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Agroforestry and Environmental Protection: A Systematic Review of Evidence from Uganda and Sub-Saharan Africa

Dr. Friday Christopher, Dr.Suzan Luyiga, Prof.Adeyemo David Oluropo

Kampala International University

Corresponding Author's Email: friday.christopher@kiu.ac.ug

ABSTRACT: Background: *Integrating trees into farmland known as agroforestry offers a promising approach to tackling environmental issues such as soil degradation, biodiversity decline, climate change, and food shortages. In Uganda, where most farmers are smallholders and environmental damage is widespread, it is vital to understand how well agroforestry works to guide policies and programmes.* ***Objective:*** *This systematic review brings together field evidence on how agroforestry supports environmental protection in Uganda and sub-Saharan Africa. It focuses on soil and biodiversity conservation, carbon storage, climate adaptation, and farmer livelihoods, while also identifying adoption barriers, enforcement weaknesses, and research priorities.* ***Methods:*** *The review followed PRISMA 2020 guidelines. A thorough search was run on Google Scholar, Scopus, Web of Science, PubMed, ScienceDirect, and institutional repositories using terms related to agroforestry, environmental protection, soil, biodiversity, carbon, Uganda, and sub-Saharan Africa. Studies were eligible if they examined agroforestry practices, reported environmental or livelihood outcomes, were conducted in the region, were published from 1999 to 2025, and were in English. Both quantitative and qualitative studies were included, and quality was assessed with appropriate tools such as the CASP checklist.* ***Results:*** *Evidence from thirty-two studies consistently shows positive environmental effects. On soil conservation, research from Ethiopia and Ghana recorded erosion reductions of eighty-seven to ninety-three percent under agroforestry compared to conventional farming. Ugandan studies in the east and west found erosion cuts of up to eighty-four percent, together with improved soil organic matter and structure. For biodiversity, agroforestry systems in the West Nile, Mount Elgon, and Kabale areas supported more plant, bird, and animal species than monocultures. Regarding carbon storage, central Ugandan research showed agroforestry holding up to eight times more carbon than conventional farms, and western Ugandan studies up to five times more. Climate benefits included better drought resistance through higher soil moisture, reduced water loss, and crop shading. Livelihood gains were also reported: farmers practising agroforestry earned more, spent less on inputs, diversified their incomes, and enjoyed greater food security. Nevertheless, adoption remains low due to insecure land rights, scarce seedlings, weak government support, limited knowledge, poor market access, and underfunded extension services.* ***Identified Gaps:*** *Key gaps include missing quantitative data on key mechanisms, no validated local measurement tools, few long-term or experimental studies, vague tree categories, poor understanding of links to nutrition and health, unknown long-term effectiveness, limited site-specific carbon data, questionable relevance of European findings to Uganda, incomplete knowledge of socio-economic adoption factors, fragmented ministry coordination, weak district capacity, and inadequate policy backing.* ***Discussion and Conclusions:*** *Agroforestry clearly contributes to environmental protection by cutting erosion by eighty-four to ninety-three percent, boosting soil fertility, increasing biodiversity, storing three to eight times more carbon than conventional farming, improving drought resilience, and raising incomes and food security. However, success depends on proper implementation, suitable tree species, good training, and supportive policies. Adoption is held back by insecure land tenure, seedling shortages, weak government support, limited technical knowledge, and poor market links. To maximise agroforestry's potential, efforts should focus on strengthening extension services, setting up tree nurseries, securing land rights, embedding agroforestry in national climate plans, creating market links, scaling up proven methods through farmer-to-farmer learning, and conducting rigorous long-term evaluations. Major research needs include longitudinal biodiversity studies, experimental intervention trials, context-specific carbon accounting, and investigations into how agroforestry affects nutrition and health. This review offers a solid evidence base for policymakers, practitioners, researchers, and farmers aiming to use agroforestry for environmental protection and sustainable farming in Uganda and across sub-Saharan Africa.*

Keywords: Agroforestry, environmental protection, soil conservation, biodiversity, carbon sequestration, climate change adaptation, Uganda, sub-Saharan Africa, smallholder farmers, sustainable land management**.**

1. INTRODUCTION

One of the critical factors of any academic endeavor is having enough knowledge about the subject area being studied, hence familiarity with the existing works. Conducting a literature review together with analyzing the findings regarding the topic being examined is essential in order to prove the adequacy of knowledge about the field and becomes a vital element of the teaching process, applications for research ethics approval, grants applications, etc., which may also lay the groundwork for further research.

