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Review Article

The Potential Role of Agroforestry in Small Holder Farmers Livelihood Improvement: A Review

Gadisse Dula Adugna[1*] and Amanuel Tilahun Etafa[1]

[1]Department of Forestry, Wollega University, P.O. Box 38, Shambu, Ethiopia

Abstract

Rural areas, particularly those inhabited by smallholder farmers, are currently confronting a multitude of challenges, including economic, socio-cultural, and technological issues, exacerbated by the impacts of climate change. Agroforestry, recognized globally as one of the most sustainable land management practices, offers a multitude of benefits to farmers. This review aims to assess the existing literature on the potential role of agroforestry in enhancing the livelihoods of smallholder farmers. The findings of various scholars indicate that agroforestry practices play a significant role in contributing to food and nutritional security, improving soil fertility and productivity, modifying microclimates, sequestering carbon, and managing pests and weeds. Besides this, agroforestry offers a viable means of building livelihood resilience against floods and droughts. However, farmers are often deterred from investing in agroforestry due to the delayed realization of its benefits, goods, and services. Additionally, agroforestry products suffer from weak markets and value chains, particularly in developing countries, leading to their predominant use in household and local markets for subsistence purposes. This review concludes that agroforestry is a more suitable land use system and technology compared to monocropping practices. Therefore, it is imperative to place significant emphasis on extending these practices and technologies to farmers, landowners, and the local community.

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***Corresponding Author:**
E-mail:
gadissedl@gmail.com

INTRODUCTION

Agroforestry encompasses a set of land-use systems and technologies that intentionally incorporate woody perennials, such as trees, shrubs, palms, and bamboo, into various temporal sequences or spatial arrangements alongside agricultural crops and/or livestock within the same land management units (Nair *et al*., 2021). Agroforestry presents a viable alternative to the limited land resources and the ever-increasing demands of a growing population, offering a solution to the challenges posed by finite land availability (Madalcho and Tefera, 2016; Dula *et al*., 2017). Through the intercropping of trees with agricultural or horticultural crops, farmers can enhance their yields, improve soil fertility, manage erosion, preserve biodiversity, and diversify their income sources (Emiru, 2015). Agroforestry is a unique approach to land management that integrates livestock, forestry, and agriculture within a single land area (Jose *et al*., 2021). It has been acknowledged for its critical role in supplying local communities with fuelwood, timber, and various byproducts within globally significant agricultural heritage systems (Santoro *et al*., 2020).

Agroforestry systems represent a promising approach to enhancing crop productivity while fostering sustainable land management practices. The integration of trees with crops offers numerous benefits, including improved soil fertility, enhanced nutrient cycling, and increased resilience to climate change (Kaur *et al*., 2023) As a result, agroforestry is recognized as a vital component of the livelihood portfolio of rural households, contributing significantly to income generation and the maintenance of other farm resources, such as livestock (Amare, 2019). Therefore, this paper aims to review the potential role of agroforestry in improving livelihoods, with a focus on its contributions to smallholder farmers.

LITERATURE REVIEW

The Concept of Livelihood and Agroforestry

Livelihood is how people make a living searching for or making an environment conducive to survive to as well as in the way they can obtain the necessities for their daily life while looking for their future. Livelihood is said to be sustainable when it can regain from devastation and boost its capabilities and resources without harming the basis of natural resources (Boliko, 2019).

In the present context, one of the most significant challenges faced by individuals, the government, and non-governmental sectors is sustaining livelihoods. However, advanced land management practices, such as agroforestry, mitigate the impacts of climate change while concurrently producing food, fodder, and fuel, thereby offering sustainable livelihood options (Bansal *et al*., 2021).

Agroforestry in Livelihood Resilience

Agroforestry plays a crucial role in enhancing resilience to droughts and floods, both directly and indirectly. For researchers and development practitioners aiming to quantify and evaluate livelihood resilience, the sustainable livelihoods approach offers a pertinent framework for conceptualization and measurement (Quandt *et al*., 2017). This land management strategy fosters sustainable living through four principal avenues: food production, nutritional and health benefits, income generation, and the provision of wood-based energy (Kuyah, 2020).

