The role of agroforestry for livelihood improvement in Ethiopia

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ABSTRACT: *Agroforestry, the intentional integration of trees with crops and/or livestock plays a critical role in enhancing rural livelihoods while addressing environmental challenges in Ethiopia. This review synthesizes evidence from various agroforestry systems, including homegardens, parklands, boundary plantings, silvopastoral, and agrosilvicultural practices, to evaluate their contributions to food security, income diversification, soil fertility, and climate resilience. Studies indicate that agroforestry can contribute up to 40–50% of household income and improve crop yields by 20–30% through soil fertility enhancement. In addition, agroforestry systems sequester approximately 1.5–3.5 Mg C ha^{-1} yr^{-1}, significantly higher than conventional croplands (<1 Mg C ha^{-1} yr^{-1}), while total carbon storage ranges from 50 to 150 Mg C ha^{-1} depending on system type and management. Despite its potential, adoption is constrained by land tenure insecurity, limited technical capacity, poor market access, delayed economic returns, climate stresses, and institutional fragmentation. Opportunities for scaling include strengthening research extension farmer linkages, developing value chains, integrating agroforestry into land-use and watershed management, supporting community-based nurseries, and mobilizing climate finance. With coordinated policy support, investment, and capacity building, agroforestry can serve as a transformative pathway toward sustainable livelihoods, ecological restoration, and climate resilience in Ethiopia.*

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1. INTRODUCTION

Agroforestry, defined as the deliberate integration of trees with crops and/or livestock on the same land management unit, represents a traditional yet increasingly recognized land-use strategy that offers ecological, economic, and social benefits (Nair, 1993; Leakey, 2014). It is particularly vital in rural contexts of developing countries where communities rely heavily on agriculture for their livelihoods. In Ethiopia, a country characterized by diverse agro-ecological zones and a mainly agrarian economy, agroforestry holds significant promise for improving rural livelihoods while addressing pressing environmental challenges (Mekuria *et al.*, 2009; Mbow *et al.*, 2014).

With over 80% of its population dependent on subsistence agriculture (MoA, 2020), Ethiopia faces challenges such as land degradation, deforestation, soil fertility loss, and climate variability. Agroforestry provides a sustainable alternative that combines productivity with environmental stewardship. Systems such as home gardens, parklands, silvopasture, and boundary plantings are widespread in the Ethiopian highlands and lowlands, often forming part of indigenous knowledge systems that enhance resilience and food security (Gebrehiwot *et al.*, 2016; Kindu *et al.*, 2014).

Recent research has emphasized agroforestry's multifaceted contributions: it diversifies income sources through the production of timber, fruits, fodder, and non-timber forest products (NTFPs); enhances food security by improving agricultural productivity; and delivers ecosystem services such as soil fertility enhancement, biodiversity conservation, and microclimate regulation (Mbow *et al.*, 2014; FAO, 2013). Moreover, agroforestry is increasingly acknowledged for its role in climate change mitigation and adaptation, sequestering carbon while providing farmers with adaptive capacity against climate shocks (Lasco *et al.*, 2014; Duguma *et al.*, 2019).

In the Ethiopian perspective, integrating agroforestry into development and environmental policy is viewed as a viable strategy to simultaneously address livelihood vulnerabilities and ecological degradation. This review explores the critical role agroforestry plays in improving livelihoods in Ethiopia, synthesizing evidence from existing studies to assess its effectiveness, opportunities, and constraints.