This systematic review deals with the contribution of agroforestry in environmental protection, particularly in Uganda and sub-Saharan Africa.

Agroforestry, which entails the incorporation of trees and shrubs into agriculture, is one of the land management practices that have become popular over the years. Agroforestry has proved to be effective in dealing with the most difficult challenges facing the environment as well as agriculture today. Agroforestry systems involve the cultivation of trees together with crops and livestock, with the benefits including increased fertility due to decayed organic matter, better biodiversity because of habitat creation, drought resistance through soil moisture and temperature regulation, and more income sources for farmers through various produce from trees such as nuts, fruits, and timber. In Uganda, where small farmers play a major role in agricultural activities and where environmental degradation is still an issue of concern, there has been increased use of agroforestry as one of the approaches aimed at enhancing livelihoods and promoting sustainable land management practices. Uganda encounters various environmental problems including soil erosion, soil infertility, deforestation, loss of biological diversity, and susceptibility to the impacts of climate change. According to Self Help Africa, the problem of soil erosion occurs significantly in areas like Rubaya, Butanda, Kamuganguzi, and Kitumba, where sustainable land management practices have been used successfully. While there are known advantages associated with agroforestry, its adoption in Uganda is still low owing to various constraints such as inconsistent land tenure, scarcity of tree seedlings, weak government support, lack of information and inputs, lack of markets, improper management, lack of motivation, and imbalance in tree species composition. In addition, there is a substantial amount of missing information concerning the efficacy of agroforestry systems in the long term, site-specific results, impact pathways, and ways to upscale successful interventions.

In summary, the major issue addressed in this systematic review is the fragmented nature of the body of evidence related to the role of agroforestry in environmental conservation in Uganda and sub-Saharan Africa. Even though many pieces of literature have found favorable impacts of agroforestry practices, many knowledge gaps still exist in the body of evidence concerning measurement of impacts, conditions required for success, limitations of the practice, and whether the results obtained are generalizable beyond specific agroecological or socioeconomic settings.

2 INCLUSION AND EXCLUSION CRITERIA

The subject matter for this systematic review was chosen due to the apparent mismatch between the positive impact on the environment from agroforestry and its poor adoption rate, especially in Uganda and other parts of sub-Saharan Africa. Preliminary research showed that although there is a vast amount of literature on the subject, including primary studies and policy documents, no systematic review has been conducted on this subject area in Uganda.

Based on the PICO criteria, the following inclusion criteria have been developed. The population or problem refers to smallholder farmers, agricultural land, and rural areas of Uganda and sub-Saharan Africa that are subjected to environmental degradation such as soil erosion, decline in fertility, loss of biodiversity, and climatic vulnerabilities. Intervention involves the use of agroforestry practices such as intercropping, alley cropping, boundary planting, home gardens, parklands, silvopasture, riparian buffers, and coffee shade. Comparison is made against conventional agriculture, monocultures, and non-adoption of agroforestry. The outcomes are divided into environmental and livelihoods outcomes. Environmental outcomes include soil conservation, biodiversity conservation, carbon storage, and adaptation to climate change. Livelihood outcomes include crop production, income, and food security. The study design includes peer-reviewed articles, systematic reviews, policy analysis, official documents, and theses. The timeframe ranges from 1999 to 2025 covering twenty-five years of relevant research literature. Language restriction is English. Geography is Uganda as the main context while sub-Saharan Africa serves as the secondary context.

Studies that concentrated on forest management practices without agricultural elements were excluded. Studies carried out outside sub-Saharan Africa unless they offered significant theoretical foundations were also left out. Publications prior to 1999 except seminal works, opinion pieces devoid of empirical findings, papers not in English language, and studies concentrating only on economic impacts without considering environmental impacts were excluded as well.

This study used a systematic approach to gather relevant literature from various databases. The search terms used involved agroforestry or agroforestry systems or tree-crop intercropping or alley farming or border planting or home gardens or parklands or silvopastoral systems coupled with environmental conservation or soil preservation or soil fertility or biodiversity or carbon capture or climate change adaptation or drought resistance coupled with Uganda or sub-Saharan Africa or Kenya or Tanzania or Ethiopia or Ghana or West Nile or Mount Elgon or Kabale coupled with small-scale farmers or adoption or obstacles or sustainable farming.

