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EXPLORING UPLAND RICE INTERCROPPING IN OIL PALM PLANTATIONS: A QUALITATIVE LITERATURE REVIEW OF ECONOMIC AND ECOLOGICAL PERSPECTIVES

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ABSTRACT

The underutilization of land in young oil palm plantations presents a major challenge to both productivity and sustainability in tropical agriculture. This article explores upland rice intercropping as a promising strategy to optimize land use during the immature phase of oil palm cultivation. This study performs a qualitative literature analysis to examine the economic and ecological aspects of upland rice intercropping within oil palm plantations. The research consolidates findings from more than 80 peer-reviewed articles and institutional reports, chosen for their topic significance and regional diversity. Intercropping provides revenue diversification and enhances food security. It enhances soil fertility, biodiversity, and climate resistance. Nonetheless, implementation is constrained by knowledge deficiencies and policy limitations. This review emphasizes key elements affecting adoption and underlines the practice's role in sustainable land management in tropical areas.

Keywords: Intercropping; Land optimization; Oil palm plantation; Sustainable agriculture; Upland rice

INTRODUCTION

The cultivation of oil palm (*Elaeis guineensis*) has emerged as a leading agricultural practice in numerous tropical regions, especially in Southeast Asia, owing to its substantial oil productivity and significant economic benefits (Wahid *et al*., 2005). Nevertheless, this growth has frequently resulted in land degradation, monoculture dependency, and underutilization of land resources during the early growth stages of the plantation (Mutsaers, 2019). In the early years of oil palm development, large areas between the rows remain idle due to the slow maturation of the crop, leading to inefficient land use (Sari *et al*., 2021). This is a critical issue, particularly in regions with increasing land scarcity, growing population pressure, and heightened food security concerns (Adade, 2022).

To address this inefficiency, intercropping has been proposed as a sustainable land management strategy (Dissanayake & Palihakkara, 2019). Intercropping involves cultivating multiple crop species simultaneously within a single agricultural plot, either simultaneously or sequentially, with the aim of maximizing resource use efficiency and improving ecological outcomes (Zhang & Li, 2003). In particular, incorporating upland rice (*Oryza sativa*) into young oil palm plantations has gained attention due to its compatibility in terms of light, water, and space requirements (Adawiah *et al*., 2024). Upland rice is well-suited for intercropping systems as it is drought-tolerant, has a short growing cycle, and does not require flooded conditions, making it ideal for rainfed and sloped areas commonly found in oil palm plantations (Ahmadi *et al*., 2004).

Economically, this practice offers significant benefits. It allows farmers to generate revenue from the same plot during the non-productive stage of oil palm, thus increasing land productivity and financial resilience (Nkongho *et al*., 2016). In regions where smallholder farmers dominate oil palm production, such practices can serve as vital livelihood strategies (Feintrenie *et al*., 2010). Intercropping with upland rice may also reduce economic risks by diversifying production, thereby buffering farmers against volatile palm oil prices (Stomph, 2017). Moreover, increased crop output can support local food security and reduce dependence on rice imports (Mohanty, 2013).

From an ecological standpoint, intercropping improves soil health by increasing organic matter and promoting microbial activity (Sapalina *et al*., 2022). It can also enhance nutrient cycling and reduce erosion, particularly in sloped plantation areas (Satriawan *et al*., 2016). The ground cover provided by rice crops helps suppress weed growth, potentially reducing the need for herbicide applications (Oluwatobi & Olorunmaiye, 2021). Furthermore, the presence of diverse crops supports biodiversity by creating habitats for various organisms, which contributes to a greater ecological balance (Ashraf *et al*., 2018).

This type of agricultural system has the potential to lessen the effects of climate change by boosting carbon uptake and retention in both the soil and plant biomass (Hairiah *et al*., 2011). By maintaining soil cover, intercropping helps retain moisture, regulate microclimate, and enhance the ability of the agroecosystem to withstand extreme climatic conditions (Biswas *et al*., 2023). These benefits align with broader goals of sustainable agriculture, which call for reduced chemical inputs, increased ecosystem services, and adaptive strategies to climate variability (Altieri *et al*., 2015).

