Science Research
2025, Vol. 13, No. 6, pp. 148-158
https://doi.org/10.11648/j.sr.20251306.11

Review Article

Ecological and Socio-economic Contributions of Coffee-based Agroforestry Systems in Ethiopia: A Systematic Review

Ewunetu Tazebew[1,*], Fekadu Tiruneh[1], Yibeltal Anbes[2]

[1]College of Agriculture, Food and Climate Science, Injibara University, Injibara, Ethiopia
[2]College of Agriculture and Environmental Science, Debre Markos University, Debre Markos, Ethiopia

Abstract

Coffee-based agroforestry, the intentional integration of trees, crops, and livestock, plays a critical role in sustaining ecosystem services, enhancing soil fertility, conserving biodiversity, and supporting rural livelihoods. Ethiopia, as the center of origin for Coffea arabica, hosts diverse coffee agroforestry systems that combine indigenous management practices with multifunctional landscapes. Despite their ecological and socio-economic significance, research on these systems remains fragmented and localized, limiting a holistic understanding of their contributions to biodiversity, carbon sequestration, and climate resilience. This systematic review synthesizes 70 studies covering key coffee-growing regions in Ethiopia, including Southwest Ethiopia, Sidama, Oromia, and Northern Ethiopia. Following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, data were extracted on woody species diversity, regeneration, carbon stocks, soil fertility, ecosystem services, and socio-economic outcomes. Quantitative synthesis revealed that shade-grown coffee systems maintain high woody species richness, support natural regeneration, and enhance carbon storage compared to monocultures or degraded lands. Qualitative analyses highlighted improved microclimate regulation, soil nutrient dynamics, and biodiversity protection. Socio-economic benefits include diversified household income, increased employment along value chains, strengthened community governance, and enhanced participation of women and youth. Comparative analysis with Latin America and West Africa confirms that Ethiopian coffee agroforestry delivers parallel ecological and livelihood outcomes, though it is uniquely embedded in semi-managed landscapes with strong reliance on indigenous knowledge. Critical research gaps remain, particularly in long-term monitoring of carbon dynamics, soil fertility, and biodiversity recovery, as well as in understanding genetic diversity, institutional frameworks, and gender-inclusive benefit-sharing. Strengthening policy integration, promoting shade-tree diversification, and supporting participatory management are essential to enhance both ecological and socio-economic outcomes. This review underscores the potential of coffee-based agroforestry in Ethiopia to contribute to climate-smart, biodiversity-friendly, and livelihood-resilient landscapes, offering insights relevant for global sustainable coffee production initiatives.

Keywords

Coffee Agroforestry, Ethiopia, Biodiversity Conservation, Carbon Sequestration, Ecosystem Services, Livelihoods, Climate Resilience

*Corresponding author: jackmanof23@gmail.com (Ewunetu Tazebew)

Received: 7 October 2025; **Accepted:** 20 October 2025; **Published:** 26 November 2025

1. Introduction

Agroforestry, the deliberate integration of trees, crops, and livestock on the same land unit, plays a fundamental role in maintaining ecosystem services, enhancing soil fertility, and improving livelihoods [33, 47, 60, 61]. As an ecologically and economically sustainable land-use practice, agroforestry contributes to biodiversity conservation, microclimate regulation, and carbon sequestration while offering diversified income sources for smallholder farmers [4, 25, 44, 58, 63, 64]. Ethiopia, recognized as the primary center of origin and genetic diversity for *Coffea arabica*, harbors rich coffee genetic resources that underpin global coffee production [3, 37]. The country's coffee-based agroforestry systems have evolved through centuries of indigenous management practices that integrate shade trees, crops, and livestock, creating multi-functional landscapes that sustain both livelihoods and biodiversity [6, 65]. Coffee agroforestry systems, in particular, play a pivotal role in forest connectivity, biodiversity conservation, and soil health maintenance [5, 20]. Empirical evidence shows that shade-grown coffee farms harbor high levels of woody species diversity, enhance pollinator habitats, and contribute to soil organic matter and carbon accumulation [10, 11]. These systems also provide ecosystem services comparable to natural forests, including carbon storage and habitat provision [43, 59]. Globally, studies indicate that traditional shade coffee systems serve as refuges for tropical biodiversity and as buffers against deforestation [12, 51]. In Ethiopia, such systems have been recognized as vital for conserving the remaining Afromontane Forest fragments and supporting sustainable rural livelihoods [27, 55].

Despite their ecological and socio-economic significance, studies on coffee-based agroforestry systems in Ethiopia remain fragmented and localized, often focusing on narrow aspects such as species diversity or yield without integrating broader ecosystem and livelihood dimensions [40, 69]. This fragmentation limits a holistic understanding of how different coffee management systems contribute to biodiversity conservation, carbon sequestration, and climate resilience. Moreover, coffee genetic diversity and forest habitats are increasingly threatened by deforestation, agricultural expansion, and climate change [8, 39]. Land-use pressures, coupled with the limited adoption of sustainable agroforestry practices, further exacerbate degradation and reduce the ecological integrity of coffee landscapes [34, 54]. While policy instruments such as Ethiopia's Climate-Resilient Green Economy (CRGE) Strategy [23] and National Biodiversity Strategy and Action Plan [16, 17] emphasize sustainable land management, their integration with coffee agroforestry initiatives remains limited. Consequently, there is a need for a comprehensive synthesis of existing research to evaluate the ecological, socio-economic, and policy dimensions of coffee-based agroforestry systems in Ethiopia.

This systematic review aims to synthesize available evidence on the ecological, environmental, and socio-economic contributions of coffee-based agroforestry systems in Ethiopia. Specifically, it seeks to (i) evaluate the role of agroforestry in enhancing biodiversity conservation, carbon storage, and soil fertility; (ii) identify the socio-economic benefits and livelihood implications associated with coffee-based agroforestry practices; and (iii) highlight research gaps and policy opportunities to promote sustainable management of these systems under changing climatic and land-use conditions.

