethiopia

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ABSTRACT

Agroforestry is often defined as a practice that provides multiple economic, social, and ecological benefits. It is a novel approach that can safeguard agricultural sustainability, provide livelihood opportunities, yield ecological benefits, and contribute to household food security. However, comprehensive studies on the socio-ecological contributions of agroforestry are limited due to a lack of evidence. Therefore, a comprehensive review was conducted to analyze and compile various fragmented findings into one cohesive piece of evidence. The review utilized both qualitative and quantitative approaches to explore the socio-economic and ecological components of agroforestry. The findings revealed that there are different integration levels of tree components with crops or livestock within the three agroforestry systems (agrosilvopastoral, silvopastoral, and agrisilvicultural). Dominant agroforestry practices in various regions of Ethiopia include home gardens, hedgerows, intercropping, perennial tree-crop systems, woodlots, scattered trees on farms, and parkland agroforestry. Agroforestry provides socioeconomic benefits through timber and non-timber tree products, as well as improved crop yields compared to monocrops. Additionally, agroforestry plays a role in soil and water management, carbon sequestration, deforestation reduction, and biodiversity preservation. The review indicated that agroforestry can store 61-85% or 2.1-115.7 Mg of carbon per hectare. Various socio-economic, institutional, and biophysical factors influence different agroforestry practices. The review results suggest that policymakers and extension agents should consider these contextual factors and potential benefits to encourage the wider expansion of agroforestry practices.

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INTRODUCTION

Agroforestry is a form of land use practice that integrates trees with crops or livestock components to provide a means of diversified farm and forest production, ensuring sustainable forest management and utilization (Chucha et al., 2022). Agroforestry practices (AFP) bridge the gap that often separates agriculture and forestry production by building integrated systems to achieve both ecological and socio-economic objectives on one piece of land (Castle et al., 2022). Currently, it is a promising land use system to address the increasing global climate change issues by integrating environmental, economic, and social benefits. Specifically, it is promoted for its potential for carbon sequestration, soil erosion control, runoff control, improved water cycling and nutrient cycling, as well as providing socio-economic benefits and enhancing agricultural productivity (Razatndratsima et al., 2021). Agroforestry is also essential for sustainable production, improved food security, enhanced water quality, poverty reduction, combating climate change, and biodiversity loss to achieve the UN 2030 Sustainable Development Goals (SDG) (Waldron et al., 2017; Agroforestry Network, 2018).

Currently, agroforestry has increasingly received recognition by governments and NGOs and is considered in national and international policy initiatives, programs, guidelines, and frameworks (Miller et al., 2020; Köthke et al., 2022). Globally, 45% of all farmers have more than 10% tree cover on their lands, making private farming an integral part of the global forest cover (Wondimneh, 2023). Agricultural land has the potential to store a total of 45.3 billion metric tonnes of carbon, with trees accounting for more than 75% of the total agricultural land carbon storage (Gassner and Dobie, 2022). In the African context, including Ethiopia, agroforestry has a significant contribution towards reducing poverty and resource degradation (Adane et al., 2019). Currently, practices are being implemented using low-cost technologies across Africa to support poverty reduction, improve food security, and enhance the livelihoods of resource-poor farmers.

It is known that the Ethiopian economy relies on agriculture and accounts for half of the gross domestic product (GDP), 83.9% of exports, and 80% of total employment for the rural population of Ethiopia (Dilla et al., 2020). This agricultural practice calls for great attention to the implementation of Agroforestry Practices (AFPs) and the utilization of products from forest resources that are declining over time for the security of the remaining natural forest endowments (Hounsou-dindin et al., 2021). Farmers are familiar with AFP and its economic, social, and environmental benefits to sustain human and ecological systems (Jiru, 2019; Getnet et al., 2023). Recently, several types of AFPs have been conducted by different smallholders based on socio-economic and biophysical characteristics and conditions in different parts of the country, such as coffee shade-based systems, scattered trees on farmlands, home gardens, woodlots, farm boundary tree planting, and trees on grazing lands (Dobo et al., 2018; Eshetu et al., 2018; Jemal et al., 2018; Amare et al., 2019).