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2. AGROFORESTRY SYSTEMS IN ETHIOPIA

Ethiopia has a wide range of agroforestry practices that are ingrained in local knowledge and rural livelihoods due to its different agro-ecological zones and traditional land-use patterns. These systems make distinct contributions to food security, income production, and ecological sustainability, and they differ according to geography, climate, and cultural context (Kindu *et al.*, 2014; Mbow *et al.*, 2014). Some of the most important agroforestry systems in Ethiopia are listed below:

2.1 Homegarden Agroforestry

One of Ethiopia's most popular and varied agroforestry systems is the home garden, which is especially prevalent in the Southern Nations, Nationalities, and Peoples' Region (SNNPR). Fruits (such as mango, avocado, and banana), vegetables, root crops, spices, medicinal plants, and livestock are all part of these multi-strata systems that surround homesteads and are covered by trees (Tesfaye *et al.*, 2005; Abebe, 2005). They improve household resilience and dietary diversity by offering year-round food, income, fuel wood and therapeutic items. According to Abebe (2005), home gardens in SNNPR supported significant biodiversity with over 30 plant species per garden and in some regions produced more than 50% of total household income.

2.2 Parkland Agroforestry

In the semiarid lowlands, especially in Oromia, Amhara, and portions of Tigray, parkland systems predominate. The purposeful preservation of sporadic trees like *Faidherbia albida, Acacia tortilis*, and *Balanites aegyptiaca* on farmed areas is what distinguishes these systems. In addition to supplying fire wood, shade, and fodder, the trees help improve soil fertility by fixing nitrogen and adding organic matter (Eshete *et al.*, 2011; Asfaw & Lemenih, 2010). According to research by Asfaw and Lemenih (2010), increased soil fertility and microclimatic control beneath F. albida canopies can result in crop yields that are up to 30% higher.

2.3 Boundary Planting and Live Fences

In Ethiopia, boundary planting is common, particularly in regions where there is a shortage of land and animals. As living fences or boundary markers, species including *Millettia ferruginea*, *Cordia africana*, *Erythrina brucei*, and *Sesbania sesban* are employed. These species provide a variety of uses, such as windbreaks, firewood, fodder, and increased soil fertility (Kindu *et al.*, 2014; Linger, 2014). According to Linger (2014), border trees helped to lessen land degradation in the Ethiopian highlands and made a substantial contribution to on-farm biodiversity.

2.4 Silvopastoral Systems

In Ethiopia's highlands and lowlands, silvopastoral systems which combine trees with grazing areas are being encouraged more and more. According to Worku *et al.* (2012), these systems increase the supply of fodder, boost animal productivity, and lessen the strain on natural forests. *Calliandra calothyrsus*, *Chamaecytisus palmensis*, and *Leucaena leucocephala* are common tree species. Worku *et al.* (2012) claim that silvopastoral systems promoted pasture regeneration in degraded areas and increased livestock productivity by 20–40%.

2.5 Agrosilvicultural Systems

In agrosilvicultural systems, trees are incorporated with annual crops including teff, wheat, barley, and maize. The Amhara and Oromia regions' highlands are home to many of these systems. Multipurpose tree species that offer shade, mulch, fuel wood, and timber, such as *Cordia africana*, *Grevillea robusta*, and *Albizia gummifera*, are frequently incorporated by farmers (Mekonnen *et al.*, 2014; Tadesse *et al.*, 2016). According to Mekonnen *et al.* (2014), agrosilvicultural farms outperformed traditional monoculture plots in terms of crop productivity and soil organic carbon.

3. CONTRIBUTION TO LIVELIHOODS

Ethiopian rural communities rely heavily on agroforestry for a variety of ecological and economic purposes. Because of its many uses, it is an essential tactic for smallholder agricultural systems' sustainable development.

3.1. Food Security and Nutrition

By incorporating fruit trees, vegetables, and multipurpose native species into agricultural systems, agroforestry increases food supply and improves nutritional diversity. Growing in homesteads and farm boundaries in Ethiopia are species including *Moringa stenopetala*, *Persea americana* (avocado), *Mangifera indica* (mango), and *Malus domestica* (apple), which augment staple foods and provide year-round nourishment (Abebe, 2005; Kindu *et al.*, 2014). For example, *Moringa stenopetala* is well known for its high nutritional content, which includes iron, calcium, and vitamins A and C nutrients that are frequently deficient in rural diets (Fentahun & Hager, 2009). Furthermore, more than 30 kinds of edible plants have been demonstrated to thrive in home garden agroforestry systems, guaranteeing a consistent and varied food supply all year round (Tesfaye, 2005).