Despite these advantages, current research on intercropping in oil palm plantations remains limited, fragmented, and often focused on legume or tuber crops rather than cereals such as upland rice (Koussihouèdé *et al*., 2020). Studies that have explored upland rice intercropping often examine agronomic outcomes in isolation without integrating economic and ecological analyses in a comprehensive framework (Hirooka *et al*., 2021). Moreover, region-specific insights are scarce, leaving a gap in understanding how different agroecological zones affect the performance of such systems (Pavithrani *et al*., 2023).

This literature gap highlights the need for a systematic analysis of the economic and ecological potentials of intercropping upland rice in oil palm plantations (Nichenametla Prasanna Kumar, 2023). As global calls for sustainable land use intensify, particularly in tropical regions with high biodiversity and carbon stocks, innovative land optimization strategies like this become increasingly relevant (Gilroy *et al*., 2014). Understanding both the benefits and challenges of such systems is essential for policymakers, development practitioners, and local farming communities (Giller *et al*., 2009).

Therefore, this article aims to critically examine the role of upland rice intercropping in optimizing land utilization in oil palm plantations. Using a qualitative literature review approach, it has been synthesized existing studies to uncover the economic benefits, ecological impacts, and implementation considerations of this intercropping system (Nuertey *et al*., 2009). In doing so, it contributes to a more integrated understanding of how intercropping practices can support food security, environmental sustainability, and rural livelihoods in palm oil-producing regions (Budiadi Susanti *et al*., 2019). This article also identifies knowledge gaps and proposes future directions for research and policy development to support the scaling-up of sustainable intercropping strategies (Vanlauwe *et al*., 2014).

Ultimately, enhancing land use efficiency through upland rice intercropping not only addresses the issue of idle land in oil palm plantations but also represents a concrete step toward achieving the broader goals of climate-smart, biodiversity-friendly, and socially inclusive agriculture (Bobihoe, 2021; Putra *et al*., 2017). Despite its promising benefits, the current literature lacks an integrated analysis that combines both economic and ecological evaluations of upland rice intercropping in oil palm systems. This review addresses this gap by synthesizing relevant studies to answer the following guiding questions: (1) What are the economic contributions of upland rice intercropping? (2) How does it affect ecological sustainability? (3) What are the barriers and enabling conditions for its wider adoption? By responding to these questions, this study contributes to a more holistic understanding of how upland rice intercropping can support sustainable agricultural intensification in tropical plantation landscapes.

METHOD

This study adopts a qualitative literature review methodology with thematic coding to investigate the financial and environmental dimensions of integrating upland rice into oil palm cultivation systems. Unlike a systematic literature review (SLR), which typically employs strict inclusion and exclusion protocols, this qualitative approach emphasizes interpretative synthesis to generate a comprehensive and multidimensional understanding of the subject matter (Onwuegbuzie *et al*., 2012; Sandelowski *et al*., 2007).

Literature was collected using a purposive sampling technique from major academic databases such as Scopus, ScienceDirect, SpringerLink, and JSTOR, along with institutional sources from FAO, CIFOR, and national agricultural agencies. The inclusion criteria comprised (1) relevance to upland rice intercropping within oil palm systems, (2) publication credibility (peer-reviewed journals or institutional reports), and (3) regional representativeness across tropical agricultural contexts. A total of 80 studies were selected that reflect thematic diversity and geographical variation.

The review process employed thematic coding to identify recurring patterns, contradictions, and knowledge gaps (Braun & Clarke, 2006). Themes were categorized into three major domains: (1) economic benefits, (2) ecological impacts, and (3) implementation challenges. This methodological approach seeks not to generalize outcomes but to construct a rich, integrated perspective on how upland rice intercropping can enhance sustainable land use in oil palm plantation systems.

RESULTS AND DISCUSSION

A qualitative literature review method is employed in this research to investigate the economic and ecological aspects of incorporating upland rice into oil palm farming systems.

1. Economic Perspective

Income Diversification

Intercropping upland rice provides smallholder farmers with an additional source of income during the immature phase of oil palm growth when the plantation does not yet yield profit. Several studies indicate that upland rice cultivation can contribute between 25% to 40% of total household income during the first 3–4 years after oil palm establishment, enhancing financial stability for farming families (Muljono *et al*., 2025; Sibhatu *et al*., 2025). This practice reduces dependency on a single commodity and creates a buffer against palm oil price volatility (Jelsma *et al*., 2010).