Despite the publication of different AFPs and benefits, the current rate of agroforestry adoption in developing countries, including Ethiopia, remains relatively low (Eskandar et al., 2016; Mukhlis et al., 2022). The absence of comprehensive evidence on agroforestry in public policy leads to little recognition of tree-based systems to tackle the current climate crisis and improve the socio-

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economic well-being and rural livelihoods of the community (Bishaw et al., 2013). This may be due to a lack of comprehensive evidence that compiles different fragmented studies related to the socio-economic and ecological aspects of agroforestry (Mukhlis et al., 2022). Furthermore, previous studies focused on one aspect of agroforestry at the farm level, making the outcomes difficult to generalize as they might be context-specific and limited to local conditions.

Therefore, to compile agroforestry studies in different parts of Ethiopia, this research review gives special emphasis to evidence depicting the socio-economic and ecological contribution of agroforestry. The primary objective of the review is to identify different AFPs, socio-economic contributions, ecological contributions, and existing factors affecting the implementation of AFPs in Ethiopia. A comprehensive literature review reveals an impressive range of socio-economic and ecological benefits from agroforestry to provide organized research evidence to concerned bodies and stakeholders.

THEORY OF CHANGE IN AGROFORESTRY PRACTICES

There are several pathways through which agroforestry can deliver socio-economic and ecological benefits. Once a farmer adopts agroforestry, they may see improved soil health and other ecological services such as enhanced water infiltration and reduced nutrient runoff, leading to increased crop productivity or lower production costs and, consequently, higher returns (Castle et al., 2022). Some agroforestry farmers may experience increased use and availability of tree or shrub fodder and shade, resulting in higher animal product production and returns. Selling other agroforestry products like timber, firewood, fruit, and nuts can also boost income and diversify food sources (Dosskey et al., 2017; Lovell et al., 2018; Wolz et al., 2018). Collectively, these outcomes are expected to enhance resilience to shocks, as well as improve overall farmer income and food security. Agroforestry is often analyzed from the perspective of the Theory of Planned Behaviour (Amare and Darr, 2023; Buyinza et al., 2020), where subjective norms, attitudes, and perceived behavior control factors influence farmers' planting intentions and behavior. There are biophysical, socio-economic, and psychological factors that influence the adoption of agroforestry innovations, as demonstrated in Pakistan (Ahmad et al., 2023), Ethiopia (Amare and Darr, 2023), Indonesia (Cahyono et al., 2020), and Uganda (Buyinza et al., 2020). Social norms, social structures, and communities play a central role in agroforestry adoption, especially for farmers lacking agroforestry knowledge. Access to conventional knowledge alone is not sufficient to promote agroforestry adoption. Studies have also shown that the positive benefits of agroforestry have driven the adoption of agricultural innovations (Amare and Darr, 2023; Buyinza et al., 2020).

There are two theories in agroforestry studies: the user context model and the economic constraint model (Jha et al., 2021). The user context model suggests that farmers' adoption and behavior are influenced by socio-economic factors, institutional conditions, and agroecological conditions (Amadu et al., 2020). On the other hand, the economic constraint model focuses more on external resources, particularly macroeconomic factors such as interest rates, unemployment, and economic growth, which can either encourage or hinder agroforestry. This is also supported by the theory of planned behavior, which highlights the role of attitudes, norms, intentions, and behaviors of adopters (Ajzen and Fishbein, 1980). As a result, agroforestry has been shown to increase agricultural productivity in Malawi (Amadu et al., 2020), Tanzania (Jha et al., 2021), Ethiopia (Bishaw et al., 2013; Endale, 2019), and North-Eastern Europe (Elbakidze et al., 2021). Currently, agricultural yields have significantly increased, accompanied by rises in the income of smallholders who rely on agriculture as their main livelihood (Adane et al., 2019). Additionally, agroforestry is crucial for

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enhancing the adaptive capacity of farmers, building resilience in the agricultural system (Jha et al., 2021), and ensuring better quality-of-life outcomes (Elbakidze et al., 2021).

METHODOLOGY

In this study, both qualitative and quantitative review approaches were conducted to compile previously published articles related to the socioeconomic and ecological benefits of agroforestry. The review of this paper was conducted between August 2023 and January 2024. The systematic review consists of a summary of scientific research articles using systematized methods with previously defined protocols (Pati and Lorusso, 2018). The review of this paper was developed based on the methods and protocols established by Sampaio and Mancini (2007). This method is organized into defining the questions, searching for evidence, reviewing and selecting studies, analyzing the methodological qualities of the studies, and finally presenting the results of selected articles.