2. Methodology

This systematic review was conducted following the PRISMA guidelines, ensuring a transparent, comprehensive, and replicable synthesis of available evidence on coffee-based agroforestry systems in Ethiopia (Figure 1). A structured search strategy was implemented across major scientific databases including *Scopus*, *Web of Science*, and *Google Scholar*, as well as relevant institutional repositories to capture both published and grey literature. The search combined key terms such as "Agroforestry," "Coffee," "Biodiversity," "Carbon sequestration," and "Ethiopia," using Boolean operators to enhance the precision and coverage of the retrieved studies. To maintain the quality and relevance of the review, inclusion and exclusion criteria were carefully defined. Eligible studies included *peer-reviewed journal articles, theses, and government or institutional reports* published between 2000 and 2025. Studies were excluded if they were non-English, duplicated, or focused on unrelated topics. All selected documents were screened through title, abstract, and full-text review stages to ensure alignment with the review objectives.

A data extraction framework was applied to systematically collect relevant information from each study, including geographic location, study objectives, land-use type, woody species diversity, carbon stock, and socio-economic impacts. This allowed for both ecological and socio-economic dimensions of coffee-based agroforestry systems to be comprehensively captured. For the data analysis, a mixed-methods approach was used. Quantitative data were synthesized to assess patterns in carbon stock accumulation and species richness across different agroforestry settings. Meanwhile, qualitative and thematic analyses were employed to interpret socio-economic contributions, ecological benefits, and the broader implications for biodiversity conservation coffee-growing landscapes.

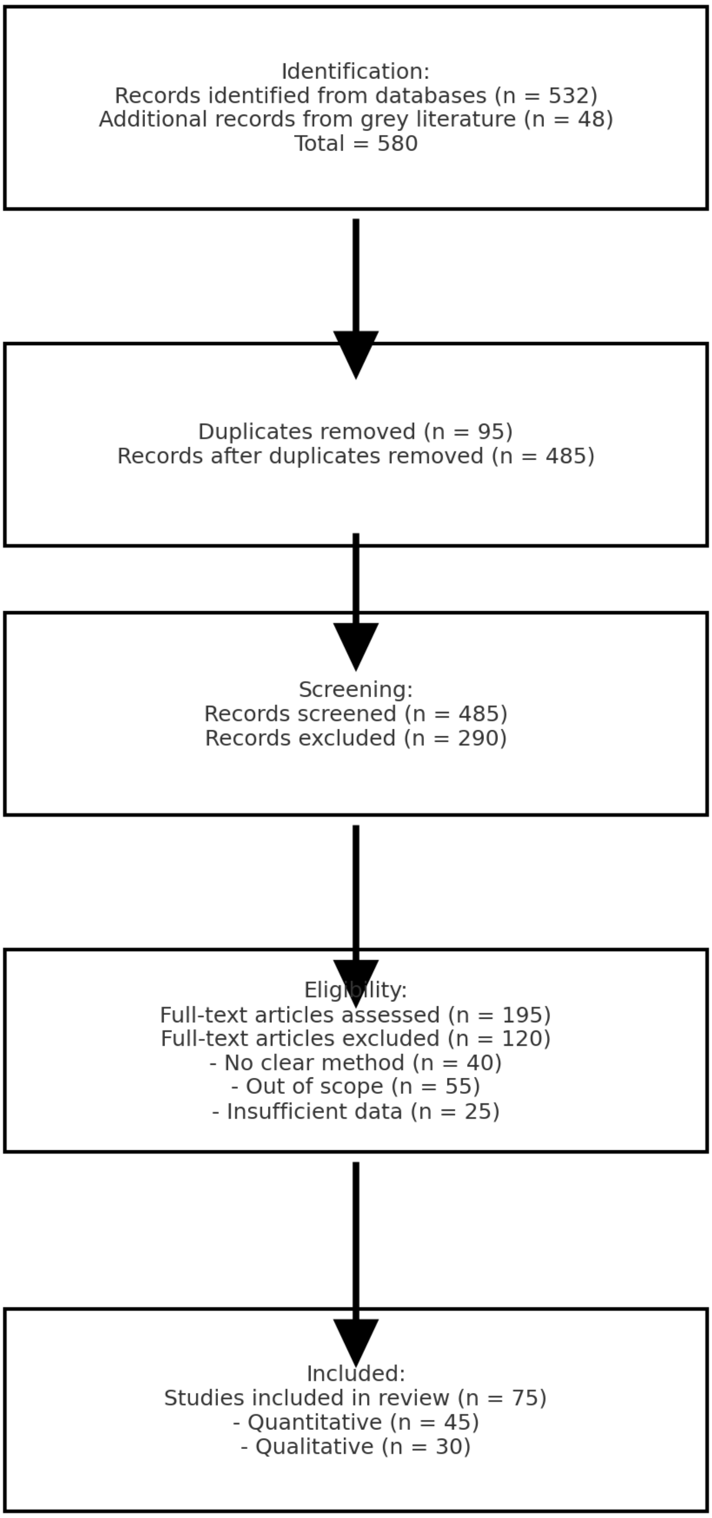

Figure 1. Flowchart of Literature Screening and Selection Process.

3. Result and Discussion

3.1. Overview of the Studies

A total of approximately 70 studies were included in this systematic review, covering a wide range of agroecological zones in Ethiopia, particularly coffee-growing regions such as Southwest Ethiopia (Jimma, Kaffa, Yayo, Illubabora, Gedeo Zone), Sidama Zone, Oromia Region, and Northern Ethiopia (Zegie Peninsula) (Table 1). The studies span diverse ecological and socio-economic contexts, reflecting the multi-functionality of coffee-based agroforestry systems [3, 29, 30, 37]. Most studies highlighted the role of these systems in biodiversity conservation, carbon sequestration, soil fertility improvement, and livelihoods enhancement, demonstrating their critical importance in sustaining both ecological integrity and rural communities [20, 33, 35, 36, 47].