The databases searched include Google Scholar for general multidisciplinary sources, Scopus for peer-reviewed literature with citation tracing, Web of Science for highly regarded journals and conferences, PubMed for literature on agriculture and environmental health, and ScienceDirect to source Elsevier journals. The sources of grey literature include documents by the Food and Agriculture Organization, World Agroforestry Centre, reports from the Self Help Africa projects, and the Ministry of Agriculture, Animal Industry and Fisheries of Uganda. Limitations used for searches include a date range from 1999 to 2025, English language, and document types of peer-reviewed articles, books, theses, and government reports.

3. SCREENING AND EXTRACTION

The screening process followed the PRISMA 2020 flow diagram guidelines and involved three stages. Stage one involved duplicate removal, whereby initial searches yielded one hundred eighty-seven records across all databases and sources. After removing duplicates, one hundred forty-two unique records remained. Stage two involved title and abstract screening, whereby of the one hundred forty-two records, seventy-eight were excluded based on title and abstract review because they did not address agroforestry in Uganda or sub-Saharan Africa, focused exclusively on forest management without agricultural components, were opinion pieces without empirical data, or fell outside the publication timeframe. Stage three involved full-text review, whereby the remaining sixty-four full-text articles were assessed for eligibility. Thirty-two articles were excluded for the following reasons: no direct measurement of environmental outcomes for twelve studies, focus on regions outside sub-Saharan Africa for eight studies, publication before 1999 without foundational relevance for five studies, unavailable in English for four studies, and duplicate publications for three studies. The final included studies comprised thirty-two studies that met all inclusion criteria and were included in the final synthesis.

Critical appraisal of included studies was conducted using appropriate tools based on study design. For qualitative studies, the Critical Appraisal Skills Programme Qualitative Checklist was used. For quantitative studies, appropriate tools were employed based on study design including cross-sectional, longitudinal, and experimental designs. For mixed-methods studies, the Mixed Methods Appraisal Tool was referenced. For grey literature, the Authority, Accuracy, Coverage, Objectivity, Date, Significance checklist was used. All included studies met acceptable quality thresholds, though limitations were noted regarding sample representativeness, potential researcher bias, measurement validity, and the generalizability of findings beyond specific study sites.

Data extraction from the thirty-two included studies used a standardized extraction form that captured author and year information, geographical context including country, region, district, and specific location, research design including qualitative, quantitative, mixed-methods, or experimental designs, sample characteristics including number of farmers, farm size, and agroecological zone, agroforestry practices including intercropping, alley cropping, boundary planting, home gardens, and parklands, environmental outcomes including soil fertility, soil erosion reduction, biodiversity, and carbon sequestration, livelihood outcomes including crop yields, household income, and food security, barriers to adoption including land tenure, seedling access, knowledge gaps, and policy constraints, and reported limitations and quality assessment scores.

4. RESULTS

As can be seen from the synthesis of the findings of thirty-two selected studies, agroforestry systems exhibit consistent beneficial effects on numerous environmental parameters in Uganda and other countries in sub-Saharan Africa. The studies analyzed include research conducted between 1999 and 2025, encompassing eighteen studies carried out in Uganda, four in Ethiopia, three in Kenya, two in Cameroon, one each in Ghana, Indonesia, and Europe, and one multi-country review. Most of the included studies used either a qualitative case study approach or combined methods, while there were fewer quantitative studies and systematic reviews among those selected.

With regards to soil conservation, this turned out to be the most consistently observed effect of agroforestry among the selected studies. Specifically, there is significant research evidence obtained both in Ethiopia and Ghana to prove that agroforestry significantly contributes to soil protection. According to an Ethiopian study, agroforestry systems decrease soil loss rate by as much as ninety-three percent compared to traditional farming techniques. Likewise, according to another study in Ghana, soil erosion rate in agroforestry systems decreased by up to eighty-seven percent.

This was the case in Uganda where several studies supported these findings. In Eastern Uganda, a study found out that agroforestry systems helped reduce soil erosion up to eight times higher than conventional agricultural systems. Further research done in western Uganda established that there was higher soil organic matter content and soil structure in agroforestry systems compared to conventional agriculture. In Kabale district, one study evaluated the role played by agroforestry in environmental protection through an assessment of intercropping, alley cropping, and boundary planting techniques. These practices were used to promote soil fertility, increase crop production, and prevent soil erosion.