The review was conducted through a comprehensive search using multiple sources to best capture an unbiased representation of existing literature. The searches were carried out on multiple bibliographic databases and relevant organizations webpages. The bibliographic databases were searched for publications found in SCOPUS, EBSCO, Agricola, Web of Science, CAB Abstracts, etc. The search strings were checked in the title, abstract, and keywords. The reviewed documents were identified from various regions of Ethiopia and were published in the context of the socioeconomic and ecological contribution of agroforestry. The reviewed articles that lacked details regarding the study paper topic and objectives were excluded from the final selected papers.

RESULTS AND DISCUSSION

Types of Agroforestry Systems and Practices

The context of agroforestry systems and practices is defined by the reviewed studies which were categorized and described in *Table 1*. The definitions and categories of agroforestry were considered and classified based on the functions or arrangement of agroforestry components. Therefore, agroforestry types were assigned to the level of aggregation that the review studies applied in presenting the results. The most common set of criteria used to classify agroforestry systems and practices are the structural basis (the composition and arrangement of the components), purposeful basis (the main operation or role of components), socio-economic basis (the scale of arrangement and goals of the system) and ecological basis (the environmental and ecological quality of systems) (Tamirat and Mekides, 2020).

Trees are the main components of agroforestry systems and are characterized by different practices, components, and functions (*Table 1*). The review results showed that agrosilvopastoral systems are characterized by AFPs such as home gardens with animals, and fodder trees/shrubs on farmlands. Similarly, different components of agroforestry such as trees/shrubs, food and cash crops, vegetables as well as livestock make up the agrosilvopastoral agroforestry system. The functions of components also played by the agrosilvopastoral system include the provision of food, fuelwood, fodder, finance, soil fertility improvement, erosion control, wind control, climate mitigation, etc. (*Table 1*).

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Table 1: Summary of different agroforestry systems and practices categorization

Agroforestry systems	Practices	Components
Agrisilvicultural system: (Crop +trees)	Shaded perennial-crop systems, multi-strata agroforestry	Perennial crops shaded with trees, e.g. shaded coffee, multilayer plant association
	Alley cropping, intercropping	Trees/shrubs planted in alleys or another spatial arrangement, intercropped with crops, e.g. intercropped apple orchards, shade trees for cash crops
	Multipurpose trees, parklands	Trees scattered on farmland with crops
	Windbreaks, buffer strips, hedgerows	Trees/shrubs around cropland to protect the farmland, e.g. as windbreaks, including riparian buffers between cropland and water bodies/rivers
	Home gardens, tree gardens	Combinations of trees and crops around homesteads
Silvopastoral system:(Trees +livestock)	Trees/shrubs on pasture	Trees/shrubs on pasture or rangelands
	Shelterbelts, living fences for fodder	Trees/shrubs are used as fences for pastures, for fodder or as shelterbelts for animals
Agrosilvopastoral system: (Crop +trees + livestock	Multipurpose hedgerows (mulching, fodder)	Woody hedges coppiced for multi-purposes, such as fodder/browse, mulch, green manure
	Scattered trees, parklands	Trees scattered in the landscape which are combined with pasture/grazing animals and/or crops or are used for mulch and/or fodder

Source: (Bishaw et al., 2013; Abate, 2020; Tamirat and Mekides, 2020; Köthke et al., 2022).

The second type of agroforestry system is silvopastoral which is characterized by two AFPs: trees on pastureland and planted fodder trees/shrubs. The main components of this system are trees/shrubs as well as fodder trees/shrubs (*Table 1*). Likewise, the major functions of this system are the provision of fodder, food, fuelwood, shade, climate moderation, and many other functions. The third, or last, type of agroforestry system is Agrisilvicultural which is the most common system practiced by farmers. It is characterized by a large number of agroforestry practices which include home garden live fences, windbreaks, trees on croplands, coffee-based plantations, improved fallows, etc. (*Table 1*). Under this system, components such as trees/shrubs, food, cash crops, and vegetables are included. It has an important function regarding the provision of food, fuelwood, soil fertility improvement, finance, climate change control, shade, erosion control, and others.