According to Oke and Odebiyi (2007), agroforestry is widely regarded as an effective land use management strategy for addressing challenges such as deforestation, land degradation, and biodiversity loss in tropical regions. By mitigating the excessive reliance of rural communities on natural forest resources, improved fallow agroforestry practices can play a significant role in preserving biodiversity within natural ecosystems.

Through a variety of goods and services such as fruit, fodder, firewood and ecological services trees in various agroforestry systems support rural income and food security. This is particularly, through its root system and litterfall detachment which improves soil productivity, soil conservation, nitrogen cycling, and soil faunal activities (Pandey, 2007). Agroforestry contributes to the improvement of sustainable livelihoods by ensuring that natural resources are used to their utmost potential and lowering the hazards associated with it (Hanif *et al*., 2018).

Due to the adverse weather conditions caused by global climate change, farmers must adapt their practices. For example, Nigussie *et al*. (2021) reported that the cultivation of *Acacia decurrens* has resulted in economic benefits such as increased employment opportunities and enabled farmers and rural households to acquire assets like houses and communication equipment. Additionally, it has been observed to reduce women's workloads, enhance social capital and community cohesion, improve educational opportunities for children, and decrease seasonal migration. These findings suggest that agroforestry species can significantly enhance the social and economic well-being of rural farmers' livelihoods if integrated and managed effectively. Agroforestry systems provide these benefits and services across various temporal and spatial scales, from individual farms to landscapes and even global levels. Therefore, increased support is needed to educate and motivate farmers about agroforestry science and its diverse ecosystem services (Atreya *et al*., 2021). Thus, agroforestry offers substantial ecological, social, and economic benefits, as illustrated in Figure 1.

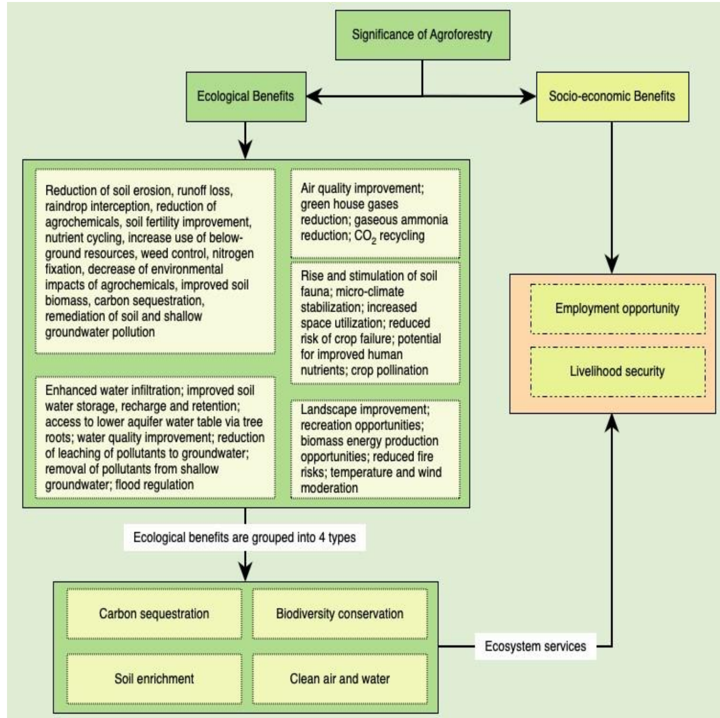

Figure. 1. Benefits of agroforestry in mountain sustainability (Atreya *et al.,* 2021).

Agroforestry for the Security of Food and Nutrition

For many years, food insecurity and poverty have posed significant obstacles to the livelihoods of the rural poor and to the sustainable development of many developing nations (El-Lakany, 2004). Agroforestry enhances food and nutritional security through crop production facilitation and edible tree and livestock products (Kuyah, 2020). The maintenance of ecosystem services, biodiversity preservation, and food production should all be integrated into multifunctional landscape management to achieve food security. According to Frison *et al*. (2011), a more consistent and sustainable food supply can only be achieved by optimizing the utilization of agrobiodiversity.

