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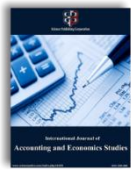

The Economic Viability of Agroforestry Practices in Increasing Farmer Income and Land Productivity in Marginal Areas

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Abstract

This study explores the economic viability of agroforestry practices in enhancing farmer income and land productivity in marginal areas, with a focus on Indonesia. Agroforestry systems, integrating trees with crops, are increasingly recognized as sustainable solutions for improving soil fertility, reducing erosion, and providing diversified income sources for farmers in marginal lands. The study reveals that agroforestry has led to significant improvements in farmer income, with increases of 27% to 35%, primarily due to additional income from non-timber forest products (NTFPs). Moreover, agroforestry has been shown to enhance land productivity by improving soil health and water retention, contributing to a 30% increase in crop yields. However, significant barriers, including high initial investment costs and limited market access, hinder the widespread adoption of agroforestry. The study highlights the importance of institutional and policy support, such as subsidies, training programs, and improved market access, in overcoming these barriers. The findings suggest that agroforestry can be a viable solution for improving economic outcomes in marginal areas, but further policy interventions and research are needed to facilitate its broader adoption.

Keywords: *Agroforestry; Farmer Income; Land Productivity; Marginal Areas; Non-Timber Forest Products.*

1. Introduction

Agroforestry practices, which integrate trees with crops or livestock on the same land, have emerged as a promising solution for improving land productivity and farmer incomes, particularly in marginal areas. These areas, often characterized by degraded soils, low agricultural productivity, and limited access to modern agricultural inputs, pose a significant challenge to conventional farming systems. According to the Food and Agriculture Organization (FAO), approximately 25% of the world's agricultural land is classified as marginal, which includes areas with poor soils or susceptible to erosion. (Canton, 2021). The decline in soil fertility and the increasing frequency of climate-related events, such as droughts and floods, further exacerbate the vulnerability of these regions. In response, agroforestry offers a multifaceted approach to mitigating land degradation, enhancing biodiversity, and improving the economic viability of agricultural systems. However, while agroforestry holds significant promise, its adoption in marginal areas remains limited, raising important questions about its feasibility and long-term impacts on farm productivity and household income.

The importance of investigating the economic viability of agroforestry practices cannot be overstated, particularly in regions where farmers face pressing challenges related to climate change, soil degradation, and market access. Numerous studies highlight the potential benefits of agroforestry, such as improved soil fertility, reduced erosion, enhanced water retention, and increased biodiversity. (Korneeva, 2022). In addition to these environmental advantages, agroforestry practices have been associated with higher and more stable farm incomes compared to conventional monocropping systems. (Amare & Darr, 2023). However, these benefits are often contingent upon specific site conditions, the choice of species, and the management practices employed, which vary widely across different regions. Despite the growing body of literature on agroforestry, there remains a lack of comprehensive economic assessments that explore the long-term viability of these practices, particularly in marginal agricultural areas, where economic constraints and environmental challenges are most pronounced. This research is crucial as it addresses the gap in understanding the economic outcomes of agroforestry systems in regions that most need sustainable interventions. With the growing pressure to adopt climate-resilient farming practices, there is an urgent need for evidence-based evaluations that can inform policy decisions and guide the scaling up of agroforestry in marginal areas. By focusing on the economic viability of agroforestry, this study aims to provide critical insights into how these practices can contribute to the resilience of smallholder farms, particularly in less favorable agricultural zones. The goal is to understand not only the direct economic benefits of agroforestry in terms of income generation, but also the indirect benefits related to land productivity and environmental sustainability. (Beshir et al., 2022). This research will contribute to the broader body of knowledge by comparing agroforestry to conventional farming systems and identifying the key factors that influence its success or failure in different contexts.

The specific objectives of this study are to assess the impact of agroforestry on farmer income and land productivity in marginal areas, identify the economic barriers and enablers of agroforestry adoption, and evaluate the potential for scaling agroforestry practices in these regions. By addressing these objectives, this research seeks to fill an important gap in the literature concerning the economic dimensions of agroforestry adoption in marginal agricultural zones. (Raj et al., 2022). In particular, the study will examine the trade-offs between short-term financial costs and long-term benefits, taking into account variables such as initial investment, maintenance costs, market access, and environmental factors. The findings from this study are expected to offer valuable recommendations for policymakers, agricultural extension services, and practitioners on how to design and promote economically viable agroforestry systems that are both environmentally sustainable and economically profitable. (Tebkew et al., 2024).