In the context of Ethiopia, the most common AFPs are home gardens, parkland agroforestry (such as scattered trees on the farmland), hedgerow intercropping, woodlots, farm boundaries, trees on grazing lands, riparian zone vegetation, enclosures and natural regeneration of species in woodlands and pasture, live fences and roadside plantations, etc. (Ereso, 2023). Most of the AFPs in the country are location-specific based on differences in agroecological conditions and types of niches (Gebru et al., 2019). For example, parkland agroforestry includes maize intercropping with *Cordia africana* in Bako and Western Ethiopia as well as *Faidherbia albida*-based agroforestry in the Hararghe Highlands and Bushoftu area (Ereso, 2023). In different areas of southern and south western Ethiopia, multistorey home gardens are also prevalent. The structural complexity of home gardens varies rangeland from complex and diversified forms comprising several species such as those found in Sidama. The results showed that

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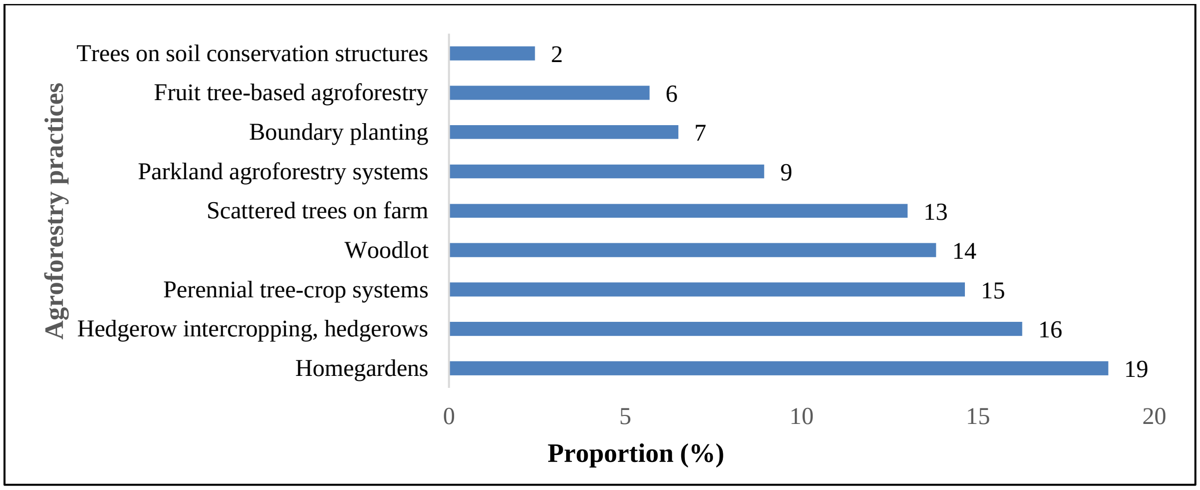
the majority of farmers grew home garden AFPs (*Figure 1*). Next to home gardens, hedgerows and intercropping are the dominant practices followed by perennial tree-crop systems, woodlots, scattered trees on farms, and parkland agroforestry (*Figure 1*). Other few farmers engage in boundary planting, fruit tree-based agroforestry, and trees on soil conservation structures.

Figure 1: Proportion of publications searched in different agroforestry practices



Socio-Economic and Ecological Contribution of Agroforestry

Socio-Economic Contribution

Different agroforestry practices offer a range of socio-economic benefits for farmers beyond just improving crop productivity (*Table 2*). Multipurpose trees in agroforestry provide various benefits, including food, fuelwood, construction materials, timber, furniture, resins, household utensils, and other socio-economic advantages (Lelamo, 2021). From an economic standpoint, adopting tree-based farming can enhance economic resilience through diversifying products (Amare et al., 2019; Amare and Darr, 2023). The use of multipurpose trees can boost the profitability of agroforestry and serve different functions, such as providing alternative incomes, sources of fodder or food during times of scarcity, enabling rural communities to withstand various shocks (Gebru et al., 2019). Furthermore, certain wood products have a higher economic value, offering additional income for rural communities beyond what is earned from annual crops.