In Southwest Ethiopia, studies in Jimma, Kaffa, and Yayo emphasized that shade-grown coffee farms support high woody species diversity, provide habitat connectivity, and serve as refuges for forest-dependent flora and fauna [10, 42, 5, 45, 52, 69]. Coffee agroforestry in these areas was also found to enhance carbon storage, particularly aboveground biomass, highlighting its role in climate change mitigation [11, 43]. Similarly, research in Sidama Zone and Southern Ethiopia indicated that indigenous knowledge in managing shade trees contributes to maintaining soil fertility, microclimate regulation, and agroecosystem resilience [6, 38].

In the Oromia Region, studies showed that coffee shade management practices influence species composition, regeneration patterns, and ecosystem services. For example, Studies reported that diversified shade trees enhance coffee productivity while providing multiple socio-economic benefits, such as fodder, fuelwood, and timber [54, 65]. Meanwhile, fragmented landscapes in Northern Ethiopia (Zegie Peninsula) demonstrated that coffee agroforestry plays a vital role in preserving Afromontane Forest remnants and maintaining woody species diversity, despite pressures from land-use change [10, 41]. Across all regions, policy and national strategy-focused studies emphasized the potential of coffee-based agroforestry to contribute to climate resilience, biodiversity conservation, and sustainable rural livelihoods [16, 17, 23, 58]. However, the literature also reveals knowledge gaps in less-studied agroecological zones, particularly semi-arid and fragmented landscapes, and highlights the need for integrated, interdisciplinary research that combines ecological, climatic, and socio-economic dimensions to guide sustainable management [34, 55].

***Table 1**. Overview of Included Studies by Region and Focus.*

Region / Zone	Key References	Main Focus Areas
Southwest Ethiopia (Jimma, Kaffa, Yayo, Illubabora, Gedeo)	[10, 13, 14, 20, 26-28, 32, 45, 66, 69]	Woody species diversity, forest connectivity, carbon stocks, ecosystem services, livelihoods
Sidama Zone / Southern Ethiopia	[6, 38, 40]	Shade tree management, soil fertility, indigenous knowledge, species diversity
Oromia Region (Western Wellega, West Wollega, Sayo)	[1, 13, 14, 22, 25, 54, 65]	Coffee shade management, species diversity, carbon sequestration, socio-economic impacts
Northern Ethiopia (Zegie Peninsula)	[10, 41, 46]	Preservation of forest fragments, woody species diversity, habitat protection
National / Multi-region	[16, 17, 23, 31, 34, 48]	Policy, climate resilience, biodiversity strategy, sustainable land management
Global / Comparative	[12, 45, 51, 53, 5, 56-58, 62].	Comparative insights on biodiversity, ecosystem services, agroforestry systems

3.2. Woody Species Diversity and Regeneration

Coffee-based agroforestry systems in Ethiopia support high levels of woody species diversity, which is crucial for maintaining ecological resilience, ecosystem services, and sustainable coffee production (Table 2). Studies in Southwest Ethiopia (Jimma, Kaffa, Yayo, and Gedeo Zone) indicate that shade trees in coffee farms contribute significantly to the conservation of native forest species, acting as refuges for both endemic and rare species [10, 45, 69]. Similarly, in Oromia Region, diversified shade trees, including *Cordia africana*, *Croton macrostachyus*, and *Albizia gummifera*, enhance woody species richness and facilitate natural regeneration within agroforestry plots [13, 22, 65].

Research also shows that indigenous management practices, such as selective pruning, protection of regeneration hotspots, and maintaining canopy heterogeneity, positively influence species composition and regeneration patterns [6, 21, 24, 38]. In contrast, studies in fragmented landscapes like the Zegie Peninsula reveal that anthropogenic pressures, including land clearing and unsustainable harvesting, reduce regeneration success, threatening both species diversity and ecosystem stability [10, 41].

Quantitative analyses across multiple studies indicate that coffee agroforestry systems maintain higher woody species richness and regeneration rates compared to open-field agriculture or monoculture plantations [11, 43]. Shade trees not only provide ecological niches for understory plants but also contribute to microclimate stabilization, soil fertility improvement, and carbon storage, further promoting natural regeneration [33, 47].

Despite these positive contributions, regeneration is species- and site-specific, influenced by factors such as altitude, shade density, management intensity, and disturbance history [20, 26]. Overall, the reviewed literature underscores that conservation of woody species diversity and promotion of natural regeneration in coffee agroforestry systems are critical for sustaining Ethiopia's unique forest ecosystems and enhancing the long-term productivity and resilience of coffee landscapes.

Table 2. *Woody Species Diversity and Regeneration.*

Region / Zone	Key References	Woody Species Diversity	Regeneration Status
Southwest Ethiopia (Jimma, Kaffa, Yayo, Gedeo Zone)	[10, 20, 45, 69]	High species richness; both native and endemic species present	Moderate to high natural regeneration under shade
Sidama Zone / Southern Ethiopia	[6, 38, 40]	Moderate to high diversity, maintained through indigenous management	Good regeneration under traditional management practices
Oromia Region (Western Wellega, West Wollega, Sayo)	[13, 22, 65]	High diversity in well-managed farms; reduced diversity in fragmented landscapes	Variable regeneration; positively influenced by canopy heterogeneity
Northern Ethiopia (Zegie Peninsula)	[10, 41, 46]	Moderate diversity; forest fragments under pressure	Low regeneration due to anthropogenic disturbances

3.3. Ecosystem Services, Carbon Sequestration and Climate Resilience

The comparative analysis of studies revealed a strong positive relationship between carbon sequestration potential and improvements in soil fertility under various land management practices in Ethiopia [11, 43, 49]. These studies consistently showed that the integration of organic matter through exclosures, agroforestry, and sustainable land use enhanced soil organic carbon (SOC) accumulation (Table 3). The increased SOC stocks contributed not only to improved soil structure and nutrient cycling but also to enhanced water retention and microbial activity. Other study demonstrated that long-term exclosures significantly increased soil organic carbon content compared with adjacent degraded open lands, indicating that vegetation recovery and litter input are critical drivers of carbon buildup [11]. Similarly, Niguse et al. reported that soil fertility indicators such as nitrogen, phosphorus, and cation exchange capacity improved under managed ecosystems, highlighting the synergy between biological regeneration and soil nutrient dynamics [49]. Manaye et al. further emphasized that sustainable land management practices facilitate carbon stabilization in soil aggregates, reducing greenhouse gas emissions and supporting climate change mitigation efforts [43].