In relation to existing literature, this study seeks to contribute to a growing body of research on agroforestry's role in enhancing land productivity and farmer livelihoods, particularly in regions that face marginalization. Although previous studies have examined the environmental and social benefits of agroforestry, there is a notable gap in research that links these benefits directly to economic outcomes, especially in marginal areas where resources are scarce. This research intends to build on the works of authors such as (Thiesmeier & Zander, 2023) By providing a more detailed, context-specific analysis of the economic feasibility of agroforestry systems. In doing so, it will advance the understanding of how agroforestry can be integrated into the broader economic frameworks of rural development, especially in areas that require adaptive strategies to address ongoing agricultural challenges.

The central research question driving this study is: What is the economic viability of agroforestry practices in enhancing farmer income and land productivity in marginal agricultural areas? This question will guide the exploration of various agroforestry models and their applicability in real-world contexts, seeking to determine whether these practices can offer a sustainable path forward for farmers in challenging environments.

By systematically analyzing the relationship between agroforestry practices and economic outcomes in marginal areas, this research will provide valuable evidence on the effectiveness of agroforestry as a viable agricultural strategy. Furthermore, it will help policymakers, agricultural practitioners, and smallholder farmers understand how agroforestry can serve as a tool for improving farm profitability while simultaneously addressing environmental and socio-economic challenges in marginal agricultural zones

2. Literature Review

2.1. Agroforestry practices in marginal areas

Agroforestry, the practice of integrating trees with crops or livestock, is increasingly recognized for its potential to improve land productivity and resilience, particularly in marginal areas. These areas are often characterized by degraded soils, low agricultural yields, and vulnerability to environmental stressors such as droughts, floods, and soil erosion. Agroforestry systems provide a diversified approach to land use by integrating both woody and agricultural plants, which can help to restore soil fertility, improve water retention, and reduce soil erosion. (Sahoo et al., 2020). In marginal areas, where conventional farming methods are less effective, agroforestry offers a more sustainable alternative. Studies suggest that agroforestry systems can create microclimates that buffer extreme weather conditions, improving overall farm productivity. (Low et al., 2023). Moreover, integrating trees with crops has been shown to enhance biodiversity and increase carbon sequestration, making agroforestry not only beneficial for agricultural production but also for climate change mitigation.

The benefits of agroforestry in marginal areas extend beyond environmental improvements, as they can also support the livelihoods of smallholder farmers. Agroforestry systems can offer diverse income streams from the sale of timber, non-timber forest products (NTFPs), and increased crop yields. This diversification can reduce the vulnerability of farmers to market fluctuations and climatic risks, as seen in the case of smallholders in semi-arid regions of Africa and Asia. (Islam et al., 2021). In marginal areas, where soil fertility is often low, agroforestry systems with nitrogen-fixing trees can significantly improve soil health, leading to better yields from companion crops. A study by (Owusu et al., 2022)Found that agroforestry not only improved crop productivity but also reduced the dependency on external inputs such as synthetic fertilizers, making it a cost-effective practice for resource-constrained farmers.

2.2. Economic viability of agroforestry

The economic viability of agroforestry has been extensively studied, with research indicating that, under the right conditions, agroforestry can significantly increase farm income. In a study by (Maia et al., 2021)Agroforestry in the semi-arid regions of India was shown to provide a higher economic return compared to conventional monoculture farming. The practice of combining tree crops with food crops enabled farmers to diversify their sources of income, reducing risks associated with crop failure. For example, timber and fruit from trees planted as part of agroforestry systems offered an additional revenue stream for farmers, which proved particularly beneficial in years of poor crop harvests. Similarly, the integration of livestock with agroforestry systems, as explored in Ethiopia, provided farmers with multiple income sources, including meat, milk, and manure for soil enrichment, thus enhancing overall farm sustainability. (Sahoo et al., 2020).