Table 2: Summary of agroforestry contribution for socio-economic components

Agroforestry practice	Socioeconomic benefits	Source
Home gardens	Food, firewood, medicinal use, fodder, shade, income, construction material, household items and timber	Jemal et al. (2018); Betemariyam et al. (2020); Furo et al. (2020); Manaye et al. (2021); Sahle et al. (2021)
Hedgerow intercropping, hedgerows	Fodder, firewood, wood, timber	Hafner et al. (2021)
Perennial tree-crop systems	Food, fodder, firewood, timber, income, poles, medicinal use, construction material	Bullock et al. (2014); Gwali et al. (2015); Biazin et al. (2018); Admasu and Jenberu (2022); Sebuliba et al. (2022)

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Agroforestry practice	Socioeconomic benefits	Source
Woodlot	Wood, firewood, fodder, income, timber, construction material	Gebreegziabher and van Kooten (2013); Mukangango et al. (2020); Reppin et al. (2020)
Scattered trees on the farm	Income, firewood, fodder, charcoal, gum arabic, resin, wood	Kalame et al. (2011); Reppin et al. (2020); Mekonnen et al. (2021)
Parkland agroforestry systems	Food, fodder, firewood, income, shade, timber, charcoal, construction material, farm implements / tools	Chiemela et al. (2018); Fahmi et al. (2018); Birhane et al. (2019); Tadesse et al. (2019); Tadele et al. (2020)
Boundary planting	Fodder, food, firewood, income, shade, timber, charcoal, wood, poles, bee forage	Duguma (2013); Nigatu et al. (2020); Reppin et al. (2020); Manaye et al. (2021); Fuchs et al. (2022)
Fruit tree-based agroforestry	Income, food	Admasu and Jenberu (2022)
Trees on soil conservation structures	Food, fodder, firewood, green manure, staking material	Nigatu et al. (2020); Cyamweshi et al. (2021)
Agroforestry in general	Fodder, food, income, medicine, fuel wood, farm implements, and utensil wood	Ereso (2023)
Agroforestry in general	Diversify income and food sources	Lovell et al. (2018); Wolz et al. (2018); Dosskey et al. (207).

Rain-fed agriculture is the primary source of livelihood for most farmers in the country where agroforestry practices are implemented. Both non-timber forest products (NTFP) and timber forest products (TFP) such as fruit, firewood, honey, spices, timber, poles, and charcoal generate income for smallholders (Melaku, 2014; Birhane et al., 2019; Nigatu et al., 2020; Manaye et al., 2021). The amount of income varies from place to place, but the additional income plays a significant role in improving farmers' livelihoods, especially during times of climate-related shocks affecting crop production, such as climate change (Kebebew and Urgessa, 2011; Eshetu et al., 2018; Cheru and Haile, 2023; Ereso, 2023).

Studies have shown that farmers in the Kaffa zone obtained 47% of their income from NTFPs (Melaku, 2014), while those in the Wolayita zone earned between 800 to 1500 Ethiopian Birr (ETB) from these products (Agize et al., 2016), and farmers in the Jimma zone earned 1683 ETB from home garden agroforestry (Melaku et al., 2014). Other research has indicated that home garden agroforestry contributes about 35% of annual household income in the Wolayita zone (Atiso and Fanjana, 2020), fruit tree-based agroforestry practices provide an average income of 2754 ETB per year in the Sidama zone (Adane et al., 2019), and agroforestry in general contributes an average income of 32,199.16 ETB for farmers in Eastern Ethiopia (Hailu and Alemie, 2024).

Agroforestry also plays a crucial role in climate change adaptation through diversified land-use practices, sustainable livelihoods, income sources, enhanced forest and agricultural productivity, and reduced weather-related production losses, ultimately enhancing resilience against climate impacts (Gifawesen et al., 2020). More than half of the plant species in home garden agroforestry are edible for household members, contributing up to 30-40% of household income (Wolde and Desalgn, 2020).

Ecological Contribution of Agroforestry

Contribution For Mitigation of Climate Change

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The other dimension of agroforestry benefit is ecological contribution related to soil fertility improvement, soil erosion control, climate change mitigation, and conservation of biological diversity (Lelamo, 2021). Among ecological benefits, climate change mitigation is one benefit provided by agroforestry (*Table 3*). The inclusion of trees in croplands and pasturelands through agroforestry practices could lead to reduced greenhouse gas (GHG) emissions into the atmosphere in three ways. First, trees provide greater above and below-ground biomass compared to herbaceous vegetation, with almost 50% of the dry mass being carbon (Pellikka et al., 2018).