Ecosystem services and climate resilience are equally enhanced through appropriate management of shade trees and diversified vegetation structures. Studies by [13, 14, 68] underline that shade trees play a vital role in microclimate regulation, soil moisture conservation, and biodiversity protection, thereby strengthening ecosystem resilience against climate-induced stressors. The presence of multipurpose shade trees moderates surface temperatures, reduces evapotranspiration rates, and improves soil organic matter through continuous leaf litter deposition. These ecological benefits contribute to the sustainability of agricultural productivity and the overall resilience of farming systems. Moreover, the incorporation of shade trees into agroforestry and exclosure systems enhances carbon storage both above and below ground, demonstrating a dual function in climate mitigation and adaptation. According to Wagner, well-managed landscapes with diversified tree cover exhibit higher adaptive capacity, buffering local communities against climatic variability and extreme events [68]. Collectively, these findings highlight that integrating vegetative cover restoration, shade tree management, and soil fertility enhancement represents a viable strategy for achieving long-term ecosystem sustainability and resilience to climate change in Ethiopia's degraded landscapes.

Table 3. Carbon Sequestration, Soil Fertility, and Ecosystem Services.

Thematic Area	Key Findings	Major Drivers/Factors	References
Carbon Sequestration	Significant increase in soil organic carbon (SOC) in exclosures and managed ecosystems compared to degraded lands.	Vegetation recovery, litter accumulation, reduced erosion, improved biomass input.	[11, 43, 49]
Soil Fertility Improvement	Enhanced levels of nitrogen, phosphorus, and cation exchange capacity (CEC) under sustainable land management.	Organic matter input, soil microbial activity, and reduced disturbance.	[43, 49]
Ecosystem Services	Improved microclimate regulation, water retention, and biodiversity protection in managed landscapes.	Shade tree cover, ground vegetation diversity, litter decomposition.	[13, 14]
Climate Resilience	Increased adaptive capacity and reduced vulnerability of ecosystems to climate variability and extreme events.	Diversified vegetation structure, shade management, carbon storage in biomass and soils.	[14, 68]

3.4. Socio-economic and Livelihood Outcomes

Agroforestry and coffee-based systems have shown significant socio-economic benefits for smallholder farmers in Ethiopia, contributing to improved livelihoods, food security, and income diversification (Table 4). Studies indicate that integrating multipurpose trees with crops enhances household income through the sale of coffee, fruits, fuelwood, and other non-timber forest products [3, 65]. The adoption of these practices also strengthens local economies by promoting sustainable resource use and market linkages for forest-based products. Such diversified income sources reduce dependency on single commodities and enhance resilience against market fluctuations and climatic shocks [8, 9]. The introduction of shade-grown coffee systems, particularly in southern and southwestern Ethiopia, has contributed to better soil fertility, increased biodiversity, and higher yields, which translate into improved farmer income [15, 18, 19, 25, 67]. Furthermore, these systems offer employment opportunities along the value chain, from cultivation to processing and marketing, thereby creating local economic multipliers [16, 17]. The collective management of community forests and exclosures has also fostered social capital and cooperation among rural households [49, 65] bstrengthening community resilience and adaptive capacity.

From a gender and social inclusion perspective, agroforestry practices have provided women and youth with better access to livelihood options, particularly through the collection and marketing of forest products, small livestock integration, and participation in cooperatives [65]. Such participatory livelihood strategies have contributed to poverty reduction and improved household welfare, particularly in regions where land degradation and low agricultural productivity were previously limiting factors.

Despite these benefits, some studies highlight challenges such as unequal benefit-sharing, limited access to credit and extension services, and insecure land tenure, which can hinder the long-term sustainability of livelihood outcomes [12]. Addressing these socio-economic constraints through policy support, training, and inclusive governance mechanisms can further enhance the contribution of agroforestry and sustainable land management practices to rural development.

Table 4. Summary of Socio-Economic and Livelihood Outcomes.

Theme	Key Findings	Socio-Economic Drivers/Impacts	References
Income and Livelihood Diversification	Agroforestry and coffee systems increase household income and provide diversified products.	Sale of coffee, fruits, fuelwood, and non-timber forest products.	[27, 50]
Employment and Value Chain Benefits	Increased local employment from coffee and tree product markets.	Labor engagement in cultivation, processing, and marketing.	[67]
Community and Social Capital	Enhanced cooperation and collective resource management.	Strengthened community networks and governance of exclosures.	[65]
Gender and Youth Inclusion	Improved women's and youth participation in agroforestry livelihoods.	Access to markets, cooperatives, and training.	[65]

Theme	Key Findings	Socio-Economic Drivers/Impacts	References
Challenges and Policy Gaps	Persistent issues of inequitable benefit sharing and limited institutional support.	Weak extension systems, credit access, and land tenure insecurity.	[45]

3.5. Comparison with Global Findings

The findings from Ethiopian coffee-based agroforestry systems share strong similarities with global experiences, particularly in Latin America and West Africa, where coffee agroforestry has long been recognized for its ecological and socio-economic value [4, 57, 67], Table 5. In Ethiopia, coffee agroforestry contributes to biodiversity conservation, carbon storage, and livelihood diversification—patterns also widely observed in Latin American coffee landscapes such as those in Costa Rica, Mexico, and Colombia. These systems maintain high levels of shade tree diversity and structural complexity, which provide habitat for birds, pollinators, and other beneficial species, while stabilizing microclimates essential for coffee production under changing environmental conditions [67, 70-75]. Similarly, studies from West Africa, particularly Ghana and Côte d'Ivoire, reveal that cocoa and coffee agroforestry systems enhance ecosystem resilience, soil fertility, and farmers' income when compared to monoculture plantations [57]. Ethiopian systems show parallel outcomes, with farmers benefiting from diversified production—such as honey, fruits, and timber—and improved soil organic matter through litter fall and root biomass from shade trees. However, unlike Latin America and West Africa, Ethiopian systems often rely on indigenous forest remnants and semi-managed landscapes rather than highly commercialized or certified systems. This highlights a unique intersection of traditional ecological knowledge and conservation practices embedded in local management approaches.