In a study done in Kibaale district, it was discovered that use of agroforestry practices such as intercropping had led to increased soil fertility, higher crop productivity, improved food security levels among farmers, hence, improving household income. In southwestern Uganda, research found that farmers who practiced agroforestry techniques had higher soil organic matter content and greater biodiversity of plants in their agricultural lands. Another study done in eastern Uganda found that use of agroforestry practices contributed towards soil structuring and reducing soil erosion thereby increasing crop production.

The ways in which agroforestry practices promote soil conservation have been extensively discussed in the existing academic literature. The presence of trees serves to stabilize slopes, limit water runoff, and increase the levels of organic matter within the soil, which improves its structure and nutrient turnover. Contour farming and alley farming have proven particularly useful for mitigating soil erosion and increasing soil fertility.

However, much still remains to be done in regard to soil conservation research. Several scholars have argued that the use of agroforestry could help ensure the sustainability of agricultural practices and protect the environment in Europe, although it is worth noting that the European case may not necessarily be applicable to Uganda. This was corroborated by the researcher's observation in Kabale district, as several farmers engaged in agroforestry did not succeed in restoring soil fertility.

With regard to biodiversity conservation, another clear benefit of agroforestry practice from all the studies reviewed was the maintenance of higher species diversity when compared with the use of monoculture practices. A study carried out in Indonesia revealed that there were high levels of plant species diversity in agroforestry systems than in monoculture systems, which contributes positively to the resilience of the ecosystem.

According to research done in the West Nile region in Uganda, it was established that agroforestry practices had high species diversity of plants compared to monoculture farms. Research done in the Mount Elgon region in Uganda showed that there were more bird species diversity in agroforestry practices than in monoculture practices. A study carried out in Kabale district in Uganda indicated that agroforestry had more plant and animal species diversity than monoculture practices.

Research has also shown that agroforestry systems could provide habitat for wildlife such as primates and small mammals, and thereby contribute to biodiversity conservation in the landscape. Similarly, research has also indicated that agroforestry systems could provide habitats for wildlife such as birds and small mammals, and thus contribute to biodiversity conservation in the landscape.

Despite such findings, there are still many areas that remain unknown to us in biodiversity studies. The dynamic process involved in the biodiversity of agroforestry system is not yet studied enough. It is crucial for researchers to examine the changing trends of biodiversity pattern and composition in agroforestry systems over time to know whether its benefits persist or diminish with time.

Concerning carbon sequestration, it is basically the core method used by agroforestry systems to deal with the negative effects of climate change. Researchers from East and Western Africa have shown that agroforestry systems sequester higher amounts of carbon than traditional farms do. In Kenya, researchers have shown that agroforestry systems sequester three times more carbon than traditional farms. Also, in Cameroon, researchers discovered that agroforestry systems sequester four times more carbon than traditional farms.

The research carried out in central Uganda showed that agroforestry systems contained up to eight times as much carbon as farming systems did. Similarly, the research done in western Uganda revealed that agroforestry systems stored five times as much carbon as monoculture systems. Hence, this means that agroforestry systems have a lot of potential when it comes to mitigating climate change.

However, there are significant limitations within the context of carbon sequestration literature. Although these findings show that agroforestry has the potential of storing significant carbon amounts in western Uganda, they fail to provide the specific carbon sequestration rate of agroforestry in Kabale district. In addition, since the age of agroforestry in Kabale is quite young, the amount of carbon that these trees would accumulate cannot be determined.

The mechanisms of carbon sequestration in agroforestry systems are already known and documented. For instance, it is already noted by researchers that agroforestry offers various ecosystem services which include carbon sequestration through biomass and soil organic carbon storage. In a systematic review conducted in Ethiopia on the effect of agroforestry on soil organic carbon and soil aggregate stability, it was found that agroforestry systems had more soil organic carbon and soil aggregate stability.

The ways in which agroforestry systems contribute towards adaptation to climate change include making the land more resistant to droughts among other approaches. The approaches used to improve drought resistance include improved moisture content in soils, reduced evapotranspiration rates and shading of crops. Besides, there is improved ability to regulate temperatures of soils, hence making the system beneficial especially when there is drought because of high temperatures. Agroforestry trees are believed to be very efficient in enhancing the capacity of soils to infiltrate water, leading to high moisture content of the soils.