However, other studies report that this additional income may be offset by increased labor burdens, particularly for households with limited labor availability. Seasonal labor competition between rice farming and oil palm maintenance can also lead to time constraints, particularly for women and elderly laborers. While most studies confirm the income benefits of intercropping, these findings suggest that socio-economic conditions must be considered to ensure net gains.

Productivity

Research has shown that integrating upland rice with oil palm results in efficient land utilization, leading to higher overall productivity per hectare. Some trials reported land equivalent ratios (LER) of 1.2 to 1.5, indicating that intercropped systems produce more total output than monocultures of either crop (Khasanah *et al*., 2020; Ozioma *et* *al*., 2024). Additionally, crop yields of upland rice in intercropped systems were only marginally lower (by 5–10%) than in sole cropping systems, while oil palm productivity remained unaffected in the long term (Ohorella *et al*., 2019).

Nonetheless, certain studies have reported that under specific soil or climatic stress conditions, the LER advantage is diminished, and rice yields may be significantly compromised. This variability underscores the importance of agroecological suitability and adaptive management. Thus, while productivity gains are broadly evident, results may vary considerably by location and resource input levels.

Market Resilience

The integration of food crops into plantation systems strengthens market resilience by allowing farmers to participate in both subsistence and commercial markets. Upland rice, being a staple food, guarantees local market demand, while palm oil remains an export-oriented commodity. This dual market engagement reduces economic vulnerability, especially in times of international market shocks (Cahyo *et al*., 2024; Jayakody *et al*., 2025).

However, the benefits of market resilience depend heavily on infrastructure and market access. In remote areas, limited access to markets or unstable rice prices may negate the economic advantages. While market diversification is beneficial in theory, effective logistics and value chain integration are essential for it to translate into tangible welfare improvements.

Farmer Welfare

Increased household income from intercropping is associated with improvements in food security, health expenditure, and access to education for farming families. Studies from rural Indonesia and Malaysia reported that households engaged in oil palm rice intercropping were 20–30% more likely to achieve food self-sufficiency and could reduce rice purchase dependency (Manorama *et al*., 2024; Santika *et al*., 2019). Additionally, the availability of staple food crops on-site helps stabilize nutrition intake in rural communities (Valešová *et al*., 2017).

Yet, some empirical studies caution that intercropping alone does not automatically improve welfare if not accompanied by access to extension services or credit support. Additionally, increased workload can reduce time for off-farm income or education, especially for children. Hence, the welfare impact of intercropping should be interpreted in conjunction with broader socio-economic dynamics.

2. Ecological Perspective

Soil Health

The practice of intercropping has demonstrated positive effects on soil quality through the enrichment of organic materials, minimization of soil erosion, and stimulation of microbial processes. Upland rice contributes to surface coverage, which minimizes runoff and soil degradation. Studies indicate that soil organic carbon increased by up to 15% in intercropped systems compared to oil palm monocultures (Handayani *et al*., 2020; Zhu *et al*., 2024). However, other sources argue that these benefits are not uniform across all soil types. In poorly drained soils, continuous rice planting may lead to compaction or anaerobic conditions. While intercropping generally supports soil health, its effects are contingent on site-specific soil and water dynamics.

Nutrient Cycling

The complementary nutrient demands of upland rice and oil palm allow for more balanced nutrient cycling within the system. Root interactions facilitate nutrient uptake and minimize leaching losses. According to multiple field trials, nitrogen use efficiency improved by 10–20%, while phosphorus availability also increased due to organic residues left by rice straw decomposition (Singh, 2020; Sravan & Murthy, 2018).

Still, excessive nutrient uptake in competitive environments can lead to localized deficiencies, particularly in low-input systems. These findings highlight the need for balanced fertilization and rotation planning. Thus, although nutrient efficiency is a prominent benefit, careful nutrient management remains necessary.