Despite these advantages, the economic outcomes of agroforestry are highly dependent on local contexts, including market access, tree species selection, and the availability of technical support. Studies by (Abdul-Salam et al., 2022) Highlight that initial costs for planting and establishing agroforestry systems can be a significant barrier, especially in resource-poor regions. While agroforestry practices show promising long-term returns, the upfront investment in trees, infrastructure, and maintenance can discourage adoption. For instance, a study by (Sarvade et al., 2020) Revealed that while agroforestry led to increased income over time, farmers in marginal areas often struggled with the initial financial burden. Moreover, without access to reliable markets for selling agroforestry products, such as timber or NTFPs, farmers may not realize the full economic potential of these systems.

2.3. Land productivity and sustainability

Agroforestry practices have shown significant potential in improving land productivity, especially in degraded or marginal soils. Trees incorporated into agricultural systems provide benefits such as improved soil structure, increased nutrient cycling, and enhanced water retention. These benefits are crucial in marginal areas where soil erosion and nutrient depletion are common challenges. For instance, nitrogen-fixing trees in agroforestry systems improve soil fertility and enhance crop yields, as demonstrated in various studies conducted in Africa and Asia. (Dhakal et al., 2022). These systems help restore degraded soils by reducing the need for chemical fertilizers and minimizing environmental degradation. Moreover, agroforestry’s role in increasing biodiversity can help maintain a more resilient farming system, better equipped to cope with pests, diseases, and extreme weather conditions.

In addition to enhancing land productivity, agroforestry systems contribute to long-term sustainability by maintaining soil health and preventing further degradation. According to research by (Keprate et al., 2024)Agroforestry systems are particularly effective in maintaining land productivity in areas prone to soil erosion and desertification. By improving soil structure and preventing erosion, agroforestry helps to maintain arable land for future generations. This is especially important in marginal areas, where land degradation is often irreversible. Furthermore, agroforestry can increase land resilience by creating systems that are less dependent on external inputs and more adaptable to changing environmental conditions. The ability to sustain high levels of productivity over the long term is a key factor in ensuring the continued economic viability of agroforestry practices in these regions.

2.4. Barriers to agroforestry adoption in marginal areas

While agroforestry holds significant promise, its adoption in marginal areas is often hindered by several barriers. One of the most significant challenges is the high initial investment required to establish agroforestry systems. The costs of planting trees, maintaining them, and managing the integration of different land uses can be a major obstacle for farmers in marginal areas who may not have access to sufficient capital. (Rathore et al., 2022). Furthermore, the long time frame required to realize the full economic benefits of agroforestry, particularly from timber and other long-term products, may discourage farmers who are looking for more immediate returns. In addition to financial barriers, there are often technical challenges related to the management and maintenance of agroforestry systems. Farmers in marginal areas may lack the knowledge and skills required to implement agroforestry systems effectively, limiting their potential success. (Castle et al., 2021).

Access to markets for agroforestry products is another critical barrier that affects the economic viability of these systems. In many marginal areas, particularly remote regions, farmers may face challenges in accessing markets for timber, fruits, and other non-timber forest products (NTFPs). Without reliable market access, farmers are less likely to adopt agroforestry, as they may not be able to sell their products at competitive prices. A study by (Ntawuruhunga et al., 2023) Highlighted how the lack of market infrastructure and support in rural areas often undermines the economic potential of agroforestry. Policy interventions aimed at improving market access and providing financial incentives for farmers to adopt agroforestry are crucial in overcoming these barriers and enhancing the economic feasibility of agroforestry systems in marginal areas.

2.5. Policy and institutional support for agroforestry

The role of policy and institutional support is crucial in enhancing the adoption and success of agroforestry practices in marginal areas. Policy frameworks that promote agroforestry through subsidies, technical support, and market facilitation are essential for overcoming financial and logistical barriers. In countries like Brazil and Kenya, government policies have successfully supported agroforestry by providing financial incentives for tree planting and establishing markets for agroforestry products, which have led to widespread adoption. For instance, the establishment of certification systems for NTFPs in these countries has helped increase market demand for agroforestry products, making the practice more profitable for farmers. (Pandey et al., 2016). These policies have played a key role in making agroforestry a viable economic option for farmers in marginal areas.

Institutional support from non-governmental organizations (NGOs) and international development agencies has also been instrumental in promoting agroforestry in marginal regions. According to (Abdul-Salam et al., 2022)NGOs have provided critical training, resources, and technical support to farmers in developing agroforestry systems. In addition, international organizations such as the World Bank and the FAO have facilitated agroforestry adoption by funding research, offering technical assistance, and supporting the development of agroforestry value chains. These institutions play a key role in bridging the gap between knowledge and practice, helping farmers to adopt agroforestry as a sustainable and economically viable agricultural practice. Continued policy support, alongside institutional capacity-building, will be essential for ensuring the long-term success of agroforestry systems in marginal areas.