In Uganda, according to a study conducted in Kabale district, it has been found out that agroforestry practices including agroforestry parkland and agroforestry home garden plays an essential part in ensuring that certain ecological services are performed such as carbon storage, soil conservation and microclimate regulation. Moreover, it has been established that the above practices play a vital part in promoting the resilience of communities against climate changes. Other studies have shown that agroforestry systems have helped improve resilience of agricultural systems against climate change through improved soil conservation, carbon storage and sheltering.

Despite these documented benefits, significant gaps remain in the climate change adaptation literature. The statement about improved soil moisture content lacks specific data or quantification, representing a methodological gap. Furthermore, research on the mechanisms of resilience building remains underdeveloped in the Ugandan context.

In terms of livelihood improvement, apart from environmental benefits, agroforestry has also been proved to lead to significant livelihood improvements among smallholder farmers. According to the Food and Agriculture Organization, agroforestry leads to diversification of agriculture and increases productivity, which ultimately improves the food security status of rural households. Apart from improving food security status, agroforestry practices also lead to additional income generation from the sale of timber and fruits, create job opportunities in planting, pruning, harvesting, and processing of trees, and empowers women who play a critical role in agroforestry management.

Various studies in Uganda have confirmed the benefits of agroforestry practices on livelihoods of Ugandans. One study carried out in northern Uganda found that planting Grevillea trees in one's farm led to increased income as a result of increased yields and reduced input costs. Other researchers reported that agroforestry practice results in improved agriculture yield and soil fertility as well as generates additional income sources for farmers in Uganda. However, they observed that due to the uncertain land tenure status and lack of seedlings, agroforestry is not yet widespread in Uganda.

An analysis of economic gains of agroforestry practices in Kabale district showed that practices such as coffee-shade trees and fruit-tree intercropping were economically viable and served as a means of income generation for farmers. Further, such practices yielded environmental gains through activities such as soil conservation and improvement in the quality of water. In another case, a research conducted in Eastern Uganda reported that agroforestry practices improved soil fertility and availability of water, thus yielding more crops and ensuring food security of farming households.

In another study about agroforestry practices in Uganda, the authors reported that the environmental gains included carbon storage and soil conservation, while the livelihood gains included increased household incomes. The authors reported that their study could have taken into consideration factors such as potential barriers to scaling-up of agroforestry practices regionally or nationally and the effectiveness of current policies and programs aimed at encouraging adoption of agroforestry practices.

Research in the Lake Victoria Basin found that agroforestry practices reduced carbon emissions by up to fifty percent compared to conventional farming systems, in addition to improving soil health and crop yields. Another study in Tororo district found that agroforestry practices contributed to improved nutrition and health outcomes for households, as well as reduced pressure on natural resources.

Despite these documented benefits, significant gaps remain in the livelihood literature. One study highlighted positive outcomes of agroforestry practices but did not explore the mechanisms of soil fertility improvement. Another study did not show the limited understanding of the factors and mechanisms by which agroforestry practices contribute to improved nutrition and health outcomes for households, specifically in Tororo district. Another study did not spell out how agroforestry practices do not immediately bring out positive results with some farmers.

Regarding agroforestry adoption barriers and enforcement gaps, despite the well-documented benefits of agroforestry, adoption rates in Uganda and across sub-Saharan Africa remain low. Multiple barriers have been identified across the included studies.

Land tenure insecurity emerged as a primary barrier. Researchers have documented that unstable land ownership limits farmers' willingness to invest in long-term tree planting. Other researchers similarly found that agroforestry adoption in Europe remains low due to lack of governmental backing and limited access to tree seedlings, with similar patterns observed in Uganda.

Limited access to tree seedlings was identified as another critical barrier. Researchers documented that due to unstable land ownership and limited availability to tree seedlings, agroforestry adoption in Uganda is still at a low level. Other researchers similarly noted that adoption remains low despite demonstrated benefits.

Knowledge and technical capacity gaps were documented, with one author noting that agroforestry requires top-notch local expertise and training that is appropriate for the area. Poor management, lack of motivation, lack of technological knowledge, and uneven species mix were identified as factors contributing to agroforestry failure when not properly maintained.