Globally, the sustainability of coffee agroforestry is increasingly linked to certification schemes, climate adaptation policies, and payment for ecosystem services (PES) initiatives. While Latin American countries have advanced institutional support for such mechanisms, Ethiopia still faces gaps in policy integration, market access, and incentive-based conservation. Nevertheless, the Ethiopian context demonstrates strong potential for scalable ecosystem-based adaptation models that combine local knowledge, biodiversity conservation, and livelihood improvement—contributing valuable insights to the global discourse on sustainable coffee production and agroforestry development [7, 2, 57, 67, 76-80].

Table 5. *Comparative Insights Between Ethiopian and Global Agroforestry Systems.*

Region	Agroforestry Focus	Key Ecological and Socio-Economic Outcomes	Distinctive Features	References
Ethiopia (Africa)	Coffee-based agroforestry	Biodiversity conservation, carbon storage, improved livelihoods	Indigenous forest integration, traditional management systems	[57, 67, 70-74]
Latin America (e.g., Costa Rica, Mexico, Colombia)	Shade coffee systems	High biodiversity, pollination services, stable yields	Certification programs, PES schemes, climate resilience focus	[67, 74]
West Africa (e.g., Ghana, Côte d'Ivoire)	Cocoa and coffee agroforestry	Soil fertility improvement, income diversification, reduced deforestation	Transition from monocultures, policy-supported restoration	[57]

3.6. Research Gaps

Despite the substantial body of evidence on the ecological and socio-economic roles of coffee-based agroforestry systems in Ethiopia, several critical research gaps remain. Most studies are short-term and site-specific, limiting understanding of long-term ecosystem dynamics and the sustainability of management interventions. There is a notable lack of longitudinal monitoring on carbon sequestration, soil fertility dynamics, and biodiversity recovery, which are essential for assessing the resilience and adaptability of agroforestry systems to climate variability and land-use change. Furthermore, research on the genetic diversity and conservation of shade tree species and traditional coffee varieties remains limited, despite their importance for maintaining ecosystem functions and supporting climate-resilient coffee production.

Socio-economic studies have primarily focused on household income and productivity, with insufficient integration of gender, youth, and policy dimensions that shape participation and benefit-sharing in agroforestry systems. The role of institutional frameworks, market incentives, and land tenure security in influencing adoption and management practices has also been underexplored. Additionally, there is a need for more interdisciplinary approaches that combine ecological, economic, and social data to evaluate trade-offs and synergies across ecosystem services. Addressing these gaps through coordinated, multi-scale, and participatory research will be crucial for developing evidence-based strategies that promote sustainable coffee agroforestry systems and rural resilience in Ethiopia.

4. Conclusion and Recommendations

Coffee-based agroforestry systems play a pivotal role in enhancing biodiversity conservation, improving ecosystem functions, and supporting sustainable livelihoods in Ethiopia. As demonstrated by multiple studies, these systems provide essential ecosystem services such as carbon sequestration, soil fertility improvement, and microclimate regulation while offering diversified income opportunities for smallholder farmers. By integrating trees with crops and maintaining semi-natural habitats, coffee agroforestry contributes significantly to landscape connectivity and ecological resilience in regions affected by deforestation and land degradation. Moreover, the system aligns with Ethiopia’s broader environmental and development priorities, particularly those outlined under the Climate-Resilient Green Economy (CRGE) strategy and the National Biodiversity Strategy and Action Plan.

To maximize these benefits, stronger policy integration and institutional support are needed to mainstream coffee agroforestry within national climate, forestry, and rural development frameworks. Promoting participatory management approaches can ensure that local communities—especially women and youth—are actively involved in decision-making and benefit-sharing processes. Shade-tree diversification should also be prioritized to enhance ecosystem stability, increase carbon storage, and support pollinator diversity.

Future research should focus on long-term ecological monitoring, genetic diversity conservation, and the assessment of carbon dynamics under different management regimes. Additionally, studies examining adaptation pathways and socio-economic trade-offs will be crucial for designing climate-smart agroforestry interventions that balance productivity with sustainability. By advancing integrated research, inclusive policies, and community-led management, coffee agroforestry can continue to serve as a cornerstone for biodiversity conservation and livelihood resilience in Ethiopia and beyond.

Abbreviations

PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
CRGE	Climate-Resilient Green Economy

Author Contributions

Ewunetu Tazebew: Conceptualization, methodology, data acquisition, data analysis, data interpretation, writing—original draft, writing—review and editing.

Fekadu Tiruneh: Conceptualization, methodology, supervision, writing—review and editing, final approval.

Yibeltal Anbes: Conceptualization, methodology, writing—review and editing.

Funding

This research did not receive any specific grant from funding agencies, either public or commercial.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

Authors declare no conflict of interest.

References

[1] Abebe, A. (2012). Smallholder farms livestock management practices and their implications on livestock water productivity in mixed crop-livestock systems in the highlands of Blue Nile basin: A case study from Fogera, Diga and Jeldu districts (Ethiopia) (Doctoral dissertation, Hawassa University).

[2] Abebe, M. G., Amare, Z. Y., Dietrich, P., Mehari, A. B., Assaye, H., Wondmeneh, T. A.,... & Freyer, B. (2025). The Contributions of Agroforestry to Achieve Food and Livelihood Security in Ethiopian Agricultural Community: A Comprehensive Review. Small-scale Forestry, 1-24.