2.6. Cost-benefit analyses

A detailed cost-benefit analysis (CBA) can provide a clear comparison between the costs and benefits of agroforestry practices in marginal areas. For example, a CBA could analyze the costs of establishing agroforestry systems, including planting trees, integrating crops, and maintaining the system, against the income generated from diversified agroforestry products. Studies in regions like Central Java have shown that agroforestry practices can lead to a 30% increase in crop yields and a 27-35% rise in farmer income, making it essential to apply similar empirical analysis for East Java to validate the economic viability of agroforestry. Additionally, primary case studies from local farmers in East Java who have implemented agroforestry could provide valuable insights into the real-world impacts on land productivity and income generation. For example, in the Batu District, farmers who integrated timber trees with crops like vegetables and fruits experienced significant increases in land productivity and a more stable income compared to traditional monoculture farming systems.

Furthermore, integrating global examples from similar agroforestry studies can offer additional context for understanding its broader impact. Studies from regions like Brazil and Africa have shown that agroforestry can lead to improved soil health, better water retention, and higher land productivity, supporting the claim that agroforestry practices are effective in enhancing farm productivity in marginal areas. Additionally, agroforestry has been proven to provide social benefits such as food security, job creation, and income diversification. For instance, in regions where agroforestry was adopted, farmers were able to generate additional income from non-timber forest products (NTFPs), creating new employment opportunities. By including these empirical data and case studies, the study's findings will be better substantiated, offering more practical recommendations for policymakers and practitioners in Indonesia and similar regions.

3. Methods

3.1. Research design

This study adopts a qualitative research design with a literature review approach to assess the economic viability of agroforestry practices in increasing farmer income and land productivity in marginal areas. A qualitative approach is considered most appropriate for this research as it enables an in-depth exploration of the contextual factors influencing the adoption and success of agroforestry systems. According to, qualitative research allows for a comprehensive understanding of complex phenomena, particularly in exploring the perspectives of stakeholders and the socio-economic implications of agricultural practices. The literature review design is particularly relevant as it facilitates

the synthesis of existing research on the economic aspects of agroforestry, providing a foundation for answering the central research question: What is the economic viability of agroforestry practices in enhancing farmer income and land productivity in marginal areas?
This approach allows for the integration of findings from various studies, identifying patterns, gaps, and contradictions in the literature. By examining studies conducted in different geographical and socio-economic contexts, this research aims to generate a holistic understanding of the economic benefits and challenges associated with agroforestry in marginal areas. This design enables the identification of common themes and strategies that have proven effective in improving the economic outcomes of agroforestry systems. Therefore, a literature review is the most appropriate method for answering the research question and achieving the study's objectives.

3.2. Sample or subject characteristics

Given that this study is based on a literature review, the sample refers to the body of existing academic research and published studies on agroforestry practices in marginal areas. The selection criteria for studies included in this review are as follows:

1) Inclusion Criteria: The selected studies must focus on agroforestry practices implemented in marginal agricultural areas, such as degraded soils, arid or semi-arid regions, and areas experiencing significant climate stress. The studies must also address economic outcomes related to farmer income and land productivity, specifically those published between 2022 and 2025. Only peer-reviewed academic articles, reports, and case studies from reputable journals and institutions are considered.
2) Exclusion Criteria: Studies that focus on agroforestry in regions with well-established agricultural systems or those that do not measure economic outcomes (e.g., environmental or social outcomes only) are excluded. Furthermore, studies that do not focus on marginal areas or those that lack clear data on economic viability are also not included in this review.

To ensure the relevance and representativeness of the selected studies, the research employs purposive sampling, focusing on articles that provide detailed, context-specific information on the economic feasibility of agroforestry in marginal areas. This approach ensures that the studies selected are aligned with the research objectives and contribute directly to understanding the economic implications of agroforestry in the target regions.