Biodiversity

The presence of upland rice increases plant diversity and creates microhabitats that support beneficial insects, birds, and soil organisms. Biodiversity indices in intercropped plots were consistently higher, with reports of 25–30% more insect species and significantly greater soil fauna abundance (Perfecto & Vandermeer, 2010; Ratnadass *et al*., 2012). Such ecological relationships support biological pest regulation, thereby decreasing reliance on synthetic chemical applications. Nevertheless, some authors have noted that biodiversity gains may be marginal if herbicides or synthetic fertilizers are used excessively. Monocultural management practices applied to intercropped fields can suppress biodiversity benefits. Therefore, biodiversity outcomes are highly dependent on ecological stewardship and agrochemical use patterns.

Climate Resilience

Intercropping systems have demonstrated higher climate resilience due to their diversified structure and improved soil-water retention. Upland rice roots improve infiltration, and canopy layering helps buffer extreme temperatures. Studies show that during drought years, intercropped plots retained 10–15% more soil moisture compared to monocultures, mitigating the impacts of erratic rainfall (Fukai & Trenbath, 1993; Lin, 2011).

However, in water-limited environments, competition between crops can occasionally exacerbate stress effects, especially where rainfall is highly erratic. This suggests the need for climate-specific varietal selection and adaptive irrigation or soil moisture conservation techniques. While resilience benefits are compelling, they require site-appropriate strategies to be fully realized.

Ecosystem Services

By combining perennial and annual crops, oil palm–rice intercropping enhances multiple ecosystem services. These include carbon sequestration, pollination support, and hydrological regulation. Life cycle assessments report a 20% increase in ecosystem service value per hectare in intercropped landscapes versus monocultures (Aulia *et al*., 2020; Ricketts *et al*., 2008). Moreover, this practice aligns with agroecological principles and sustainable land management goals promoted by global development agencies (Arifin *et al*., 2024; Wezel *et al*., 2020).

Nevertheless, the quantification of ecosystem services remains inconsistent across studies. Many assessments lack standardized metrics or long-term observation. Thus, while ecosystem service enhancement is a strong argument for intercropping, further empirical validation is essential to substantiate these claims. Overall, the integration of upland rice into oil palm systems contributes significantly to both economic empowerment and ecological integrity, supporting the case for sustainable land-use intensification in tropical agricultural landscapes (Lim *et al*., 2024; Palm *et al*., 2014).

The Strategic Potential of Upland Rice to Increase Economic Productivity and Sustainability

The findings of this review highlight the strategic potential of upland rice intercropping in oil palm plantations to improve economic productivity and ecological sustainability simultaneously. The increase in household income derived from dual cropping supports the theory of diversified farming systems as a means to reduce rural poverty and economic vulnerability in monoculture-dominated regions. This aligns with agroecological frameworks that advocate mixed cropping for resilience and long-term land productivity (Gliessman, 2021; Pound & Snapp, 2008). The substantial contribution of upland rice to food security and income during the non-productive phase of oil palm development confirms the temporal complementarity between the two crops, which has been observed in tropical Southeast Asia and parts of Sub-Saharan Africa (Koczberski *et al*., 2012; Sitorus, & Zasari, 2023). These results reinforce previous empirical evidence that intercropping in perennial crop systems can achieve land equivalent ratios exceeding 1.2, indicating superior output efficiency compared to monoculture systems (Liu *et al*., 2018; Samrin *et al*., 2024).

Globally, incorporating food crops into plantation systems has gained significance as a strategic response to climate change, food insecurity, and the pursuit of Sustainable Development Goals (SDGs). Intercropping, as examined in this research, aligns with SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land) by enhancing land efficiency and supporting ecological diversity (Kuyah *et al*., 2021; Pretty *et al*., 2018). The consistent improvement in soil health parameters such as organic carbon levels, microbial biomass, and nutrient cycling validates ecological theories on belowground biodiversity restoration through mixed cropping systems (Cong *et al*., 2015; Tiemann *et al*., 2015). Furthermore, the increased presence of beneficial insects and birds in intercropped plots confirms landscape ecology hypotheses regarding habitat heterogeneity and species richness (Bianchi *et al*., 2006; Fahrig *et al*., 2011).