[3] Alemayehu, D., Benti, T., Beksisa, L., Merga, D., Getaneh, A., Tefera, F., & Addisu, M. (2023). The Exploration and Utilization of Coffee (Coffea arabica L.) Genetic Resource in Its Center of Origin. Available at SSRN 4664900.

[4] Amamo, A. A. (2014). Coffee production and marketing in Ethiopia. European journal of Business and Management, 6(37), 109-122.

[5] Asare, R., Afari-Sefa, V., Osei-Owusu, Y., & Pabi, O. (2014). Cocoa agroforestry for increasing forest connectivity in a fragmented landscape in Ghana. Agroforestry systems, 88(6), 1143-1156.

[6] Asfaw, Z., & Ågren, G. I. (2007). Farmers’ local knowledge and topsoil properties of agroforestry practices in Sidama, Southern Ethiopia. Agroforestry Systems, 71(1), 35-48.

[7] Babo Gembel Agricultural Office (BGAO). (2016). Annual report on agricultural and natural resource management. Babo Gembel, Ethiopia.

[8] Barboza, R. B. (2021). The Decrease in Coffee Biodiversity and Its Implication for Ethiopia.

[9] Barlow, J., Gardner, T. A., Araújo, I. S., Ávila-Pires, T. C., Bonaldo, A. B., Costa, J. E.,... & Peres, C. A. (2007). Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. Proceedings of the National Academy of Sciences, 104(47), 18555-18560.

[10] Belay, B., Zewdie, S., Mekuria, W., Abiyu, A., Amare, D., & Woldemariam, T. (2019). Woody species diversity and coffee production in remnant semi-natural dry Afromontane Forest in Zegie Peninsula, Ethiopia. Agroforestry Systems, 93(5), 1793-1806.

[11] Betemariyam, M., Negash, M., & Worku, A. (2020). Comparative analysis of carbon stocks in home garden and adjacent coffee based agroforestry systems in Ethiopia. Small-Scale Forestry, 19(3), 319-334.

[12] Bhagwat, S. A., Willis, K. J., Birks, H. J. B., & Whittaker, R. J. (2008). Agroforestry: a refuge for tropical biodiversity?. Trends in ecology & evolution, 23(5), 261-267.

[13] Birhanu, A., & Terefe, D. (2022). The role of shade trees in coffee production systems: The case of Yayo District, Ilubabora Zone, Oromiya Region, Southwest Ethiopia. South Asian Res J Bio Appl Biosci, 4(2), 37-50.

[14] Bracken, P., Burgess, P. J., & Girkin, N. T. (2023). Opportunities for enhancing the climate resilience of coffee production through improved crop, soil and water management. Agroecology and Sustainable Food Systems, 47(8), 1125-1157.

[15] Brokaw, J. (2013). Pollinator Habitat Availability and Diversity in Various Tropical Agroforestry Management Systems of Coffea Arabica in Santa Clara, Chiriqui.

[16] CBD (Convention on Biological Diversity). (2015). Ethiopia's National Biodiversity Strategy and Action Plan 2015–2020. Addis Ababa: Federal Democratic Republic of Ethiopia. Retrieved from https://www.cbd.int/doc/world/et/et-nbsap-v2-en.pdf

[17] CBD (Convention on Biological Diversity). (2022). Kunming-Montreal Global Biodiversity Framework. Montreal: CBD Secretariat. Retrieved from https://www.cbd.int/gbf

[18] Cerda, R., Avelino, J., Harvey, C. A., Gary, C., Tixier, P., & Allinne, C. (2020). Coffee agroforestry systems capable of reducing disease-induced yield and economic losses while providing multiple ecosystem services. Crop Protection, 134, 105149.

[19] Condit, R., Hubbell, S. P., & Foster, R. B. (1996). Changes in tree species abundance in a neotropical forest: impact of climate change. Journal of tropical ecology, 12(2), 231-256.

[20] Denu, D., Platts, P. J., Kelbessa, E., Gole, T. W., & Marchant, R. (2016). The role of traditional coffee management in forest conservation and carbon storage in the Jimma Highlands, Ethiopia. Forests, trees and LiveLihoods, 25(4), 226-238.

[21] Eshete, G. T. (2013). Biodiversity and livelihoods in southwestern Ethiopia: forest loss and prospects for conservation in shade coffee agroecosystems (Doctoral dissertation, University of California, Santa Cruz).

[22] Etafa, A. T., Adugna, G. D., & Dugassa, F. D. (2023). Soil physicochemical properties and coffee production under canopies of Croton machrostachyus and Cordia Africana tree species in Sayo district, western Ethiopia. Agroforestry Systems, 97(4), 519-531.

[23] FDRE (Federal Democratic Republic of Ethiopia). (2011). Ethiopia's Climate-Resilient Green Economy (CRGE) Strategy. Addis Ababa: FDRE. Retrieved from https://www.greengrowthknowledge.org/national-documents/ethiopia-climate-resilient-green-economy

[24] Frrao, R., VolpiI, P., Ferrao, M., da Fonseca, A. F. A., & Verdin Filho, A. C. (2019). Origin, geographical dispersion, taxonomy and genetic diversity of Coffea canephora.

[25] Gebremedhin, B., Tadesse, T., Hadera, A., Tesfay, G., & Rannestad, M. M. (2023). Risk preferences, adoption and welfare impacts of multiple agroforestry practices. Forest Policy and Economics, 156, 103069.

[26] Geleta, K. (2013). Effect of coffee management and fragmentation on plant communities and regeneration patterns in Afromontane moist evergreen forests in South West Ethiopia.

[27] Gezahegn, T., Negash, M., & Yirsaw, E. (2025). Socio-Economic Benefits of Indigenous Agroforestry in Enhancing Climate Adaptation in the Gedeo Zone, Southeastern Ethiopia. Integrated Environmental Assessment and Management, vjaf061.