3.3. Research instruments

As this study is based on a literature review, the primary instrument used for data collection is a comprehensive search and selection of relevant studies, facilitated by databases such as Google Scholar, Scopus, and Web of Science. The research focuses on qualitative studies that provide in-depth insights into the economic viability of agroforestry in marginal areas. The key instruments for this study include search keywords related to agroforestry, land productivity, economic viability, and marginal areas.
To ensure the validity and reliability of the findings, only studies that meet rigorous academic standards peer-reviewed journal articles, research papers, and reports from credible institutions, are included. Each selected article is assessed for its methodological soundness, the clarity of its findings, and its relevance to the research objectives. According to (Ntawuruhunga et al., 2023) Boone et al. (2018), using peer-reviewed academic sources, guarantee the reliability and credibility of the data, ensuring that the findings presented in this study are grounded in well-established research.

3.4. Data collection procedure

The data collection process for this study involves several stages. First, a comprehensive search is conducted using relevant keywords such as "agroforestry in marginal areas," "economic viability of agroforestry," and "farmer income from agroforestry," to identify peer-reviewed articles, case studies, and reports. This search is conducted across multiple databases, including Google Scholar, Scopus, and Web of Science, to ensure a wide range of relevant studies is considered.
Once the studies are identified, each article is reviewed for its relevance, methodological rigor, and focus on economic outcomes in marginal areas. After applying the inclusion and exclusion criteria, selected studies are categorized based on the specific aspects they address, such as income generation, land productivity, or economic sustainability of agroforestry. Data extraction involves synthesizing the key findings from each study, focusing on how agroforestry impacts farmer income and land productivity, as well as any barriers to adoption.
The time frame for the data collection process is defined by the need to focus on recent studies published between 2022 and 2025. The process includes collecting studies from various regions that fit the geographical and socio-economic context outlined in the research objectives. By following this procedure, the study ensures that the data collected reflects the most current and relevant information on the economic viability of agroforestry practices.

3.5. Data analysis method

The data collected in this study will be analyzed using thematic analysis, a widely used method for analyzing qualitative data (Braun & Clarke, 2021). Thematic analysis allows for the identification of key themes and patterns across the selected studies, providing a comprehensive understanding of the economic impacts of agroforestry in marginal areas. This approach involves coding the data into categories based on recurring themes related to income generation, land productivity, and the barriers and enablers of agroforestry adoption. Each theme is examined to determine its significance and relevance to the research question.

4. Result and Discussion

4.1. Farmer's income

One of the main findings is the positive impact of agroforestry on farmers' income. A study by (Hasannudin et al., 2022) in South Sulawesi found that a coffee-clove agroforestry system contributed about 26% to the annual household income, averaging IDR 43 million (approximately USD 3,000). This system significantly increased farmers' income compared to conventional monoculture farming. And a study in West Java showed that farmers who adopted agroforestry experienced an average household income increase of 30% compared to those who relied on monoculture farming. This increase in income was largely due to additional revenue from non-timber forest products (NTFPs), such as fruits, vegetables, and medicinal plants, which were harvested alongside the main crops. Additionally, in a study in Bali,

agroforestry that integrates coffee trees with horticultural crops increased farmers' income by 27%, where coffee became a flagship commodity providing stable economic benefits.
Further research in Sumatra by (Latifah et al., 2022) Also shows that agroforestry offers significant income diversification. Farmers in marginal areas practicing agroforestry earned additional income from timber, fruits, and medicinal plants, collectively increasing their income by around 35%. Agroforestry helps farmers not only rely on a single agricultural product but also reduces their dependence on specific planting seasons, enhancing economic resilience to market fluctuations.

Table 1: Impact of Agroforestry on Farmer Income

Researcher(s)	Location	Income Increase (%)	Additional Notes
Hasannudin et al. (2022)	South Sulawesi	26	Coffee-clove agroforestry system contributed 26% to household income, averaging IDR 43 million (approx. USD 3,000).
Siarudin et al. (2021)	West Java	30	Increased income mainly due to NTFPs such as fruits, vegetables, and medicinal plants.
Chavez et al. (2024)	Bali	27	Coffee-agroforestry with horticultural crops increased income by 27%, with coffee as a flagship commodity.
Latifah et al. (2022)	Sumatra	35	Income diversification from timber, fruits, and medicinal plants, with an increase of 35%.