In terms of practical implications, the adoption of oil palm–upland rice intercropping could be promoted as a cost-effective approach to sustainable intensification, particularly for smallholders in tropical developing countries. The practice enhances farmer welfare through stable yields and reduced dependence on external food sources while also improving land efficiency and reducing input costs due to natural pest control and improved soil fertility (Pypers *et al*., 2011; Tittonell & Giller, 2013). For policymakers, these results suggest the need to support intercropping initiatives through subsidies, extension services, and regulatory frameworks that recognize diversified farming as a legitimate land-use category (Iles & Marsh, 2012; Kassie *et al*., 2013). Moreover, the establishment of cooperatives or farmer groups focused on intercropping could facilitate knowledge exchange, improve market access, and increase bargaining power for smallholders (Sikwela *et al*., 2016; Wossen *et al*., 2017).

Nevertheless, this review has several limitations. First, while the results are drawn from a wide array of studies, they rely heavily on literature from Southeast Asia, which may not fully capture local agroecological and socio-economic conditions elsewhere. Second, much of the available data pertains to the early stages of oil palm development, with limited longitudinal studies covering full plantation life cycles (Coe *et al*., 2014; Dhandapani *et al*., 2022). Additionally, variability in intercropping techniques, rice varieties, and management practices across studies presents challenges in drawing generalized conclusions. However, the strength of this review lies in its synthesis of both ecological and economic outcomes, offering a more holistic understanding than many single-focus studies.

Future research should focus on long-term field experiments that evaluate the impact of intercropping on oil palm yield over the full 25–30-year plantation lifespan. There is also a need for more regionally diversified studies that explore the feasibility of intercropping in West Africa, Latin America, and other oil palm-producing regions with differing climates and soil types (Comte *et al*., 2012; Meijaard *et al*., 2018). Additionally, research should examine the potential of integrating other staple crops alongside upland rice, such as legumes or root vegetables, which may offer even greater ecological and nutritional benefits (Raseduzzaman & Jensen, 2017; Snapp *et al*., 2010). Lastly, incorporating participatory approaches that involve local farmers in the design and evaluation of intercropping models would strengthen the relevance and applicability of findings, especially in contexts where traditional knowledge plays a critical role in land management (He *et al*., 2009).

CONCLUSION

This review concludes that intercropping upland rice within oil palm plantations presents a strategic approach to optimizing land utilization, offering tangible benefits across both economic and ecological dimensions. From an economic perspective, the integration of upland rice provides significant opportunities for income diversification, improved productivity during immature oil palm phases, enhanced market resilience, and strengthened farmer welfare. Ecologically, intercropping contributes to improved soil health, more efficient nutrient cycling, increased biodiversity, better climate resilience, and enhanced delivery of ecosystem services. These outcomes collectively demonstrate the potential of intercropping systems to support sustainable agricultural development, particularly in regions where oil palm monoculture dominates rural landscapes.

Practically, this study recommends that intercropping should be more systematically incorporated into land use policies and rural development strategies. Extension services should be strengthened to provide technical guidance on intercropping models, while local governments can support adoption through subsidies, training, and inclusive agricultural planning. On the scientific front, further empirical research is encouraged to evaluate long-term impacts, region-specific models, and the integration of additional food crops beyond upland rice. A transdisciplinary approach involving agronomists, ecologists, economists, and farmers themselves will be essential in refining sustainable intercropping systems for broader implementation.

Nonetheless, this review has methodological limitations. As a qualitative literature review, the findings rely on interpretative synthesis rather than statistical generalization. The review did not employ formal meta-analytic techniques or quantitative effect-size comparisons, and some insights are constrained by the heterogeneity of data sources and regional focus, particularly in Southeast Asia. The absence of standardized indicators across studies further limits direct comparability of outcomes.

Future research should prioritize quantitative meta-analyses, longitudinal field studies across diverse agroecological zones, and comparative trials involving multiple staple crops. Moreover, empirical validation through participatory and transdisciplinary research is essential to assess the real-world performance of intercropping under varying socio-environmental contexts. Attention should also be given to the development of standardized metrics for evaluating ecological and economic outcomes to strengthen evidence-based policy and practice.

In sum, upland rice intercropping represents not only an agronomic innovation but also a socio-environmental strategy to address land use efficiency, food security, and ecosystem sustainability. It challenges the conventional logic of monoculture and supports a transition toward multifunctional, regenerative landscapes. As global pressures on land and food systems intensify, integrated intercropping approaches offer a resilient and equitable pathway for the future of tropical agriculture.

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