[28] Gole, T. W., Borsch, T., Denich, M., & Teketay, D. (2008). Floristic composition and environmental factors characterizing coffee forests in southwest Ethiopia. Forest Ecology and Management, 255(7), 2138-2150.

[29] Hedberg, I., Friis, I., & Edwards, S. (2004). Flora of Ethiopia and Eritrea: Vol. 5, Part 2. Asteraceae (Compositae). The National Herbarium, Addis Ababa University; Department of Systematic Botany, Uppsala University.

[30] Hennink, M. M., Kaiser, B. N., & Weber, M. B. (2019). What influences saturation? Estimating sample sizes in focus group research. Qualitative health research, 29(10), 1483-1496.

[31] Hussain, Z., Bezanjo, M. A., Ahmad, S., Mithal, U., Arshad, M. U., Kamran, M.,... & Basheer, N. (2025). Agroforestry for Climate Mitigation, Resilient Farming, and Food Security. Global Research Journal of Natural Science and Technology.

[32] Jha, S., Bacon, C. M., Philpott, S. M., Ernesto Méndez, V., Läderach, P., & Rice, R. A. (2014). Shade coffee: update on a disappearing refuge for biodiversity. BioScience, 64(5), 416-428.

[33] Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry systems, 76(1), 1-10.

[34] Kpoviwanou, M. R. J. H., Sourou, B. N. K., & Ouinsavi, C. A. N. (2024). Challenges in adoption and wide use of agroforestry technologies in Africa and pathways for improvement: A systematic review. Trees, Forests and People, 17, 100642.

[35] Krannich, R. S., & Humphrey, C. R. (1986). Using key informant data in comparative community research: An empirical assessment. Sociological methods & research, 14(4), 473-493.

[36] Krebs, C. J. 1985. The Experimental Analysis of Distribution and Abundance, Harper & Row Publishers, New York, NY, USA.

[37] Labouisse, J. P., Bellachew, B., Kotecha, S., & Bertrand, B. (2008). Current status of coffee (Coffea arabica L.) genetic resources in Ethiopia: implications for conservation. Genetic Resources and Crop Evolution, 55(7), 1079-1093.

[38] Lameso, L., & Bekele, W. (2020). Farmers local knowledge on Niche selection, management strategies and uses of Cordia africana tree in agroforestry practices of Sidama zone, southern Ethiopia. American Journal of Agriculture and Forestry, 8(6), 258-264.

[39] Laurance, W. F., Sayer, J., & Cassman, K. G. (2014). Agricultural expansion and its impacts on tropical nature. Trends in ecology & evolution, 29(2), 107-116.

[40] Legesse, A., & Negash, M. (2021). Species diversity, composition, structure and management in agroforestry systems: the case of Kachabira district, Southern Ethiopia. Heliyon, 7(3).

[41] Libmogn, Y., Wolle, H. S., & Tazebew, E. (2025). Wood species diversity, regeneration status and anthropogenic threats in Gewecha natural forest, Northwestern Ethiopia. Discover Plants, 2(1), 97.

[42] Lucie, F. Ã., Etchike, A. B. D., Solefack, M. C. M., Tumenta, P., & Nkwelle, J. (2020). Woody species diversity conservation and carbon sequestration potential of coffee agroforestry systems in the Western Region of Cameroon. Journal of Horticulture and Forestry, 12(2), 35-48.

[43] Manaye, A., Tesfamariam, B., Tesfaye, M., Worku, A., & Gufi, Y. (2021). Tree diversity and carbon stocks in agroforestry systems in northern Ethiopia. Carbon Balance and Management, 16(1), 14.

[44] Mlambo, D., Álvarez-Álvarez, P., & Chavan, S. B. (2025). Agroforestry for biodiversity and ecosystem services. Frontiers in Forests and Global Change, 8, 1616451.

[45] Moguel, P., & Toledo, V. M. (1999). Biodiversity conservation in traditional coffee systems of Mexico. Conservation biology, 13(1), 11-21.

[46] Mulugeta, G., & Admassu, M. (2014). Woody species diversity and their preferences on farmers' land holding. Journal of Natural Sciences Research, 4(9), 96-108.

[47] Nair, P. R., Kumar, B. M., & Nair, V. D. (2022). Agroforestry for biodiversity conservation. In An introduction to agroforestry: four decades of scientific developments (pp. 539-562). Cham: Springer International Publishing.

[48] Nasiro, K. (2024). The Benefits of Agroforestry Coffee Production Systems: A Review. World Journal of Food Science and Technology, 8(4), 86-105.

[49] Niguse, G., Iticha, B., Kebede, G., & Chimdi, A. (2022). Contribution of coffee plants to carbon sequestration in agroforestry systems of Southwestern Ethiopia. The Journal of Agricultural Science, 160(6), 440-447.

[50] Odeny, D. A. (2016). Effect of cordia African lam shade on physiology, yield and quality of Arabica coffee (Doctoral dissertation, University of Nairobi).

[51] Perfecto, I., & Vandermeer, J. (2015). Coffee agroecology: a new approach to understanding agricultural biodiversity, ecosystem services and sustainable development. Routledge.

[52] Perfecto, I., Vandermeer, J., & Philpott, S. M. (2014). Complex ecological interactions in the coffee agroecosystem. Annual Review of Ecology, Evolution, and Systematics, 45(1), 137-158.

[53] Philpott, S. M., Arendt, W. J., Armbrecht, I., Bichier, P., Diestch, T. V., Gordon, C.,... & Zolotoff, J. M. (2008). Biodiversity loss in Latin American coffee landscapes: review of the evidence on ants, birds, and trees. Conservation Biology, 22(5), 1093-1105.

[54] Raga, A., Beyene, F., Haji, J., & Siyum, C. (2024). Determinants of Smallholder Farmers' About Choices of Sustainable Land Management Practices in West Wollega Zone, Oromia Region, Ethiopia. Sustainable Agriculture Research, 13(1), 74-90.