Agroforestry could play an important role in mitigating climate change as it sequesters more atmospheric carbon in plant parts and soil than conventional mono-cropping farming systems (Mulhollen, 2018). Hence, a variety of multipurpose trees planted and maintained on farmers' agricultural land have a role in carbon sequestration (Gebrewahid et al., 2018) due to their above and below-ground biomass (Zomer et al., 2016). Additionally, agroforestry is a major contributor to the global carbon pool and national carbon budgets (Zomer et al., 2016). For example, scattered trees on farmland could greatly contribute to the climate resilience of a green economy strategy in Ethiopia (Negash and Starr, 2015; Gebrewahid et al., 2018). Agroforestry sequestered a total biomass carbon stock averaging 67Mg per hectare with trees accounting for 39-93% of the carbon stock in the south-eastern rift valley escarpment of Ethiopia (Negash and Starr, 2015). Home gardens and adjacent coffee-based agroforestry reduce emissions and enhance carbon sinks on agricultural landscapes and can be used in other mixed cropping systems on cropland, pastureland, or rangeland to address the threats of climate change (Betemariyam et al., 2020).

Biomass and carbon storage largely depend on the agroforestry in place, the structure, and function, contributing 61-85% of carbon storage (*Table 3*). Findings demonstrated that trees in agroforestry accounted for 61-79% of carbon storage, which was on average 73% of the carbon in agroforestry (Getnet et al., 2023). Similarly, Negash and Starr (2015) and Betemariyam et al. (2020) found that 77% and 67-85% of carbon storage accounted for agroforestry practices, respectively. For example, in southern Ethiopia, agroforestry has a mitigation potential of 772.02 Mg CO_2e per hectare (Molla and Kewessa, 2019) and 27.2± 13.5 Mg CO_2e per hectare per year (Kim et al., 2016). Moreover, other studies found that 63.1 Mg per hectare (Betemariyam et al., 2020) and 58.3 Mg per hectare (Mohammed and Bekele, 2014) of carbon was stored from coffee-based agroforestry in southwest Ethiopia.

Contribution to Soil and Water Management

The agroforestry land use option provides improvements in soil and water management as an ecological function for local peoples (*Table 3*). Trees in agroforestry systems offer shade and mulch for the integrated insect-coffee agroforestry practice to control soil erosion, regulate moisture and temperature, and enhance soil nutrition, creating favorable conditions for crop growth (Lelamo, 2021). Agroforestry plays a crucial role in land improvement and erosion control by enhancing and sustaining the agroecological processes of soil fertility management (Sileshi et al., 2020). Therefore, farmers consider the presence of these tree species essential for providing ecosystem services in the form of soil and water conservation to address a wide range of global challenges (Amare et al., 2018).

The interaction of trees and crops in different agroforestry systems is a significant contributor to improving soil fertility, which in turn affects crop productivity (Dori et al., 2022). In Ethiopia, agroforestry is a key soil management option among various alternatives, crucial for enhancing soil nutrient and physical properties and restoring soil fertility (Wolle et al., 2021; Mebrate et al., 2022). Additionally, agroforestry serves as a suitable and

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effective management option for both economic and ecological aspects to increase soil nutrient concentration, enhance water use efficiency, and improve soil quality and health to sustain production and benefits (Asfaw, 2016).

Contribution of Agroforestry Practice for Forest and Biodiversity Conservation

Agroforestry systems can play a significant role in the conservation of plant species by providing a variety of habitats for different species (*Table 3*). Agroforestry provides habitat for wildlife, supports high biodiversity conservation, and promotes the natural regeneration of native species, which can help restore plant diversity in an area (Behanu and Asfaw, 2014). For example, in the highlands of Ethiopia, traditional agroforestry tree management has provided refuge for a considerable number of native woody species (Abate, 2020). It is possible that these native tree and shrub species are still preserved as farmland tree resources and will serve as a major source of biodiversity rehabilitation in the future. Similarly, parkland agroforestry is one of the most noticeable traditional practices across most agroecosystems in the highlands of Ethiopia, contributing to biodiversity conservation (Bekele, 2018).