Addressing food and nutritional security requires the integration of multiple interconnected agricultural strategies, such as enhancing the yield of staple crops and diversifying the range of edible plants to provide a broader variety of fruits, vegetables, and other food sources for diverse diets. As noted by Bayala *et al*. (2014), fruit trees and other edible tree products are vital sources of vitamins and micronutrients that complement diets predominantly based on cereals. Additionally, the diverse array of underutilized native foods found in woody areas and forests often richer in fiber, protein, and micronutrients than conventional crops hold potential for diversifying crop production. Properly arranged components in home garden agroforestry practices can enhance their effectiveness. For instance, Figure 2, taken from Guduru District, Gubbaa Bunaa Village in July 2023, illustrates a traditional home garden design lacking optimal integration of components. With professional support, such gardens could yield greater benefits and multiple outputs

Figure 2. Farmers' homegarden (photo taken from Gubbaa bunaa village since July, 2023)

Agroforestry For Soil Fertility and Productivity Improvement

Since tree species fix nitrogen in the soil biologically and maintain soil organic matter, agroforestry has the potential to improve soil fertility. According to Okonkwo *et al*. (2008), biological nitrogen fixation is a naturally occurring process in which the enzyme nitrogenase converts atmospheric nitrogen gas (N2) to ammonia at normal temperature and pressure. By contributing significant amounts of organic matter both above and below ground and facilitating the release and recycling of nutrients within agroforestry systems, non-nitrogen-fixing trees can enhance the physical, chemical, and biological properties of the soil (Jose, 2009). Agroforestry systems, such as improved fallows and contour hedgerows with permanent cover, are vital in combating and reversing land degradation due to their ability to provide consistent ground cover, improve soil structure, increase organic carbon content, enhance water infiltration, boost soil fertility, and promote biological activity (Masebo and Menamo, 2016

Agroforestry in Microclimate Modification and Carbon Sequestration

Agroforestry helps people to adapt to changing socioeconomic and climatic conditions. The major livelihood benefits during uncertain conditions such as the occurrence of floods and drought were fruit for sale and consumption (Charles *et al.*, 2013). To maximize the potential of agroforestry for climate change adaptation and mitigation, it is essential to adopt a more integrated management approach. This strategy will enhance the benefits of agroforestry while mitigating its potential negative impacts on the climate (Murthy *et al*., 2016)

Trees and shrubs in agroforestry systems can enhance the microclimate by providing windbreaks and shade. These modifications to microclimatic factors such as temperature, water vapor content, and wind speed can positively impact agricultural growth and animal health (Debangshi, 2021). Additionally, the reduction of wind erosion offers multiple benefits for crops, including improved quality and growth rate, protection against wind-blown soil, moisture control, and soil preservation (Smith, 2010).

In addition to influencing air temperature, humidity, soil temperature, soil moisture content, wind movement, and insect and disease dynamics, trees also induce a range of environmental changes (Asena, 2018). Tree litter and canopies affect the microclimate by enhancing rainwater infiltration, improving soil structure, and supporting microfauna. They also reduce evapotranspiration and temperature extremes while increasing relative humidity (Kerr, 2012).

The carbon storage capacity of agroforestry systems varies based on factors such as system type, species combinations, age of component species, location, climate, and management practices. According to Jose *et al*. (2012), agroforestry species sequester substantial amounts of carbon, with trees and shrubs storing carbon in both their shoots and roots while concurrently protecting crops and soils. Agroforestry systems contribute to the nitrogen cycle and enhance soil organic carbon accumulation by providing a continuous supply of organic matter and supporting soil microorganisms (Singh *et al*., 2020). Furthermore, as noted by Agevi *et al*. (2017), trees and shrubs have the potential to store considerable carbon stocks in both soil and plant biomass, thereby mitigating the impact of greenhouse gases on the environment.

Agroforestry in Pest and Weed Management

Any species, biotype, or animal that harms plants or plant products is considered a pest under the International Plant Protection Convention. According to Sileshi *et al*. (2007), it also includes weeds and other species that indirectly affect plants. Increasing resistance to pests and diseases raises productivity and predictability, which raises food security. One of the primary advantages of agroforestry systems, particularly in developing countries, is their effectiveness in managing weeds and pests (Kuar *et al*., 2016).