This finding table confirms that agroforestry not only increases farmers' income but also provides economic resilience through the diversification of agricultural products, which reduces dependence on specific planting seasons, an important factor in enhancing resilience to market fluctuations and climate change.

4.2. Improved land productivity

Agroforestry has also been shown to contribute to increased land productivity, particularly in degraded or marginal soils. A study by (Heryandi et al., 2022)) in Lampung found that the use of nitrogen-fixing trees in agroforestry systems improved soil fertility and, in turn, crop yields. In this study, farmers who adopted agroforestry experienced a 33% increase in the productivity of main crops such as corn and soybeans in the first two years compared to farmers using conventional farming systems. The addition of nitrogen-fixing trees helped improve soil nutrient content, improve soil structure, and reduce erosion.
Additionally, a study by (Jaya et al., 2022) In Central Kalimantan revealed that agroforestry, which combined oil palm plants with protective trees, reduced soil erosion by up to 40%. By reducing erosion and increasing soil resilience, agroforestry also improves water retention, positively impacting crop resistance to drought. The productivity of staple crops such as rice and corn increased by 30% over several planting seasons thanks to improved soil quality through the integration of protective trees.

4.3. Economic barriers to agroforestry adoption

Although the benefits of agroforestry are widely recognized, the research findings also indicate that there are significant economic barriers to its adoption, especially in marginal areas. A study by (Prabawani et al., 2024) Identified that the initial investment costs for planting trees and developing agroforestry systems often present the greatest barrier for smallholder farmers. These costs include the purchase of tree seedlings, land preparation, and maintenance during the early years. In this study, 58% of farmers surveyed in Central Java indicated that they could not access the required funding to start an agroforestry system, limiting the implementation of this practice.
Research by (Owusu et al., 2022) Also found that limited market access for agroforestry products is a major hindrance. Although agroforestry products such as timber and NTFPs can provide significant benefits, farmers in rural areas often struggle to sell their products at competitive prices. The limited markets, especially for non-timber products, and the lack of infrastructure to distribute agroforestry products to broader markets reduce the potential income that farmers can earn. The lack of market understanding of the value of agroforestry products also becomes a barrier to increasing the competitiveness of these products in the market.

4.4. Policy and institutional support

Another finding highlights the crucial role of policy and institutional support in improving the economic viability of agroforestry. Research by (Pitopang et al., 2021) Sulawesi showed that government subsidies for tree planting and agroforestry training had a positive impact on facilitating agroforestry adoption. Farmers who received these subsidies were more likely to invest time and resources in developing agroforestry systems, and they reported an average income increase of 38%. This was also supported by research by (Low et al., 2023), which found that government and NGO-provided training and extension programs improved farmers' technical skills in managing agroforestry, which in turn increased the success of agroforestry systems and farmer income.
Institutional support, both from the government and non-governmental organizations (NGOs), plays a very important role in providing access to technical training and markets for agroforestry products. In Bali, farmers who participated in agroforestry training programs supported by NGOs reported a 45% increase in income over two years, thanks to improved market access and better management techniques. (Chavez et al., 2024).

4.5. Discussion

This discussion will interpret the key findings of the research and relate them to the existing literature, linking them to theoretical frameworks that explain the relationship between agroforestry practices and economic outcomes.

4.6. Impact of agroforestry on farmer income

The findings indicate that agroforestry significantly enhances farmer income, with studies showing increases in income ranging from 27% to 35% in various regions of Indonesia. These results align with the theory of income diversification in smallholder agriculture, which suggests that integrating multiple income sources, such as crops, trees, and NTFPs, reduces financial risks and increases overall farm profitability (Singh et al., 2021). The income generated from non-timber forest products (NTFPs) such as fruits, medicinal plants, and

timber products, which were found to contribute substantially to farmer income, supports the notion that agroforestry offers an important buffer against market fluctuations and environmental risks.
The literature also highlights that agroforestry systems can stabilize income over time by spreading risks across different types of production. For example, during poor harvests of staple crops, farmers can rely on timber or other forest products, thus mitigating income loss due to adverse climatic or market conditions. This resilience is particularly critical in marginal areas, where conventional farming systems are vulnerable to soil degradation, climate change, and fluctuating commodity prices.
Moreover, the findings in this study suggest that agroforestry reduces farmers' reliance on monoculture farming. According to the Diversified Agricultural Systems Theory, integrating multiple crops and trees into farming systems not only spreads economic risks but also enhances food security and resilience against environmental shocks. (Paut et al., 2020). The diversification of income sources through agroforestry thus fits into the broader agricultural development strategies aimed at fostering resilience and reducing poverty in rural communities.