3.2. Income Diversification

Because agroforestry makes it possible to produce lumber, fuel wood, honey, medicinal plants, and non-timber forest products (NTFPs), it diversifies farm income. Multiple species and products increase resilience against market swings and climate shocks by reducing reliance on a single crop and giving households other sources of income (Mbow *et al.*, 2014; Mekonnen *et al.*, 2014). Linger (2014) states that Ethiopian smallholders reported making a substantial profit from the sale of fruits, poles, and honey, especially from species like *Ziziphus spina-christi* and *Cordia africana*. Agroforestry in the southwestern and southern regions accounted for as much as 40% of household income (Abebe, 2005).

3.3. Employment Generation

Employment in rural areas is directly and indirectly supported by agroforestry. In rural Ethiopia, wage labour and self-employment opportunities are offered by activities such nursery development, seedling sales, tree planting, fodder gathering, pruning, and the processing of agroforestry products (*e.g.*, drying, oil extraction, and honey harvesting) (FAO, 2013; GIZ, 2019). According to Gebrehiwot *et al.* (2016), community-based agroforestry businesses gave women and young people seasonal work, particularly in highland areas that were being restored. In many areas, nursery operations with the help of regional cooperatives and non-governmental organizations have emerged as sustainable sources of employment and revenue.

3.4. Soil Fertility and Crop Yield Improvement

Leucaena leucocephala, Faidherbia albida, and *Sesbania sesban* are examples of leguminous trees that are included into agroforestry to improve soil health. These plants increase organic matter through litter fall, lower erosion, and raise soil nitrogen levels (Kindu *et al.*, 2014; Worku *et al.*, 2012). During the cropping season, the leaves of the commonly utilised species Faidherbia albida shed, enabling sunshine to enter and recycling nutrients. According to studies, maize yields in canopy areas are 20–30% higher than in open fields (Asfaw & Lemenih, 2010). Furthermore, by reducing reliance on synthetic fertilizers, these systems help smallholders save their production costs (Mekonnen *et al.*, 2014).

3.5 Climate Change Mitigation and Adaptation

Climate change, largely driven by increasing greenhouse gas concentrations particularly carbon dioxide (CO_2) from deforestation and land-use change poses significant challenges to agricultural productivity and ecosystem stability (IPCC, 2022). Although terrestrial ecosystems function as major carbon sinks by storing carbon in biomass and soils, their capacity has been significantly reduced due to ongoing land degradation (FAO, 2022). In this context, agroforestry has emerged as a climate-smart land-use system that contributes to climate change mitigation by enhancing carbon sequestration. It achieves this through carbon fixation in tree biomass, long-term storage in woody components, and improvements in soil organic carbon through litter deposition and root turnover (Duguma *et al.*, 2021). Empirical studies indicate that agroforestry systems sequester approximately 1.5–3.5 Mg C ha^{-1} yr^{-1}, which is substantially higher than conventional croplands that typically store less than 1 Mg C ha^{-1} yr^{-1} (Lasco *et al.*, 2014; Kuyah *et al.*, 2016). In tropical regions such as Ethiopia, total carbon storage in agroforestry systems ranges from 50 to 150 Mg C ha^{-1} depending on species composition and management practices (Mbow *et al.*, 2014).