Pests and weeds diminish agricultural productivity and can significantly impact harvest yields. The application of pesticides and herbicides to eradicate weeds has resulted in numerous unforeseen consequences for non-target organisms' deterioration of the ecosystem, and decreased crop land sustainability (Khan *et al*., 2023). Although relatively inexpensive, pesticides are often unaffordable in developing countries. Agroforestry trees help reduce weed populations by shading them and serve as physical barriers against airborne pests and viruses, thereby mitigating insect infestations (Altieri & Nicholls, 2008).

Agroforestry in Supplying Fodder

According to Subedi *et al*. (2015), livestock is an essential source of power for plowing, manure for agricultural crops, and revenue. In addition to improving the site, an agroforestry system is crucial for providing fuelwood and feed (Kadirvel *et al*., 2003). Large levels of output from high-quality fodder-tree legumes can only be achieved when livestock production is the primary economic activity. Fodder tree species are adaptable and have significantly contributed to high socioeconomic value **(**Mekoya**,** 2008)**.** The provision of nutrient-rich tree fodder by agroforestry is crucial for livestock, as animals require such fodder for their development, maintenance, production, and reproduction (Jose & Dollinger, 2019).

Economic Contribution of Agroforestry

Agroforestry trees and shrubs offer real economic benefits, such as improved microclimate effects in the nearby and surrounding areas, restored water table to a level that crops can absorb, and fuelwood for domestic energy consumption. The provision of food and fodder for cattle, as well as the mitigation of wind and water erosion caused by trees that block the impact of raindrops on the soil and shorten the duration of bush fallowing (Udofia *et al*., 2010).

Agroforestry has a vital economic benefit than monocultures. For instance, Amadalo & Jama (2003) reported that from their on-farm trial with crotalaria 7-9 months fallow and continued maize cropping in Western Kenya, improved fallow agroforestry systems are more profitable than continuous cropping and natural fallow practices. This applies to both scenarios of land scarcity and labor scarcity.

Table. 1. Economic benefits of 7–9-month-old *Crotalaria grahamiana* fallow in Western Kenya

Farming	Returns to land (KES/ha)	Returns to labor (KES/ha)
Continuous cropping+0 P	18,300	111.80
Continuous cropping+50 kg P	14,175	100.50
Crotalaria fallow+ 0 P	11,325	148.50
Crotalaria fallow+ 50 kg P	26,250	148.50

Source: Amadalo and Jama (2003)

a KES=Kenya shillings, valued here at 75 to 1US dollar

Takimoto and Post (2013) conducted a cost-benefit analysis of live fence and fodder bank agroforestry practices and concluded that farmers are likely to benefit from these practices, irrespective of their involvement in carbon trading. According to Adane *et al*. (2019), fruits serve as a safety net for consumption and income generation, hence contributing to livelihoods. Furthermore, fruits serve as food, nutrition, and a source of revenue, particularly in times of famine and other stress.

Summary

Agroforestry is a sustainable land management practice that integrates trees, shrubs, and other woody perennials with crops and/or livestock within a single land management unit. The practice offers a wide array of benefits, making it a promising approach for enhancing the livelihoods of smallholder farmers, particularly in rural areas facing economic, socio-cultural, and environmental challenges exacerbated by climate change.

The reviewed literature highlights agroforestry's significant contributions to food and nutritional security, soil fertility improvement, microclimate modification, carbon sequestration, and pest and weed management. Furthermore, agroforestry systems help mitigate the impacts of floods and droughts, thereby enhancing the resilience of smallholder farmers to climate variability.

One of the strengths identified across various studies is agroforestry's ability to improve soil fertility through nitrogen fixation and organic matter accumulation. The integration of trees with crops and livestock enhances nutrient cycling, soil structure, and biological activity, leading to higher productivity and sustainability. Additionally, agroforestry's role in modifying microclimates by providing shade and windbreaks contributes to improved agricultural growth and animal health. The carbon sequestration potential of agroforestry systems is another notable strength, as it helps mitigate the effects of climate change by storing significant amounts of carbon in both plant biomass and soil.