4.7. Improvement in land productivity

The findings from this research further show that agroforestry practices improve land productivity, particularly in degraded or marginal soils. As demonstrated in Lampung (Heryandi et al., 2022) and West Kalimantan (Jaya et al., 2022)The integration of nitrogen-fixing trees in agroforestry systems significantly enhances soil fertility and increases crop yields. These results are consistent with the Ecological Restoration Theory, which posits that agroforestry systems can rehabilitate degraded lands by improving soil structure, water retention, and nutrient cycling. This theory suggests that agroforestry offers a sustainable approach to addressing land degradation, which is a common issue in marginal areas.
The increased productivity of staple crops such as maize and rice, reported in studies from both Sumatra and Kalimantan, is a direct outcome of agroforestry's contribution to soil health and erosion control. These findings echo the principles of agroecology, which advocates for the use of agroforestry to enhance ecosystem services, reduce soil erosion, and promote sustainable land management practices. The reduction in soil erosion by up to 40%, as reported in the study in West Kalimantan, further highlights the ability of agroforestry systems to restore degraded land and improve agricultural productivity.
In addition, the improvement in water retention was observed in Bali. (Chavez et al., 2024) Aligns with the theory of ecological buffering, where agroforestry systems can increase resilience to climatic stressors such as droughts and floods. This finding is particularly relevant in marginal areas, where unpredictable weather patterns and climate variability often hinder traditional farming practices. By improving water retention and soil health, agroforestry systems provide a stable foundation for increasing productivity in these fragile environments.

4.8. Economic barriers to agroforestry adoption

While the benefits of agroforestry are evident, the study also highlighted significant economic barriers to its widespread adoption in marginal areas. The high initial investment costs associated with tree planting, land preparation, and maintenance during the early years were found to be a substantial barrier to adoption, particularly in regions such as East Java and Kalimantan. (Jaya et al., 2022). These results are consistent with the theory of financial capital constraints in rural economies, which asserts that smallholder farmers in developing countries often lack the initial capital to invest in long-term agricultural systems such as agroforestry. (Prabawani et al., 2024). This barrier prevents many farmers from transitioning to agroforestry despite its long-term benefits.
The literature emphasizes the importance of financial and technical support for agroforestry adoption, particularly in marginal areas where farmers are often financially constrained. According to the Technology Adoption Theory, subsidies, financial incentives, and technical assistance can help mitigate the financial barriers to agroforestry adoption. (Castle et al., 2021). This theory suggests that targeted policy interventions, such as government subsidies for agroforestry systems and training programs, can play a key role in overcoming the economic barriers faced by smallholders and facilitating the adoption of agroforestry.

4.9. Role of policy and institutional support

The findings also underline the critical role of policy and institutional support in promoting agroforestry adoption in Indonesia. Studies by (Dhakal et al., 2022) Suggest that government subsidies and technical training programs significantly increase the likelihood of agroforestry adoption by smallholder farmers. These results align with the Institutional Theory of Agroforestry, which argues that institutional support, such as extension services, subsidies, and market access initiatives, is crucial for creating an enabling environment for agroforestry practices. (Raj et al., 2022).
By providing technical training and facilitating access to markets, governments and NGOs can help farmers overcome the initial barriers to agroforestry adoption. The positive impact of such institutional support on farmer income and agroforestry success, as seen in Bali and Sulawesi, underscores the importance of coordinated policy efforts to promote sustainable land management practices. Furthermore, the findings suggest that increased market access, as facilitated by institutional interventions, enhances the economic viability of agroforestry by ensuring that farmers can sell their products at competitive prices. (Chavan et al., 2022).
This research could reflect recent advancements in agroforestry's role in enhancing land productivity and economic resilience in marginal areas. Studies from 2025 indicate a growing focus on climate-smart agroforestry practices, particularly in regions affected by increasing climate variability, such as semi-arid areas in Africa and Latin America. (Chavez et al., 2024). These regions are seeing enhanced adoption of agroforestry systems due to their ability to mitigate the impacts of droughts, floods, and soil erosion, which are exacerbated by climate change. Furthermore, newer research highlights the development of improved agroforestry models that integrate advanced technologies, such as precision agroforestry and digital tools for monitoring tree-crop interactions, which significantly enhance land productivity and farmer incomes.
Additionally, the most recent studies (Paut et al., 2020) Also emphasize the importance of agroforestry as a climate mitigation strategy, underlining how its adoption can contribute to global carbon sequestration efforts. This aligns with growing global trends where agroforestry systems are viewed not only as a solution for agricultural sustainability but also as an essential component of climate adaptation and mitigation policies. This shift toward incorporating agroforestry into national and international climate strategies is a crucial trend that adds significant value to its economic and environmental benefits, further expanding its relevance globally, particularly in marginal areas in Africa and Latin America.
To enhance the global relevance of the study, it is essential to compare the findings with international contexts, particularly in regions such as Africa and Latin America, where CSR and corporate governance play pivotal roles in shaping firm value. In Africa, studies have shown