Beyond mitigation, agroforestry also plays a critical role in climate change adaptation by enhancing farm resilience to climate variability. Tree components improve microclimatic conditions by moderating temperature extremes, reducing evapotranspiration, and enhancing soil moisture retention. Additionally, agroforestry systems diversify farm outputs, thereby reducing farmers' vulnerability to climate-related risks and stabilizing crop production under stress conditions. Species such as *Faidherbia albida*, *Cordia africana*, and *Grevillea robusta* are particularly effective due to their high biomass production, nitrogen-fixing capacity, and adaptability. Structurally complex systems such as parklands and homegardens further enhance both carbon storage and resilience through their multi-layered vegetation. Moreover, tropical agroforestry systems generally exhibit higher carbon sequestration potential than temperate systems due to faster growth rates and year-round productivity, making them especially suitable for climate resilience in regions like Ethiopia (Mbow *et al.*, 2014).

4. POLICY AND INSTITUTIONAL SUPPORT

The Ethiopian government has incorporated agroforestry into important national plans and development initiatives in recognition of its many advantages. Notably, agroforestry is incorporated within the Forest Sector Development Program (FSDP) and the Climate Resilient Green Economy (CRGE) strategy, which seek to enhance rural livelihoods, restore damaged landscapes, and boost carbon stocks (MoA, 2020; EFCCC, 2018). Agroforestry is emphasised as a key tool for low-emissions development and climate resilience in the 2011 CRGE Strategy. It encourages sustainable land

management, lessens deforestation, and increases the amount of trees on farmland (FDRE, 2011).

Agroforestry is also acknowledged as a crucial strategy for community-based forest management by the Forest Sector Development Program (2018–2028), which aims to increase forest cover and offer alternatives for livelihood (EFCCC, 2018). Through technical training, input provision (seeds and seedlings), extension services, and value chain development, non-governmental organizations (NGOs) like World Agroforestry (ICRAF), Farm Africa, and GIZ, as well as research institutions like the Ethiopian Environment and Forest Research Institute (EEFRI), have supported the adoption of agroforestry in addition to government initiatives (FAO, 2013; GIZ, 2019). While GIZ has funded farmer field schools that emphasize tree-crop integration and agro ecological restoration, ICRAF has carried out agroforestry initiatives in the Central and Southern Highlands, encouraging sustainable land management (GIZ, 2019).

5. CHALLENGES OF AGROFORESTRY ADOPTION IN ETHIOPIA

Notwithstanding its widely acknowledged advantages, Ethiopia has a number of administrative, socioeconomic, and environmental obstacles to the broad implementation and expansion of agroforestry. Its ability to support sustainable livelihoods and environmental restoration is hampered by these obstacles. Important difficulties include:

5.1. Land Tenure Insecurity and Communal Land Use Conflicts

One of the biggest obstacles to agroforestry investment in Ethiopia is still unclear land tenure agreements. Long-term expenditures like planting trees are discouraged in many rural areas since land is either temporarily granted by the state or retained under communal ownership. Farmers are less likely to embrace agroforestry approaches when they fear losing their land, particularly when it becomes "improved" or "productive" (Deininger *et al.*, 2008; Gebreegziabher *et al.*, 2016). For example, farmers in the Tigray region are frequently hesitant to plant trees on community grazing property because of the possibility of future land redistribution, according to Gebre egziabher *et al.* (2016). Furthermore, many smallholders are in limbo regarding their tenure because land certification initiatives have not been equally covered (Holden *et al.*, 2009).

5.2. Limited Awareness and Technical Capacity

Many farmers and even some extension agents lack the technical know-how and expertise necessary to properly set up and maintain agroforestry systems. In Ethiopia, traditional extension services have traditionally concentrated on cereal-based agriculture and monocropping, with little incorporation of tree-based systems (Kindu *et al.*, 2014). Extension personnel continue to get inadequate training on tree selection, pruning, spacing, and agricultural integration (Tadesse *et al.*, 2016). Because of this, farmers frequently plant unsuitable species, which causes crop competition and ultimately results in the abandonment of agroforestry operations.