Live fences, windbreaks, and isolated trees also significantly contribute to biodiversity conservation in agricultural lands (Worku and Bantihun, 2017). Agroforestry also plays a vital role in reducing pressure on natural forests and shrublands by providing fuel, construction wood, and other forest products. It makes a high contribution to reducing deforestation by meeting the energy demand for household livelihoods (Cheru and Hailu, 2023). Agroforestry has the potential to conserve economically and environmentally important species of indigenous trees such as *Acacia tortilis, Acacia nilotica, Balanites aegyptiaca, Tamarindus indica, Tamarix spp., and Ziziphus spp*. (Worku and Bantihun, 2017). Other studies have also demonstrated that 50 woody species (85% of which were indigenous) belonging to 31 families are found in traditional agroforestry practices in Ethiopia (Molla and Kawessa, 2019). Agroforestry also has the potential to maintain a significant number of native plant species that are deteriorating or at risk of disappearing in their natural habitat (Mulatu and Hunde, 2019). According to Mulatu and Hunde (2019), between 32 and 419 native tree species were conserved in different agroforestry practices.

Table 3: Summary of agroforestry contribution for ecological components

Ecological elements	Function	Source
Soil and water management	improve soil nutrient and physical properties, and recover soil fertility	Wolle et al. (2021); Mebrate et al. (2022)
	Improving water use efficiency	Asfaw (2016)
	soil quality and health	Asfaw (2016)
	control soil erosion, regulate soil moisture and temperature, improve soil nutrition	Lelamo (2021); Bekele (2018);
Carbon storage	Trees in agroforestry have accounted for 61–79% of the carbon storage	Getnet (2023)
	77% carbon storage	Negash and Starr (2015)
	67- 85% of carbon storage	Betemariyam *et al*. (2020)
	Estimates (Mg C ha^{-1}) 2.1 ± 0.01- 28.2 ± 6.0 aboveground carbon storage; 1.9 ± 0.8- 9.6 ± 2.8 belowground carbon storage and 14.5 ± 1.4- 115.7 ± 15. 1 soil	Manaye et al. (2021), Nigatu et al. (2020); Furo et al. (2020); Negash and Starr (2015); Sahle et al. (2018); Betemariyam et al. (2020); Birhane et al. (2020); Negash

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Ecological elements	Function	Source
	organic carbon from different agroforestry practices	et al. (2022); Gebrewahid et al. (2018); Gebremeskel et al. (2021); Hagos et al. (2021);Gurmessa et al. (2016).
Biodiversity conservation	Agroforestry activities boost biodiversity on farmland.	Worku and Bantihun (2017); Gifawesen et al. (2020); wolde and Desalgn (2020); Ereso (2023)
Forest conservation	Reducing deforestation by filling energy demand for the livelihood of household 32-419 native species conserved in different agroforestry practices	Worku and Bantihun (2017); Mulatu and Hunde (2019); Cheru and Hailu (2023); Mulatu and Hunde (2019)

Factors Affecting Agroforestry Practices

The use of agroforestry varies greatly in Ethiopia due to a variety of factors in different agroecological zones and practices (Wondimenh, 2023). For example, Gebru et al. (2019) demonstrated that the adoption of agroforestry needs to be sensitive not only to the characteristics of the technology and biophysical environment but also to the socioeconomic conditions, which are often not given due attention. The promotion of agroforestry is constrained by numerous factors, including small landholdings, lack of adequate financial and technical support, poor soil, and incidences of drought exacerbated by climate change. The different factors of agroforestry practices by smallholder farmers are categorized as socio-economic, institutional, and biophysical factors (*Table 4*).

Hence, the presence of an agroforestry system and practice in a particular area is dependent on several factors influencing resource availability, economic feasibility, and topographical, sociocultural, and environmental conditions (Amare et al., 2019). The socio-economic factors that affect the diversity of species in agroforestry systems/practices are commercialization, access to the market, farm size, access to resources, and extent of reliance on off-farm income. Consequently, agricultural systems close to the market or towns, particularly in well-off households, tend to emphasize high-value cash crops instead of staple foods (Worku and Bantihun, 2017; Amare et al., 2018; Gebru et al., 2019). Different farm-level studies can provide insights into key social and economic factors affecting farmer use and management of AF practices and their effects on the household resource base (Cheru and Hailu, 2023). AF systems, however, can often be more complex than existing crop and other farming practices (Cheru and Hailu, 2023). Thus, there is a need to isolate factors that might specifically affect the adoption of AF technologies. This is even more important because sometimes where trees are especially scarce, rural people may be unwilling to grow them. It is unlikely that the reason for this is ignorance of the benefits of trees or of the technologies used in cultivating them: it is far more likely that there is another real constraint. Ahmad et al. (2023) also reported that socio-economic variables such as family size, land ownership, subsidies, livestock rearing, sources of energy, and total income had a significant positive influence on the planting of trees on farmland, while age had a negative influence.