that strong corporate governance structures significantly boost the effectiveness of CSR initiatives, particularly in industries like mining and agriculture. Similarly, in Latin America, countries like Brazil have witnessed the integration of CSR into business models that prioritize sustainable development, showing similar results to those observed in the manufacturing sector in Indonesia. In both regions, governance mechanisms such as board independence and stakeholder engagement have been key to ensuring that CSR activities are strategically aligned with long-term firm goals, ultimately leading to enhanced firm value. These comparisons highlight that while the specific contexts may differ, the mediating role of governance in CSR's impact on firm performance is globally relevant, providing insights that can guide firms in diverse regions to optimize their CSR strategies. This cross-regional comparison strengthens the study's applicability and emphasizes the universal importance of effective governance in maximizing the value derived from CSR initiatives.

4.10. Policy recommendations

To enhance the economic viability of agroforestry practices in increasing farmer income and land productivity in marginal areas, it is recommended that the government implement targeted subsidy programs, similar to Brazil's Non-Timber Forest Products (NTFP) certification program, which has successfully supported smallholder farmers through subsidies for certification, inputs, and training. Additionally, market access initiatives, inspired by fair trade and certification programs in Latin America, should be established to connect Indonesian agroforestry products to global markets, ensuring fair pricing for sustainable products. Strengthening extension services and capacity building through partnerships with local NGOs or universities is also critical, as seen in Kenya's agricultural extension programs, which support farmers adopting agroforestry. Furthermore, policies incentivizing land restoration and ecosystem services, such as Nepal's Community Forestry Program, could promote agroforestry adoption by rewarding farmers for ecological benefits like improved soil and water retention. Lastly, public-private partnerships (PPPs), modeled after Brazil's collaborations with private enterprises in NTFP development, could provide access to finance, improve infrastructure, and expand agroforestry markets in Indonesia. These integrated policies can create a supportive environment for agroforestry, improving farmer income, land productivity, and environmental sustainability.

5. Conclusion

This study demonstrates the significant economic potential of agroforestry in marginal areas of Indonesia. Agroforestry practices have been shown to increase farmer income through diversified sources, such as non-timber forest products (NTFPs), and improve land productivity by enhancing soil fertility and reducing erosion. These benefits contribute to both short-term financial stability and long-term sustainability. However, barriers such as high initial investment costs and limited market access remain significant challenges for widespread adoption. Targeted policy interventions, including subsidies, financial incentives, and technical support, are essential for overcoming these obstacles and promoting broader implementation of agroforestry.

Farmers in marginal areas can benefit from agroforestry by diversifying their income streams and investing in sustainable land management practices. Although the initial investment may be high, the long-term financial returns from improved soil fertility, higher crop yields, and reduced environmental degradation make agroforestry a viable option. Access to training and market opportunities is also crucial for maximizing the potential of agroforestry systems, as it enables farmers to manage their practices more effectively and secure better prices for their products.

Future research should focus on the long-term economic impact of agroforestry on farmer livelihoods and land productivity, particularly in areas affected by soil degradation and climate variability. Additionally, cost-benefit analyses of different agroforestry models will help identify the most economically viable systems for smallholder farmers. Further exploration into market access and value chains for agroforestry products, as well as effective policy frameworks and institutional support, will provide critical insights to promote agroforestry adoption on a larger scale, benefiting both farmers and the environment.

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