[55] Rago, D. E., Gbadegesin, A. S., & Gole, T. W. (2025). Contribution of Arabica Coffee Production Systems into Ecosystem Services in Southwestern Ethiopia. TWIST, 20(2), 474-487.

[56] Scheper, A. C. (2019). The potential of coffee agroforestry systems to enhance crop productivity, pest control, carbon sequestration and biodiversity: Evidence from the Eje Cafetero, Colombia (Master's thesis).

[57] Schroth, G., & Harvey, C. A. (2007). Biodiversity conservation in cocoa production landscapes: an overview. Biodiversity and Conservation, 16(8), 2237-2244.

[58] Schroth, G., Läderach, P., Martinez-Valle, A. I., Bunn, C., & Jassogne, L. (2016). Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation. Science of the Total Environment, 556, 231-241.

[59] Senbeta, F., & Denich, M. (2006). Effects of wild coffee management on species diversity in the Afromontane rainforests of Ethiopia. Forest Ecology and Management, 232(1-3), 68-74.

[60] Sereke-Brhan, H. (2010). Coffee, culture, and intellectual property: Lessons for Africa from the Ethiopian fine coffee initiative. Boston University Frederick S. Pardee Center for the Study of the Longer-Range Future.

[61] Siles, P., Cerdán, C. R., & Staver, C. (2022). Smallholder coffee in the global economy—A framework to explore transformation alternatives of traditional agroforestry for greater economic, ecological, and livelihood viability. Frontiers in Sustainable Food Systems, 6, 808207.

[62] Soto-Pinto, L., Perfecto, I., Castillo-Hernandez, J., & Caballero-Nieto, J. (2000). Shade effect on coffee production at the northern Tzeltal zone of the state of Chiapas, Mexico. Agriculture, ecosystems & environment, 80(1-2), 61-69.

[63] Tamru, S., & Minten, B. (2023). Value addition and farmers: Evidence from coffee in Ethiopia. Plos one, 18(1), e0273121.

[64] Taylor, D., Kent, M., & Coker, P. (1993). Vegetation description and analysis: A practical approach. The Geographical Journal, 159(2), 237.

[65] Tazebew, E., & Asfaw, Z. (2018). Tree species diversity, preference and management in smallholder coffee farms of Western Wellega, Ethiopia. Journal of Biology, Agriculture and Healthcare, 8(24), 43-53.

[66] Tesfay, H. M., Oettel, J., Lapin, K., & Negash, M. (2024). Plant diversity and conservation role of three indigenous agroforestry systems of Southeastern Rift-Valley Landscapes, Ethiopia. Diversity, 16(1), 64.

[67] Tscharntke, T., Clough, Y., Bhagwat, S. A., Buchori, D., Faust, H., Hertel, D.,... & Wanger, T. C. (2011). Multifunctional shade - tree management in tropical agroforestry landscapes–a review. Journal of Applied Ecology, 48(3), 619-629.

[68] Wagner, S. (2022). The potential of shade trees to improve microclimate in coffee production systems and contribute to the protection of coffee yield and quality in a changing climate (Doctoral dissertation, Manchester Metropolitan University).

[69] Worku, M., Lindner, A., & Berger, U. (2015). Management effects on woody species diversity and vegetation structure of coffee-based agroforestry systems in Ethiopia. Small-scale forestry, 14(4), 531-551.

[70] Tumwebaze, S. B., & Byakagaba, P. (2016). Soil organic carbon stocks under coffee agroforestry systems and coffee monoculture in Uganda. Agriculture, Ecosystems & Environment, 216, 188-193.

[71] Awazi, N. P. (2025). Climate change mitigation and adaptation in Cameroon through cocoa and coffee-based agroforestry systems. Discover Forests, 1(1), 8.

[72] Fahad, S., Chavan, S. B., Chichaghare, A. R., Uthappa, A. R., Kumar, M., Kakade, V.,... & Poczai, P. (2022). Agroforestry systems for soil health improvement and maintenance. Sustainability, 14(22), 14877.

[73] Kasongo, R. K., Verdoodt, A., Kanyankagote, P., Baert, G., & Ranst, E. V. (2011). Coffee waste as an alternative fertilizer with soil improving properties for sandy soils in humid tropical environments. Soil use and Management, 27(1), 94-102.

[74] Maro, G., Kilambo, D., Kiwelu, L., & Mbwambo, S. (2024). Integrated soil fertility management practices for coffee in Tanzania: a review. World Journal of Agricultural Research, 12(1), 8-17.

[75] de Souza, H. N., de Goede, R. G., Brussaard, L., Cardoso, I. M., Duarte, E. M., Fernandes, R. B.,... & Pulleman, M. M. (2012). Protective shade, tree diversity and soil properties in coffee agroforestry systems in the Atlantic Rainforest biome. Agriculture, Ecosystems & Environment, 146(1), 179-196.

[76] Chemeda, B. A., Wakjira, F. S., & Birhane, E. (2024). The role of coffee-based Agroforestry in improving food security through dietary diversification. Discover Agriculture, 2(1), 131.

[77] Jemal, O. M., Callo-Concha, D., & van Noordwijk, M. (2021). Coffee agroforestry and the food and nutrition security of small farmers of south-western Ethiopia. Frontiers in Sustainable Food Systems, 5, 608868.

[78] Mbow, Cheikh, Meine Van Noordwijk, Eike Luedeling, Henry Neufeldt, Peter A. Minang, and Godwin Kowero. "Agroforestry solutions to address food security and climate change challenges in Africa." Current Opinion in Environmental Sustainability 6 (2014): 61-67.

[79] Jemal, O. M., Callo-Concha, D., & van Noordwijk, M. (2022). Does income imply food security in coffee growing communities? A case study in Yayu, Southwestern Ethiopia. Frontiers in Sustainable Food Systems, 6, 1051502.

[80] Shilabu, M. D. T. (2008). The contribution of agroforestry to household food security and income generation in Maswa District, Shinyanga region (Doctoral dissertation, Sokoine University of Agriculture (SUA)).