Market and economic barriers were documented by researchers who identified limited market opportunities for agroforestry products as a constraint to adoption. One researcher noted that the time lag between planting trees and realizing benefits may discourage adoption among resource-constrained farmers.

Policy and enforcement gaps were documented across multiple studies. Researchers noted that lack of governmental backing represents a significant barrier in Europe, with similar patterns observed in Uganda. Another author documented that despite the benefits of agroforestry, there is a lack of suggestions for overcoming identified barriers and no suggested further research directions for addressing gaps in knowledge.

5. IDENTIFIED GAPS

This review identified significant gaps across multiple domains of the agroforestry and environmental protection literature. These gaps are organized into methodological, conceptual, contextual, enforcement and policy, livelihood, and climate change categories.

Methodological gaps include the lack of specific quantification and baseline data for key mechanisms such as improved soil moisture content. One study mentioned that trees in agroforestry systems can improve soil water infiltration and retention, which indirectly leads to better soil moisture content, but this statement lacks specific data or quantification. There is an absence of validated measurement instruments for assessing agroforestry outcomes in the Ugandan context. Limited longitudinal studies exist tracking long-term dynamics of biodiversity, soil fertility, and carbon sequestration rates. There are few experimental or quasi-experimental evaluations of agroforestry interventions. Minimal research examines optimal tree species compatibility regarding nutrient requirements, root system characteristics, water use efficiency, and allelopathic effects. One study could have explored the compatibility and synergies between specific tree species and crops in terms of nutrient requirements, root system characteristics, water use efficiency, allelopathic effects, and other factors that may influence soil fertility and crop productivity.

Conceptual gaps include unclear definitions of specific tree categories when defining agroforestry. One author defined agroforestry as the combination of trees with crops and livestock but did not specify which category of trees are combined with crops and livestock such as Calliandra and Grevillea which fix nitrogen in the soil, thereby improving soil fertility. There is inadequate attention to mechanisms linking agroforestry to improved nutrition and health outcomes. One study did not show the limited understanding of the factors and mechanisms by which agroforestry practices contribute to improved nutrition and health outcomes for households. There is limited understanding of long-term effectiveness and scalability of specific practices like contour planting and alley cropping. One study did not give an understanding of the long-term effectiveness and scalability of agroforestry practices, specifically contour planting and alley cropping, in reducing soil erosion and improving soil fertility. There is absence of research on using agroforestry trees such as Grevillea for non-traditional purposes including building canoes for lake transport and handcrafts supporting ecotourism.

Contextual gaps include insufficient evidence on site-specific carbon sequestration rates in Kabale district where trees remain young. Although some findings indicate the role of agroforestry in carbon sequestration in western Uganda, they do not show its rate of sequestration in Kabale district, which is a contextual gap. There is limited generalizability of findings from Europe to local Ugandan contexts. One study looked at the context of Europe which may not be very true according to the local context, for example in Kabale district, though some farmers have practiced agroforestry practices, their soils have remained infertile. There is lack of country-specific research within sub-Saharan Africa. One study carried out research in sub-Saharan Africa but did not specify the exact country where the study was carried out. There is incomplete understanding of socio-economic factors influencing adoption including farmer preferences, knowledge, attitudes, access to resources, and socio-cultural considerations. One study did not spell out the socio-economic factors that influence the adoption of agroforestry practices for soil conservation in Uganda, and could have explored the role of factors such as farmer preferences, knowledge, attitudes, access to resources, and socio-cultural considerations in promoting or hindering the widespread adoption of agroforestry systems. There is absence of research on how agroforestry practices may not immediately produce positive results for some farmers. One study did not spell out how agroforestry practices do not immediately bring out positive results with some farmers.

Enforcement and policy gaps include fragmented coordination between agricultural, environmental, and forestry ministries, inadequate resourcing of extension services, weak district-level implementation capacity, lack of centralized agroforestry monitoring systems, insufficient governmental backing, and limited access to tree seedlings. One study acknowledged the benefits of agroforestry and the barriers to adoption but did not give suggestions for overcoming the identified barriers and did not suggest further research directions for addressing the gaps in knowledge. Another study mentioned the benefits of agroforestry but did not talk about how it could improve the livelihoods of farmers, hence reducing pressure on land. Another study mentioned the benefits of agroforestry but did not talk about mitigating climate change through carbon sequestration.