Agroforestry's contribution to livelihood resilience is another critical strength. By providing a diverse range of products, such as food, fodder, fuelwood, and timber, agroforestry reduces farmers' reliance on single crops and enhances their ability to withstand economic shocks and environmental stresses. This diversification of income sources is particularly important in regions where climate change poses significant risks to agricultural productivity.

Despite its many benefits, agroforestry faces several challenges that hinder its widespread adoption. One of the main weaknesses is the delayed realization of benefits, which can deter farmers from investing in agroforestry practices. The initial costs of establishing agroforestry systems, including the need for technical knowledge and labor, can be prohibitive for smallholder farmers with limited resources. Additionally, the weak markets and value chains for agroforestry products, especially in developing countries, limit the economic returns from these practices. As a result, agroforestry products are often used primarily for subsistence purposes, reducing their potential contribution to income generation.

Another weakness is the lack of professional support and extension services to help farmers optimize the integration and management of agroforestry components. The success of agroforestry systems depends on the careful arrangement of trees, crops, and livestock to maximize benefits and minimize negative interactions. However, without adequate training and guidance, farmers may struggle to achieve the full potential of agroforestry practices.

The literature review also reveals gaps and contradictions that need to be addressed to fully understand and harness the potential of agroforestry. For instance, while many studies emphasize the ecological and economic benefits of agroforestry, there is limited research on the long-term social impacts of these practices on rural communities. Additionally, the effectiveness of agroforestry in different agro-ecological zones and under varying socio-economic conditions remains underexplored. Further research is needed to assess the scalability and adaptability of agroforestry practices in diverse contexts.

Moreover, some studies highlight the potential for agroforestry to contribute to carbon sequestration and climate change mitigation. Still, there is ongoing debate about the extent to which agroforestry systems can offset greenhouse gas emissions. The variability in carbon storage potential across different agroforestry systems, species combinations, and management practices complicates the assessment of their overall impact on climate change.

The review highlights the multifaceted benefits and underscores the unique contributions of agroforestry to sustainable land management and livelihood improvement. It provides insights into how agroforestry can be integrated into broader agricultural policies and development strategies. Unlike monocropping practices, agroforestry promotes biodiversity conservation, soil health, and ecosystem services while providing a diverse range of products for farmers. This holistic approach to land use makes agroforestry a valuable tool for addressing the multifaceted challenges facing smallholder farmers, particularly in developing countries.

Agroforestry's ability to integrate trees with crops and livestock in a single land management unit represents a departure from conventional agricultural practices, offering a more sustainable and resilient alternative. The continuous flow of nutrients and organic matter within agroforestry systems, coupled with their capacity to sequester carbon and modify microclimates, sets agroforestry apart as a land-use strategy with significant ecological, social, and economic benefits.

CONCLUSION

Agroforestry emerges as a viable and sustainable land-use system with immense potential to improve the livelihoods of smallholder farmers. Its strengths, including enhanced soil fertility, microclimate modification, carbon sequestration, and livelihood resilience, make it a promising approach to addressing the challenges of climate change and environmental degradation. However, the widespread adoption of agroforestry practices is hindered by challenges such as delayed benefits, high initial costs, and weak markets for agroforestry products. Addressing these challenges requires increased support for farmers, including training, technical assistance, and the development of value chains for agroforestry products. To fully realize the potential of agroforestry, further research is needed to explore its long-term social impacts, scalability, and adaptability across different agro-ecological zones. Additionally, efforts to promote agroforestry should focus on enhancing farmers' access to resources and markets, as well as providing professional support to optimize the integration and management of agroforestry components. By addressing these challenges and leveraging the unique contributions of agroforestry, it is possible to create more sustainable and resilient agricultural systems that benefit both farmers and the environment. In conclusion, while agroforestry offers significant promise as a sustainable land-use strategy, its success depends on overcoming the barriers to adoption and ensuring that farmers have the necessary support to implement and manage these systems effectively. By fostering a more holistic approach to land management, agroforestry has the potential to play a crucial role in enhancing the livelihoods of smallholder farmers and contributing to sustainable development in rural areas.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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