5.3. Market Access Constraints for Agroforestry Products

The capacity of smallholders to sell agroforestry products like fruits, honey, lumber, and medicinal plants is hampered by inadequate road networks, a lack of organized value chains, and limited market infrastructure. As a result, farmers have fewer financial incentives to invest in agroforestry (Linger, 2014; FAO, 2013). Mekonnen *et al.* (2014) point out that despite an increase in fruit yield from agroforestry, post-harvest losses are still substantial because of inadequate storage and restricted access to urban markets. Additionally, the commercialization of high-value agroforestry products is hindered by the lack of buyer networks and price information.

5.4. Delayed Returns from Tree-Based Systems

Benefits from tree-based systems, including fruit, lumber, or increased soil fertility, frequently take years to materialize. Given their immediate requirements for food and revenue, smallholder farmers may find this wait to be a significant deterrent (Kuyah *et al.*, 2016; Mbow *et al.*, 2014). Without temporary incentives or assistance, many smallholders leave agroforestry plots before the trees reach maturity, according to Kuyah *et al.* (2016). Additionally, because yearly cropping systems yield faster financial returns, risk-averse consumers find them more appealing.

5.5. Climate-Related Stresses

Particularly in Ethiopia's dry and semi-arid regions, agroforestry systems are also susceptible to climate-related pressures like drought, pest outbreaks, and unpredictable rainfall. In addition to increasing competition between trees and crops for water, extended droughts can lower tree productivity and seedling survival (Duguma *et al.*, 2019). For instance, during prolonged dry spells, Kindu *et al.* (2014) noted a decrease in tree survival rates in the central highlands. Moreover, flowering and fruiting cycles are impacted by climate variability, which consequently affects food security and agroforestry-based revenue.

5.6. Institutional Fragmentation and Policy Gaps

Even while national programs like the CRGE and FSDP mention agroforestry, its implementation is frequently dispersed across several entities (MoA, 2020). Insufficient coordination across the environmental, forestry, and agricultural sectors results in inconsistent policies and wasteful resource utilization (FAO, 2013). FAO (2013) noted that there is no clear institutional home for agroforestry in Ethiopia, and duties are frequently divided between federal ministries and provincial bureaus without explicit directives. This fragmentation makes it more difficult to provide monitoring, incentive programs, and cogent extension services for the promotion of agroforestry.

6. OPPORTUNITIES AND WAY FORWARD

Despite the obstacles that Ethiopian agroforestry faces, there are a number of encouraging prospects that might be used to increase its contribution to climate resilience, sustainable land management, and livelihood enhancement. Coordination between farmers, policymakers, researchers, and development partners is necessary to take advantage of these opportunities. Key starting points for upcoming interventions are found in the following areas:

6.1. Strengthening Research Extension Farmer Linkages

Strong cooperation between farmers, agricultural extension agencies, and research institutions is essential for the successful development of agroforestry. Nonetheless, Ethiopia's present farmer-extension-research ties are still weak and ill-coordinated (Kindu *et al.*, 2014; Tadesse *et al.*, 2016). Co-creation and distribution of locally relevant agroforestry technology and practices will be ensured by fortifying this connection. According to Tadesse *et al.* (2016), agroforestry innovations are more likely to be adopted when farmers are involved in trial designs and demonstration sites. Organizations that are well-positioned to facilitate these kinds of partnerships include ICRAF (World Agroforestry) and EEFRI (Ethiopian Environment and Forest Research Institute). Enhancing farmer access to technical knowledge and innovations can be achieved through the promotion of farmer field schools (FFS), farmer-research-extension platforms (FREPs), and digital agroforestry advising tools (FAO, 2013).

6.2. Promoting Value Chains for Agroforestry Products

To encourage farmer investment, it is essential to create inclusive and functional value chains for agroforestry goods like fruits, honey, timber, and medicinal plants. Agroforestry systems can become more profitable by enhancing post-harvest handling, storage, market accessibility, and processing capability (Linger, 2014; Mekonnen *et al.*, 2014). In Ethiopia's arid regions, Gebrehiwot *et al.* (2016) highlight the potential of non-timber forest products (NTFPs) such as honey and frankincense, where agroforestry systems can be connected to export and niche markets. Local employment and incomes would also be improved by the creation of small businesses and local cooperatives for the processing and packaging of agroforestry goods.