Livelihood gaps include limited attention to how agroforestry improves farmer livelihoods beyond environmental benefits, particularly reducing pressure on land. One author mentioned the benefits of agroforestry but did not talk about how it could improve the livelihoods of the farmers, hence reducing pressure on land. There is lack of research on barriers and opportunities for scaling-up agroforestry practices at regional and national levels. One study could have explored the barriers and opportunities for scaling-up agroforestry practices at the regional or national level, as well as the effectiveness of existing policies or programs that promote agroforestry adoption and support farmers in realizing its environmental and livelihood benefits.

Climate change gaps include absence of research on mitigating climate change through carbon sequestration. One author mentioned the benefits of agroforestry but did not talk about mitigating climate change through carbon sequestration. There is limited understanding of mechanisms for reducing greenhouse gas emissions.

6. DISCUSSION

This systematic review demonstrates that agroforestry significantly contributes to environmental protection across multiple dimensions. The evidence synthesized from thirty-two studies consistently shows positive effects on soil conservation, soil fertility improvement, biodiversity conservation, carbon sequestration, climate change adaptation, and livelihood improvement. However, the effectiveness of agroforestry is contingent upon proper implementation, context-appropriate species selection, adequate training, and supportive policy environments.

The finding that agroforestry reduces soil erosion by eighty-four to ninety-three percent across multiple African contexts is particularly noteworthy. This level of erosion reduction has significant implications for agricultural sustainability, soil fertility maintenance, and water quality protection. The mechanisms through which trees stabilize slopes, reduce runoff, and enhance soil organic matter are well-established, but the magnitude of effect varies by context, species selection, and management practices. The observation that some farmers in Kabale district continue to experience infertile soils despite practicing agroforestry underscores the importance of implementation quality and the need for context-specific guidance on species selection and management.

The biodiversity conservation benefits of agroforestry, demonstrated through higher species diversity across plant, bird, and animal taxa, suggest that these systems can contribute to landscape-level conservation goals. However, the long-term dynamics of biodiversity in agroforestry systems remain poorly understood, representing a critical gap given that biodiversity benefits may require decades to fully materialize and may be sensitive to management practices and landscape context.

The carbon sequestration potential of agroforestry, with estimates ranging from three to eight times higher carbon storage than conventional systems, positions agroforestry as a significant climate change mitigation strategy. However, the wide range in estimates reflects substantial variation in tree species, age, density, management practices, and measurement methods. The finding that young trees in Kabale district have not yet sequestered the levels reported in other studies highlights the need for site-specific carbon accounting that accounts for tree age, species, and growth conditions.

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The livelihood benefits documented across multiple Ugandan studies provide evidence that agroforestry can contribute to poverty reduction and food security alongside environmental objectives. The finding that coffee-shade trees and fruit-tree intercropping in Kabale district are profitable suggests that market-oriented agroforestry can generate both environmental and economic returns. However, the time lag between planting and realizing benefits represents a significant barrier for resource-constrained farmers who may require immediate returns to meet basic needs.

The adoption barriers identified across the included studies are substantial and multi-faceted. Land tenure insecurity, limited seedling access, inadequate governmental backing, insufficient technical knowledge, and weak market linkages collectively constrain adoption. These barriers are interconnected, such that addressing any single barrier in isolation is unlikely to substantially increase adoption. For example, improving seedling access without addressing land tenure insecurity may not incentivize farmers to invest in long-term tree planting, as they may not be confident that they will remain on the land long enough to realize benefits.

The enforcement gaps documented in this review are severe, with significant gaps between policy commitments and implementation reality. The finding that agroforestry adoption in Europe remains low due to lack of governmental backing, with similar patterns observed in Uganda, suggests that policy support gaps are not unique to the African context but may be particularly consequential in resource-constrained settings where extension services and seedling distribution systems are weak.

7. CONCLUSIONS

This systematic review provides compelling evidence that agroforestry significantly contributes to environmental protection across multiple dimensions including soil conservation, biodiversity conservation, carbon sequestration, climate change adaptation, and livelihood improvement. The convergent findings from thirty-two studies demonstrate that agroforestry reduces soil erosion by up to ninety-three percent, supports higher biodiversity than monoculture systems, sequesters three to eight times more carbon than conventional farming, enhances drought tolerance through improved soil moisture and microclimate regulation, and generates livelihood benefits through increased yields, diversified income, and improved food security.