The biophysical factors showed that the availability of natural resources and geographical locations are one of the biophysical factors that affect a farmer's choice to adopt a particular agroforestry practice/system (Beyene et al., 2019). For example, this finding further explained that people who live in the surrounding forests and own livestock might prefer to adopt silvopastoral or agrosilvopastoral agroforestry systems as resources like cattle, goats, etc. are available and they can access the feed from naturally grown shrubs or grasses in the forests

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while generating another income from growing timber or crops.

Similarly, agroforestry adoption is a complicated process that may be influenced by several institutional factors such as access to and level of resources, provision of extension, infrastructure, market, and other institutional factors. For instance, Tega and Bojago (2024) demonstrated that extension service had a positive association with the adoption of agroforestry practices, which implies that regular contact with extension agents motivates farmers to adopt agroforestry technologies. Furthermore, other institutional factors such as access to credit, access to seedlings, access to training, etc. can moderate the adoption of agroforestry (*Table 4*).

Table 4: Summary of factors affecting the adoption of agroforestry practices in Ethiopia

Factors	Sub-factors	Sources
Socioeconomic	Age	Guteta and Abegaz (2015); Amare et al. (2018); Beyene et al. (2019); Gebru et al. (2019); Ahmad et al. (2023)
	Education	Guteta and Abegaz (2015); Gebru et al. (2019); Tafere and Nigussie (2018); Tega and Bojago (2024)
	Family size	Guteta and Abegaz 2015; Amare et al. 2018; Gebru et al. 2019
	Income	Alelign et al. (2011); Agidie et al. (2013); Guteta and Abegaz (2015);
	Land size	Agidie et al. (2013); Guteta and Abegaz (2015); Amare et al. (2018); Gebru et al. (2019)
Institutional	Access to training	Guteta and Abegaz (2015); Amare et al. (2018); Beyene et al. (2019); Gebru et al. (2019)
	Access to seedling	Amare et al. (2018)
	Access to credit	Amare et al. 2018; Gebru et al. (2019); Beyene et al. (2019)
	Access to extension services	Tega and Bojago (2024)
	Tenure security	Beyene et al. (2019)
Biophysical	Distance to town/market	Guteta and Abegaz (2015); Beyene et al. (2019)
	Water availability	Alelign et al. 2011
	Environmental Awareness	Beyene et al. (2019)

CONCLUSION

Agroforestry is a unique land use system that integrates socio-economic and ecological benefits. Based on the findings of the review, farmers mainly practice agroforestry systems such as agrosilvopastoral, silvopastoral, and agrisilvicultural systems. These systems involve practices like home gardens, parkland agroforestry, hedgerows, trees/shrubs on farmlands, live fences, windbreaks, coffee-based plantations, and related practices. Agroforestry provides both socio-economic and ecological benefits. Socio-economic benefits include income from timber and non-timber forest products (NTFPs) from combining trees with crops or livestock. Ecological benefits include biodiversity conservation, soil and water conservation, carbon sequestration, and reduction of deforestation. Factors such as socio-economic, institutional, and biophysical factors influence the wider adoption of agroforestry practices. Socio-economic factors like farmers' age, education, farm size, family size, and income level are crucial in moderating the adoption of agroforestry practices. Institutional factors such as access to extension services, seedlings, and land tenure security can also influence adoption. Biophysical factors like

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environmental awareness, distance to market, and water availability are important for adoption as well.

The findings of this review paper suggest that a farmer-centered approach to research and development in agroforestry is key to wider adoption of the practice. Recognizing and addressing the socio-economic and ecological conditions of an area is vital for wider adoption of agroforestry. Governments and NGOs should focus on strengthening institutional, socio-economic, and biophysical characteristics of specific areas to expand agroforestry practices and enhance socio-ecological benefits. The results of this study suggest that policymakers, researchers, and extension providers should collaborate closely with farmers to identify suitable agroforestry practices in Ethiopia for effective adoption and scaling out. This collaboration could be facilitated by government policies that encourage the wider use of agroforestry practices and expand research and extension services.

DECLARATION OF COMPETING INTEREST

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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