6.3. Integrating Agroforestry into Land Use Planning and Watershed Management

The degraded highlands and dry areas of Ethiopia can benefit greatly from agroforestry's transformative power in watershed management and sustainable landscape restoration. Agroforestry can optimize its ecosystem and livelihood advantages by being incorporated into integrated land use plans, soil and water conservation initiatives, and exclosure rehabilitation programs (Kindu *et al.*, 2014; Duguma *et al.*, 2019). In watershed-level interventions, agroforestry has already been integrated into the government's Sustainable Land Management Program (SLMP). Cross-sectoral collaboration, long-term monitoring, and strong planning tools will be necessary to scale up similar approaches in additional areas (GIZ, 2019). Additionally, as part of climate-resilient agriculture, agroforestry improves groundwater recharge and protects delicate ecosystems from erosion.

6.4. Supporting Community-Based Nurseries and Seed Systems

Expanding agroforestry requires a steady and locally appropriate supply of tree seedlings and germplasm. Cooperatives, youth organizations, or women's associations run community-based nurseries that create jobs locally and offer reasonably priced planting supplies (FAO, 2013; GIZ, 2019). According to Linger (2014), agroforestry adoption was facilitated by nurseries associated with watershed restoration initiatives in Amhara and Tigray, which expanded availability to native and quickly growing tree species. Sustainability requires strengthening seed systems, especially for high-value species (such *Moringa, Cordia,* and *Faidherbia*), and creating standards for quality control. The performance of these grassroots projects will be further improved by government assistance in the form of technical training, credit, and infrastructure (such as water access for nurseries).

6.5. Enhancing Climate Finance Access for Scaling Up Agroforestry

Agroforestry is in line with the goals of the global climate, which include land restoration, ecosystem-based adaptation, and carbon sequestration. However, Ethiopia hasn't made the most of climate finance instruments to expand its agroforestry. There are opportunities to integrate agroforestry into national climate action plans to mobilize finance from the Adaptation Fund, REDD+ programs, and the Green Climate Fund (GCF) (FDRE, 2021; Duguma *et al.*, 2019). Carbon credits and payments for ecosystem services (PES) can be obtained by measuring and confirming the carbon benefits of agroforestry systems (Lasco *et al.*, 2014). Agroforestry is already acknowledged in Ethiopia's CRGE strategy and Nationally Determined Contributions (NDCs); therefore, future initiatives should give priority to agroforestry projects that are measurable, reportable, and verifiable (MRV-compliant).

7. CONCLUSION

This review addressed the critical gap in integrating livelihood improvement with environmental sustainability in agroforestry systems in Ethiopia. Evidence shows that agroforestry significantly enhances income diversification, food security, and soil fertility while contributing to carbon sequestration (1.5–3.5 Mg C ha^{-1} yr^{-1}) and climate resilience. However, adoption remains constrained by land tenure insecurity, weak institutional coordination, limited technical capacity, and poor market access. To fully realize its potential, future efforts should focus on: (i) strengthening policy integration of agroforestry into national development frameworks, (ii) improving value chains and market access, (iii) enhancing research-extension-farmer linkages, and (iv) promoting climate finance mechanisms such as carbon credits and ecosystem service payments.

Further research is needed to generate site-specific data on carbon sequestration and economic returns across different agroforestry systems in Ethiopia. Agroforestry represents a practical and scalable solution for achieving climate resilience, poverty reduction, and sustainable land management.

Declaration of Competing Interest

The authors declare that there have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

Esubalew Molla: Conceptualization; reviewing literature; Investigation; Writing review & editing and manuscript preparation.

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