However, the effectiveness of agroforestry is contingent upon proper implementation, context-appropriate species selection, adequate training, and supportive policy environments. Current adoption levels remain low due to multiple barriers including unstable land tenure, limited seedling access, inadequate governmental backing, insufficient technical knowledge, and weak market linkages. Enforcement mechanisms are severely under-resourced, with significant gaps between policy commitments and implementation reality.

The evidence suggests that maximizing agroforestry's environmental protection potential requires strengthening extension services and farmer training on context-appropriate species selection and management practices, establishing tree seedling nurseries and improving access to quality planting materials, securing land tenure rights to incentivize long-term tree investments, integrating agroforestry into national climate change adaptation and mitigation strategies, developing market linkages for agroforestry products including timber, fruits, nuts, and medicinal products, scaling up proven practices through participatory approaches and farmer-to-farmer learning, conducting rigorous long-term impact evaluations with validated measurement instruments, investigating site-specific carbon sequestration rates and soil fertility mechanisms, exploring the compatibility of tree-crop combinations for different agroecological zones, researching innovative uses of agroforestry trees for ecotourism and sustainable livelihoods including using Grevillea to build canoes for lake transport and handcrafts, and addressing socio-economic and cultural barriers to adoption through targeted interventions.

Significant research gaps remain, particularly regarding longitudinal studies of biodiversity dynamics, experimental evaluations of integrated interventions, context-specific carbon accounting, the mechanisms linking agroforestry to nutrition and health outcomes, the long-term effectiveness and scalability of specific practices, the socio-economic factors influencing adoption including farmer preferences, knowledge, attitudes, access to resources, and socio-cultural considerations, and the barriers and opportunities for scaling-up agroforestry practices at regional and national levels.

This review provides a comprehensive evidence base for policymakers, development practitioners, researchers, and farmers seeking to harness agroforestry for environmental protection and sustainable agricultural development in Uganda and across sub-Saharan Africa, with particular relevance to high-priority regions such as Kabale district where soil erosion, land degradation, and food insecurity remain critical challenges. The findings underscore that agroforestry is not a panacea but rather a context-specific intervention that, when properly designed and implemented, can generate substantial environmental and livelihood co-benefits. Success depends on sustained commitment to capacity building, policy support, and stakeholder engagement that transcends conventional agricultural development approaches, ultimately contributing to enhanced environmental protection and sustainable development outcomes for rural communities in Uganda.

8. RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the gaps identified in this systematic review, the following priorities for future research are recommended.

First, longitudinal studies are needed to track the long-term dynamics of soil fertility, biodiversity, and carbon sequestration in agroforestry systems. Such studies should assess how outcomes change over time and whether observed benefits persist or diminish over extended periods.

Experimental and quasi-experimental evaluations of agroforestry interventions are needed to establish causal relationships between specific practices and environmental outcomes. These evaluations should include control groups and baseline measurements to enable rigorous impact assessment.

Site-specific research on carbon sequestration rates is needed in understudied regions such as Kabale district, with particular attention to young trees and the time lag between planting and carbon accumulation.

Research on optimal tree species compatibility should examine nutrient requirements, root system characteristics, water use efficiency, and allelopathic effects to provide evidence-based guidance for species selection in different agroecological zones.

Investigations into the mechanisms linking agroforestry to nutrition and health outcomes are needed to understand how tree-crop integration affects household food security and dietary diversity.

Socio-economic research should examine the factors influencing adoption including farmer preferences, knowledge, attitudes, access to resources, and socio-cultural considerations to inform targeted intervention design.

Research on the long-term effectiveness and scalability of specific practices such as contour planting and alley cropping should assess performance under different management regimes and landscape contexts.

Studies on the barriers and opportunities for scaling-up agroforestry practices at regional and national levels should examine policy, institutional, and market factors that constrain or enable widespread adoption.

Innovative research on non-traditional uses of agroforestry trees, including the use of Grevillea for building canoes for lake transport and handcrafts supporting ecotourism, should explore opportunities to diversify income streams and create additional incentives for adoption.

Research on the reasons why agroforestry practices may not immediately produce positive results for some farmers should examine implementation quality, species selection, management practices, and contextual factors that influence outcomes.

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